RP197

Cost-effective Water Quality Protection in the Midwest

HEARTLAND
Regional Water Coordination Initiative

EPA Region VII

University of Nebraska–Lincoln
Iowa State University
Kansas State University
University of Missouri-Columbia

USDA
United States Department of Agriculture
National Institute of Food and Agriculture

Iowa State University

K-State
Kansas State University

University of Missouri Columbia

University of Nebraska Lincoln

EPA Region 7

National Water Program

Corresponding author
Charles Wortmann, Soil Fertility and Nutrient Management Specialist
University of Nebraska–Lincoln

Co-authors
Iowa State University
Lois Wright Morton, Rural Sociologist
Matt Helmers, Agricultural and Water Resources Engineer
Chad Ingels, Extension Watershed Specialist

Kansas State University
Daniel Devlin, Environmental Quality Specialist
Josh Roe, Agricultural Economist

University of Missouri-Columbia
Laura McCann, Agricultural Economist

University of Nebraska–Lincoln
Michael Van Liew, Watershed Modeling Specialist

Cover photo by Dan Devlin

The Heartland Regional Water Coordination Initiative is a partnership of Iowa State University, Kansas State University, the University of Missouri, the University of Nebraska–Lincoln, the United States Environmental Protection Agency (EPA), and the National Institute of Food and Agriculture of the U.S. Department of Agriculture (NIFA-USDA). The Heartland Initiative creates and strengthens multistate, multi-institutional partnerships and collaboration to make research, education, and extension resources of the land grant universities more accessible to federal, state, and local efforts on regional priority water issues.

This material is based on work supported by NIFA-USDA under Agreement No. 2008-51130-19526.

Introduction

Agricultural land is a major source of sediments, nutrients, pesticides, and other pollutants entering surface waters, and of nitrates and other mobile pollutants entering groundwater. In recent years, much attention and expense has focused on implementing best management practices (BMPs) on agricultural lands to reduce pollutant movement into surface and groundwater. These BMPs refer to water quality protection and are made with the realization that other management objectives also must be considered. Examples of widely used BMPs include terraces, grassed waterways, conservation tillage systems, and nutrient management.

This publication is a resource that watershed planners can use to understand opportunities to improve the cost-effectiveness of BMPs for water quality protection. It is targeted to the states of Iowa, Kansas, Missouri, and Nebraska.

Most BMP implementation on agricultural lands has been voluntary, often with federal, state, and local cost share and incentive programs assisting farmers with technical assistance and funding. In the future, it is expected that even more rapid and extensive BMP implementation will be required to reach water quality goals. In addition, future climate change predictions call for increased occurrence of runoff, flooding, and leaching events, which will make the control of agriculturally derived nonpoint pollution even more important and expensive. Maximizing cost-effectiveness in future water quality protection efforts will enable greater achievement for the resources used.

Pollutant losses vary from field to field, with some fields being much greater sources of pollutants than others. It is estimated that 80 percent of some pollutants, such as phosphorous, often come from less than 20 percent of the landscape. This disproportionality occurs because some locations are more susceptible to pollutant loss than others and need to be managed with practices that prevent these losses. Cost-effective implementation of BMPs requires identifying these most sensitive source areas (e.g., the top 20 percent) and adopting BMPs that are most effective relative to the cost of implementation. Targeting locations and cost-share assistance is a technical, economic, and social challenge. The reluctance of some land managers to revise management strategies for greater natural resource protection is likely to be an ongoing challenge because of inadequate financial resources, technical assistance, or motivation.

This publication:

- addresses factors affecting the adoption of BMPs;
- presents estimates of the cost effectiveness of BMPs;
- discusses using models and GIS (Geographic Information Systems) to improve targeting and selecting cost-effective BMPs for different situations in a watershed; and
- presents examples of cost-effective programs already adopted.

Amanda Schielke

A notepad computer is used to collect field information used in watershed characterization and planning.

Adoption is an individual's decision to use a new technology or implement a practice. Diffusion is the adoption or the process of adoption of an innovation in a population. Farmers' adoption of a new practice depends on their understanding of the benefits and workings of the practice, its perceived value relative to current practices towards meeting their goals, and social interactions with other farmers and the technical and scientific community.

Often, a farmer's major goal is to increase profits by decreasing costs or increasing revenues. Other goals may include easier management, saving time, regulatory compliance, and reduced impacts to the environment. Some BMPs for environmental protection, such as improved nutrient management, may increase profitability. Rates of adoption vary by perceptions of the innovation and the individual farmer's situation and characteristics.

Adoption is an individual's decision to use a new technology or implement a practice.

Profitability

The effect of a BMP on profitability, or other advantages compared with current practices, often affects the adoption of a wide range of practices, such as using new corn hybrids or conducting manure testing. The concept of profitability takes into consideration the opportunity cost of a farmer's time — practices that don't have an out-of-pocket cost may still divert farmers' time from other activities. Under these conditions the farmer has to make decisions about time use, impacts to current management processes, and the benefits of learning and implementing a new practice versus continuing with an existing one.

Risk and Uncertainty

The perception of increased risk or uncertainty is likely to discourage adoption unless adequately offset by benefits. Farmers often apply higher levels of fertilizer than recommended as a form of insurance against inadequate nutrient supply because of adverse environmental conditions or particularly favorable growing conditions or prices. Perceptions of risk may be a particularly significant barrier for practices that are nonreversible or that require a large investment, such as a new manure management system.

If a BMP can be tested on a small scale on a farm, such as planting a new crop variety or changing fertilization rates, the uncertainty of adopting the practice on the whole farm is reduced.

Trialability

If a BMP can be tested on a small scale on farm, such as planting a new crop variety or changing fertilization rates, the uncertainty of adopting the practice on the whole farm is reduced. This is called trialability. Acceptance of any new or refined practice is increased by trials on the farm or on a neighbor's farm. For technologies that are not easily trialable, demonstrations on research farms and exposure to farmers who have already adopted the practice can be effective.

Observability

Visible results from a technology or practice can provide immediate feedback on its impact to the farm operation. Higher yields from a new variety or increased efficacy from a new herbicide are examples of observable results.

The observability of effective sediment control in grassed waterways after a severe rain on vulnerable lands may encourage adoption. Such visibility may increase farmers' motivation to manage for environmental outcomes. Conversely, there are few observable indicators to show the impact of changing nitrogen or phosphorus rates or in making short term changes in soil quality. Local algal blooms make nutrient pollution highly observable and are more likely to lead to a positive response (practice adoption) than reports of water impairments that are located far from the agricultural areas that contribute to elevated nutrient levels.

Dan Devlin

The effect of well designed terrace systems and contour farming is easily observed with ponding sediment accumulation in the channels and reduced sediment load in runoff compared with similar unprotected fields.

Feedback Mechanisms

Providing feedback to farmers that signals the need to adjust existing practices or adopt new technologies can increase the adoption of practices that support water quality protection.

For example, a recent innovation is the use of agronomic measures such as the soil conditioning index (SCI), phosphorous index (P-index), and cornstalk nitrate tests to make the environmental impact of nutrient management changes more apparent (this is further discussed on page 15). When farmers employ user friendly tests and learn how to interpret their findings, they are more open to trying new or modified practices. In order to maintain the motivation to continue and improve these measures, and thus reduce nutrient pollution, farmers must see progress, preferably while also seeing a reduction in costs.

Complexity

Complicated practices are less likely to be adopted. Nutrient management plans that combine practices and sources of information, and require additional detailed record-keeping are relatively complicated. Perceptions of complexity can affect adoption more than time required. Adopting a suite of conservation practices is more complex than adopting single practices. If new technologies or educational programs can reduce the perceived complicated nature of the BMPs, adoption should increase.

The concern of complexity may be reduced if farmers know that advisory support is available. An example may be engaging a crop consultant who has the experience and tools to streamline the implementation of nutrient management plans for feeding operations.

Farming System Compatibility

Practices that are compatible with the existing crop rotation, manure management system, labor allocation, beliefs, etc., are more likely to be adopted. New varieties of an existing crop are more likely to be adopted than a new crop that requires different machinery. A new practice that requires a significant time commitment during a busy time of the year is less likely to be adopted than if the labor requirement occurred during a less busy time of the year. Support services such as financial assistance may help ease the transition if an otherwise desirable BMP is not compatible with the existing farming system.

Shared trials also create social networks that increase the acceptance of a new technology.

Educational/Extension Efforts

Both informal and structured learning opportunities that provide research-based information can increase adoption. Providing information on the characteristics of the practice (such as profitability or environmental effectiveness) and conditions where it works well, as well as shortcomings of the practice, can reduce uncertainty. In addition to experimentation on one's own farm, farmers in the same area can work together to try variations of the practice and share their findings on adapting it to local conditions. When wanting to increase adoption on a landscape scale, such as a watershed, shared trials also create social networks that increase the acceptance of a new technology. Extension can facilitate these group learning experiences by providing structured programs that encourage farmer-to-farmer exchanges as well as scientist-to-farmer interactions.

Farm Size

Farm size has been found to positively affect adoption of profitable environmental BMPs. This is related to economies of scale and the availability of credit, both of which are associated with some technologies and practices requiring a large, up-front investment for equipment or inputs. Even for scale-neutral technologies, larger farms can use any new skills learned and reap an increased profit per acre or per animal on more units. Similarly, larger farms gain proportionately higher rewards from participating in government conservation programs. Where financial incentives are used to encourage adoption, ready access to credit and the flexibility to use different practices can positively impact the decisions on smaller farms. Livestock-intensive farms with high potential environmental impact also may have a small land base, introducing an additional size issue in the case of incentives for conservation BMPs that are paid on a per acre basis.

Farmer Characteristics

Education, the amount and nature of off-farm income, and the age of the farmer have been shown to affect adoption. Better educated farmers are more likely to adopt new technologies and practices, possibly because of an increased ability to obtain and use information. Adoption by high school graduates tends to be higher than nongraduates. Education beyond high school can further increase adoption of some practices, but some studies show there is little effect of education beyond a bachelor's degree [9].

One size does not fit all.

The amount and nature of off-farm income also can affect adoption since it reduces the time available but increases financial capability. Farmers with full-time jobs are less likely than full-time farmers to be able to attend educational events during the day.

The effect of age on adoption varies. Younger farmers typically are more likely to adopt new technologies and practices. This is especially true if the benefits accrue over a long period of time. While older farmers have a shorter time horizon, they are often more likely to adopt certain practices, probably because of their greater experience relative to younger farmers.

Implications

Farmer decisions to adopt new technologies and practices are influenced by many factors, including their economic and environmental goals, beliefs and experiences, farm and financial situation, age, social interactions with others, access to information about the BMPs, and characteristics of the BMPs. Extension educators and other groups trying to promote BMPs need to be aware of these issues; one size does not fit all. Making environmental outcomes observable will enhance educational effectiveness. Research to develop BMPs needs to consider environmental outcomes and profitability, as well as simplicity and complementarity to farming systems.

Farmer decisions to adopt new technologies and practices are influenced by many factors.

Table 1. Cost-effectiveness of several BMPs for water quality protection for no-till farming in Kansas[7].

Best Management Practice	Cost $/Acre	Atrazine Herbicide	Nutrients: Soluble P	Nutrients: Total P	Nutrients: Total N	Sediment
	—— (% reduction in runoff by adopting BMP) ——					
Use postemergence herbicide applications	6.02	50	0	0	0	0
Use alternative herbicides	10.12	100	0	0	0	0
Inject N and P fertilizer	3.50	0	70	50	70	0
Fall-apply atrazine	8.34	50	0	0	0	0
Apply atrazine prior to May 1	5.56	50	0	0	0	0
Split apply atrazine e.g., 2/3 before May 1 and 1/3 at planting	6.02	25	0	0	0	0
Reduce atrazine rates and follow with a postemergence application	6.02	33	0	0	0	0
Rotate crops	0	30	25	25	25	25
Establish vegetative buffer strips	a/	25	25	50	35	50
Avoid applying atrazine, N and P within 100 feet of streams	b/	20	25	25	25	0
Contour farming (without terraces)	6.8	20	20	30	20	20
Terraces with tile outlets	c/	10	10	30	10	30
Terraces with grass waterways	d/	30	30	30	30	30
Soil sampling and testing	1	0	0 - 25	0 - 2	50 - 25	0
Sound fertilizer recommendations	0	0	0 - 25	0 - 25	0 - 25	0

a/Establishment cost of $100 per acre plus an annual cost equal to the average per-acre land rental rate for the acreage within the vegetative buffer strip
b/Annual cost equal to the average per acre land rental rate for the acreage where herbicides and nutrients are not applied (i.e., acres within 100 feet of streams or where runoff enters a stream)
c/One-time installation cost of $40 per-acre, assuming 90 percent cost-share assistance for installation, plus an annual cost of $15 per acre
d/One-time installation cost of $30 per-acre, assuming 90 percent cost-share assistance for installation, plus an annual cost of $35 per acre (all crop acres in the field) plus an annual cost equal to the average per-acre land rental rate for the acreage within the grass waterways

The cost-effectiveness of BMPs varies because of differences in effectiveness for environmental protection and the cost of implementation. BMPs that address multiple concerns are generally more cost-effective. Local knowledge of cost-effectiveness can be a valuable asset. Typical values have been determined for Kansas and the Upper Mississippi River Sub-Basin which can complement local knowledge in choice of BMPs.

Kansas Cost-effectiveness Estimates

Cost-effectiveness values for several practices were estimated based on: 1) results of small-plot and field-sized experiments, and 2) expert opinion of Kansas State University research and extension specialists[7]. Estimates for no-till conditions are summarized in *Table 1*. Similar estimates were made for tilled conditions and for animal manure management. These are estimates of typical costs and effectiveness, both of which vary across farming systems, environmental conditions, and over time.

Table 2. Cost-effectiveness of practices, estimated from several studies, for reducing sediment, nitrogen, and phosphorus losses.

Practice	Sediment reduction ($/ton)	Nitrogen reduction ($/lb)	Total phosphorus reduction ($/lb)
No-till[4]	1.46	0.38 (TN)	1.0
Contour farming[4]	0.51	0.10 (TN)	0.26
Strip cropping[1]	1.03	0.22 (TN)	0.56
Terraces with vegetative outlets[4]	5.00	1.11 (TN)	2.84
Drainage water management[3]	N/A	1.48-4.17 (NO_3-N)	N/A
Nutrient removal wetlands[13]	N/A	1.38 (NO_3-N)	N/E
Buffers and vegetative filters with typical tillage[12]	1.4-2.2	0.4-0.6 (TN)	1.0-1.4
Buffers and vegetative filters with no-till[12]	11.3-16.9	1.4-2.3 (TN)	4.4-7.3
Annual cover crops[15]	N/E	0.57-1.42 (NO_3-N)	N/E

N/A, not applicable; N/E, not estimated.
TN = total nitrogen
NO_3-N = nitrate-nitrogen

Upper Mississippi River Sub-Basin Cost-effectiveness Estimates

Scientists from the Upper Mississippi states reported research findings on the cost-effectiveness of various nutrient management practices (*Table 2*). No-till, contour farming, and strip farming were relatively more cost-effective, and drainage water management was relatively less cost-effective compared with other practices for reducing nitrogen, phosphorus, and sediment loss to bodies of water. However, some practices perform well for contaminants transported via surface runoff (e.g., total phosphorus and total nitrogen) versus those transported via subsurface flow (e.g. nitrate-nitrogen). Reducing nitrogen rate by 40 lb/ac from the economically optimal nitrogen rate was more cost-effective than other in-field nitrogen management practices for reducing nitrate nitrogen in drainage water (*Tables 2* and *3*).

Multiple BMPs and Multiple Benefits

Often, multiple BMPs in a watershed will be required to meet water quality goals (*Figure 1*). This figure illustrates that some BMPs are appropriate for relatively little of the land. Others are more costly. The analysis shows that 40 percent of the target reduction of 12,000 ton/year loss of nitrate-nitrogen in drainage water can be achieved with little or no in-field cost, and 80 percent of the target can be achieved at an added cost of about $10 million per year. The final 20 percent of the target, however, will cost another $15 million per year or about five times as much per pound of nitrogen loss reduction compared with the first 80 percent. Such analyses are needed for setting other water quality targets, selecting practices, and determining fair compensation to land managers who adopt appropriate practices.

Cost-effectiveness can be enhanced if a BMP has multiple benefits. A reduced nitrogen rate may reduce nitrate-nitrogen loss to groundwater or to tile drainage but also reduce emission ammonia and the greenhouse gases, carbon dioxide and nitrous oxide. Similarly, cost-effectiveness can be reduced by a negative effect from a BMP. For example, band injection of nitrogen to no-till land may be preferable to broadcast surface application to reduce ammonia volatilization loss and nitrogen loss in runoff to surface waters but may result in increased nitrous oxide emission.

Table 3. Cost-effectiveness of several in-field nitrogen management practices for reducing leaching of NO_3-N to tile drainage in Iowa[19,20].

Practice	Reduction	Cost, $/acre/year
Reducing N rate: 125 to 85 lb/ac for corn-soybean rotation	17%	$5.85
Avoid fall N application	15%	$5-10
Nitrification inhibitor with fall N application	14%	$7.50

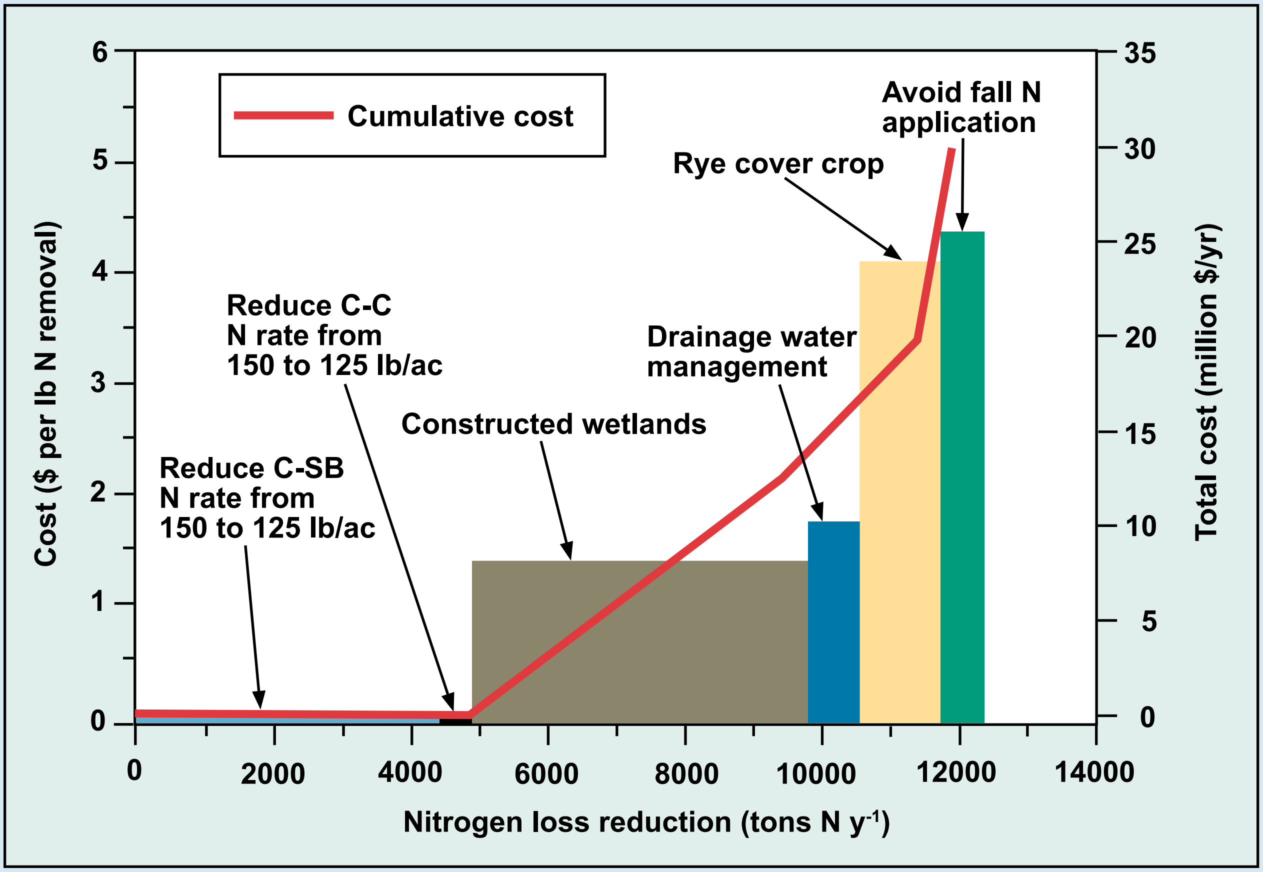


Figure 1. A hypothetical case of deploying six BMPs in Iowa to reduce nitrate-N loss in drainage water by 12,000 tons per year in a 4.2 million acre watershed with approximately 3.3 million acres of corn-soybean land. The cost ($/1b N) and potential impact of BMPs is represented by the bars. The red line represents the cumulative cost of achieving the targeted nitrogen loss reduction. C-C and C-SB refer to continuous corn and corn-soybean rotation, respectively.

Models and Decision Support Tools for Optimization of Cost-effectiveness

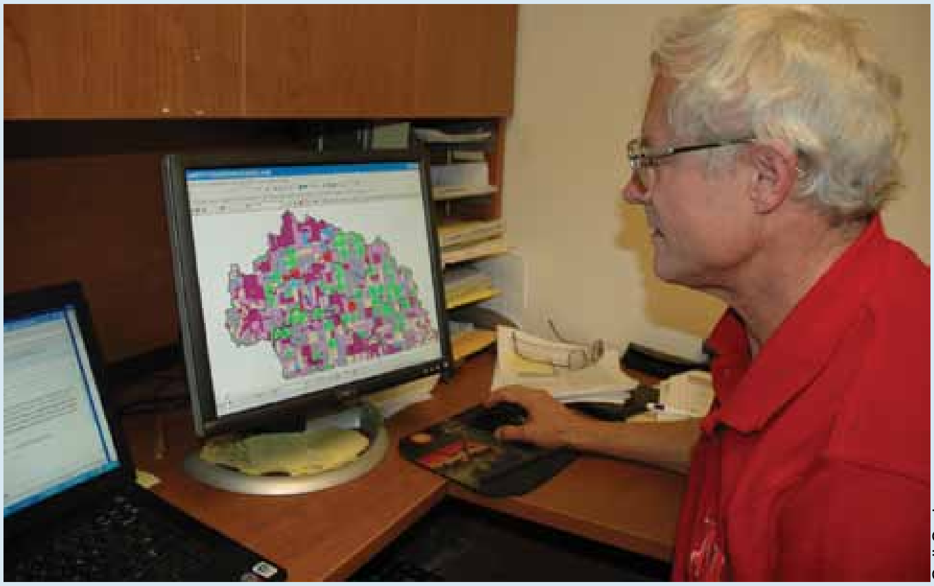
Considerable attention has been given to the implementation of BMPs to reduce nonpoint source pollution, such as sediment, nitrogen, phosphorus, and pesticides that enter bodies of water from agricultural land. Based on measured data, computer models have been employed to estimate the effectiveness of various BMPs for a range of environmental settings and climatic conditions. Because of the many and complex interactions among environmental factors as well as constraints on existing resources, the efficacy of BMP implementation is site specific. This implies that it may not be necessary to implement BMPs on every farm in a watershed. Land use, soils, and topography cause some locations within a watershed to be more critical for BMP implementation than other areas in meeting reductions in pollution. Thus, noting particular resource and economic constraints, BMPs should be implemented strategically, with a focus on locations that can provide appreciable reductions in pollution loadings.

Interactions among various environmental and ecological factors as well as economic constraints affect the cost-effectiveness and choice of BMPs used at a landscape or watershed level. Because of the many possible BMP scenarios for cost-effective pollution reduction, it often is not feasible to find the optimal scenario through on-site evaluation. To illustrate, trillions of combinations of BMPs are possible for a watershed with 100 farms, and six different BMPs possible for every farm (6^{100}).

Depending on the management level, from landscape to large watershed scale, various approaches can be employed to evaluate the effectiveness of a suite of BMPs. One approach might involve a random placement of BMPs on the landscape. A second approach might target critical areas based on topography, soils, or crop and livestock management practices. Often in the past, the selection and placement of BMPs has focused on pollutant reduction alone without adequate consideration of costs to the land owner, producer, and/or the public. A more acceptable and feasible approach simultaneously considers both cost and pollutant reduction. In this third approach, the cost and benefits of various possible scenarios of alternative BMPs are compared to the current practices that exist on the landscape or the watershed.

Optimization techniques can find options that are both economically viable and ecologically effective.

An approach with multiple objectives uses a protocol to search for the optimum alternative(s) among many possible BMP scenarios. This protocol can range from a simple to a more elaborate and computerized system. Recently Mamo et al. (2009)[17] released an interactive computer-based tool for selecting BMPs for major cropping systems in Nebraska. Users can set up current farm input and output factors, current prices, and cropping and management information. Based on the user's tolerance of economic loss and the soil erosion targets for a landscape, output from this tool provides stakeholders with several BMP alternatives. Daggupati et al. (2009)[8] report the use of the watershed scale model, referred to as the Soil and Water Assessment Tool (SWAT), to evaluate field-scale implementation of BMPs for reducing cropland sediment yields. They developed an add-on to SWAT to generate sediment output for individual fields. The output was in turn ranked to quantify the greatest soil loss reductions that could be achieved by implementing specific conservation practices on the fields.



Gail Ogden

Michael Van Liew, UNL watershed modeling specialist, uses models to better select and target management solutions in watersheds to optimize benefits relative to costs.

For large, complex watersheds an optimization technique that employs a genetic algorithm[11] represents a powerful multiple objective approach for BMP selection. The generic algorithm has the ability to provide a number of near-optimal solutions when evaluating the cost-effectiveness of various types of BMPs. This technique generates a solution from an ensemble of solutions that are both economically viable and ecologically effective for given watershed conditions[16]. Because these tools can be used to estimate a range of responses that will provide the least expensive control for different levels of pollutants, there is the added benefit of potential flexibility for solutions that are suited to stakeholders. As such, stakeholders have the option of choosing among various BMP scenarios that are most personally suitable, weighing tradeoffs between convenience and cost[10].

Stakeholders have the option pf choosing among various BMP scenarios.

For the optimization scheme to evaluate the objective functions for a given watershed project (see the Appendix on page 20 for more on optimization schemes), the following inputs are required:

- the baseline pollutant loading for the partitioned land use/soil grid-cells in the modeled watershed configuration;

- the possible set of BMPs that can be placed on a particular land use/soil grid-cell given specified land use constraints; and

- the pollution reduction efficiency and corresponding costs associated with BMP implementation.

During the optimization process:

- the algorithm searches first for a particular management practice from the possible BMP options for a given land use[16];

- the subsequent estimation of the pollution loading and cost estimates for the placement of a particular BMP in the selected land use/soil grid-cell is obtained from the BMP tool; and

- a weighted average of the pollutant loading and the net costs at the land use/cell level are calculated to provide an estimate at the watershed level[16].

The continued development of optimization schemes and decision support tools for BMP selection and placement on the landscape holds considerable promise for achieving cost-effective pollution reductions in agricultural settings. Since many of the latest tools have the capability of identifying alternative solutions, an additional benefit exists whereby stakeholders have the flexibility of choosing from a suite of BMPs that best meet their particular needs. As refinements continue to be made in the efficiency of optimization search techniques, linkage of tool components, and characterization of uncertainty in model inputs and parameter estimation, decision support tools can increasingly serve as powerful methods to achieve economically feasible reductions in pollutant loadings to improve the quality of both surface and groundwater resources.

A Performance Incentive Program in Iowa

A performance-based incentive program compensates farmers for improving or maintaining high performance related to one or more agronomic or environmental measures[18]. The program is managed by a watershed council composed of residents of the watershed. The council addresses environmental goals through citizen participation in performance based management (*Figure 2*).

Four northeast Iowa watershed councils are using incentives to address nitrogen, phosphorus, and sediment issues based on field-level measures, including the fall cornstalk nitrate test, the Iowa Phosphorus Index, and the Soil Conditioning Index. These performance measures were chosen because they were previously used in other programs or have a history of use by producers and agencies in Iowa.

The stalk nitrate test is a post-maturity measurement of nitrate in the lower cornstalk to determine if nitrogen has been overapplied. Watershed councils compensate producers for the cost of sampling and analysis, with payments ranging from $25 to $50 per sample. A second set of incentives are paid if the farm average is within the optimal range, with two levels of payment: $200 per farm if stalk nitrate-nitrogen levels are below excessive and between 1,700 to 2,000 ppm; and $400 per farm for near optimal levels, for example 1,300 ppm. These incentives are small when compared to savings that farmers can achieve by reducing nitrogen rates. For example, a 20 pound reduction could be an $8 per acre savings across all corn acres.

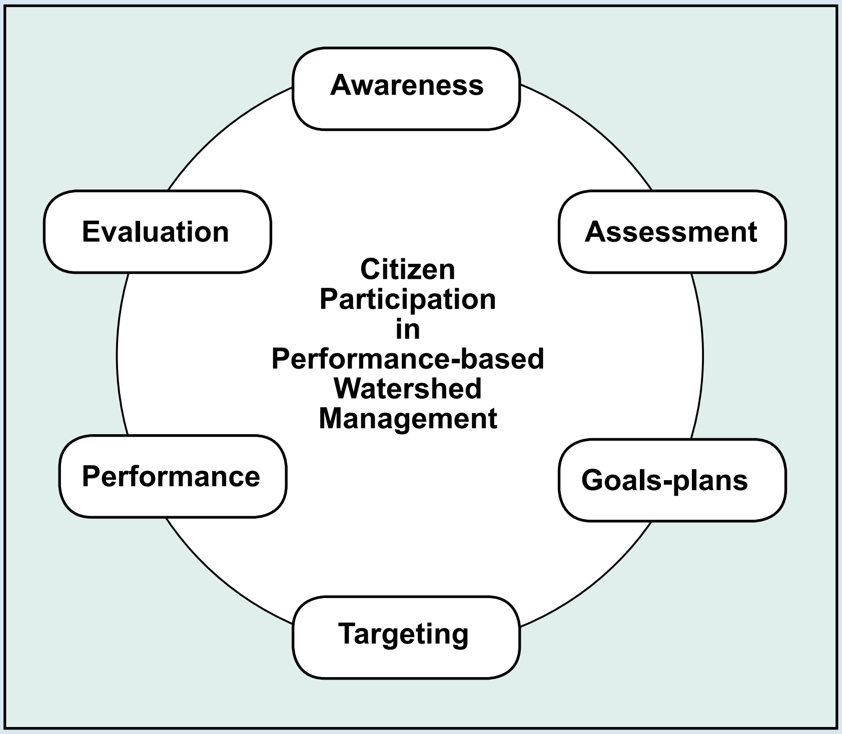


Figure 2. A process of stakeholder involvement in watershed management.

The Iowa Phosphorus Index (IPI) is used to rate the risk of phosphorus loss to the environment with an index value greater than 5 showing a high probability of phosphorus loss to the environment. Watershed councils provide three types of incentives. The first is for baseline performance with first-year incentives of $0 or $300 per farm paid if the whole-farm average is above or less than 3, respectively. Future baseline performance incentives of $150 are often paid if the farm average IPI value is less than 2. The second incentive paid is $50 to $100 per farmer to repeat the IPI evaluation annually in order to provide updated information. The third set of incentives can be received for IPI improvement. A council may pay $50 per 0.1 point improvement in the whole-farm average IPI score. For example, if the average farm IPI score changes from 2.60 to 1.90, or a 0.7 point improvement, due to change from

Table 4. Allocation of resources ($ per year) for performance incentives in the Hewitt Creek (2008) and Coldwater-Palmer (2009) watersheds of northeastern Iowa.

	Hewitt Creek	Coldwater-Palmer
Iowa Phosphorus Index	7830	15098
Soil Conditioning Index	16013	2310
Nitrogen performance	3930	11370
Other incentives	9343	11062
Watershed performance	4200	9200
Total incentives	$46,226	$49,040
Number of cooperators	50	46

tillage to no-till, the payment would be $350. Other councils may pay on a field basis. For example, a 0.7 point improvement in IPI score would result in a payment of $175 for an 80-acre field if the rate is $25 per field for 0.1 point improvement.

The Soil Conditioning Index (SCI) is a Natural Resource Conservation Service (NRCS) tool that provides a qualitative indication of the effects of agronomic practices on soil organic matter, assuming that higher values are related to less sediment loss from the watershed. Cooperating farmers like the SCI, realizing the importance of soil organic matter to maintaining and increasing productivity. As with the Iowa P Index approach, farmers can receive incentives for baseline and continuing performance levels, annual review, and SCI improvement. The SCI range is -1 to 1.1, and higher scores are better. Baseline performance payments are usually $200 per 0.1 above zero, so a farm average SCI score of 0.4 would result in an $800 payment. An annual review incentive of $50 per 0.1 would provide an incentive of $200 on the same farm. Incentives for SCI improvement range from $200 to $400 per 0.1; therefore, an improvement from 0.4 to 0.55 nets an incentive of $600 if the incentive is $400 per 0.1 SCI improvement.

The above indexes are three examples of useful tools for performance incentives. The extent of their use and other incentives in two northeastern Iowa watersheds is summarized in *Table 4.* A field- or farm-level performance measure needs to be relevant to the water quality targets of the watershed level. For example, a watershed with high nitrate as a concern would require a focus on reducing nitrogen application through the use of the corn stalk nitrate test. A watershed may need more than one performance tool to determine field- or farm-level performance, or to encourage farmer participation in meeting the watershed targets. Performance incentives must be simple to understand and use.

The performance program enrollment form developed by a watershed council should fit on one side of one sheet of paper (*Table 5*). The program may evolve over time as watershed priorities are modified with performance incentives added, removed, or revised as appropriate. Most of the Iowa watershed councils' incentives are on a farm rather than an acre basis, and treat all operations similarly regardless of size. This works well if the changed practice results in increased profit per acre, but the incentives may not be attractive to larger operations if profitability is not improved.

A performance-based incentive program can be an information rich system that promotes or advocates changes in conservation management. Farmers can measure their environmental performance, as they may already measure yield, against a performance goal. Watershed-wide summary documents allow cooperators to anonymously compare their operation's performance to others in the watershed, introducing a level of competition into conservation management practice adoption. Watershed councils can use the information to determine the effectiveness of the performance-based incentives (Figure 3). Performance-based incentives provide participants with the flexibility to choose the most cost-effective course of action to improve environmental performance on their operation, and to measure how that choice moves their farm closer to a watershed goal. In an evaluation, all or

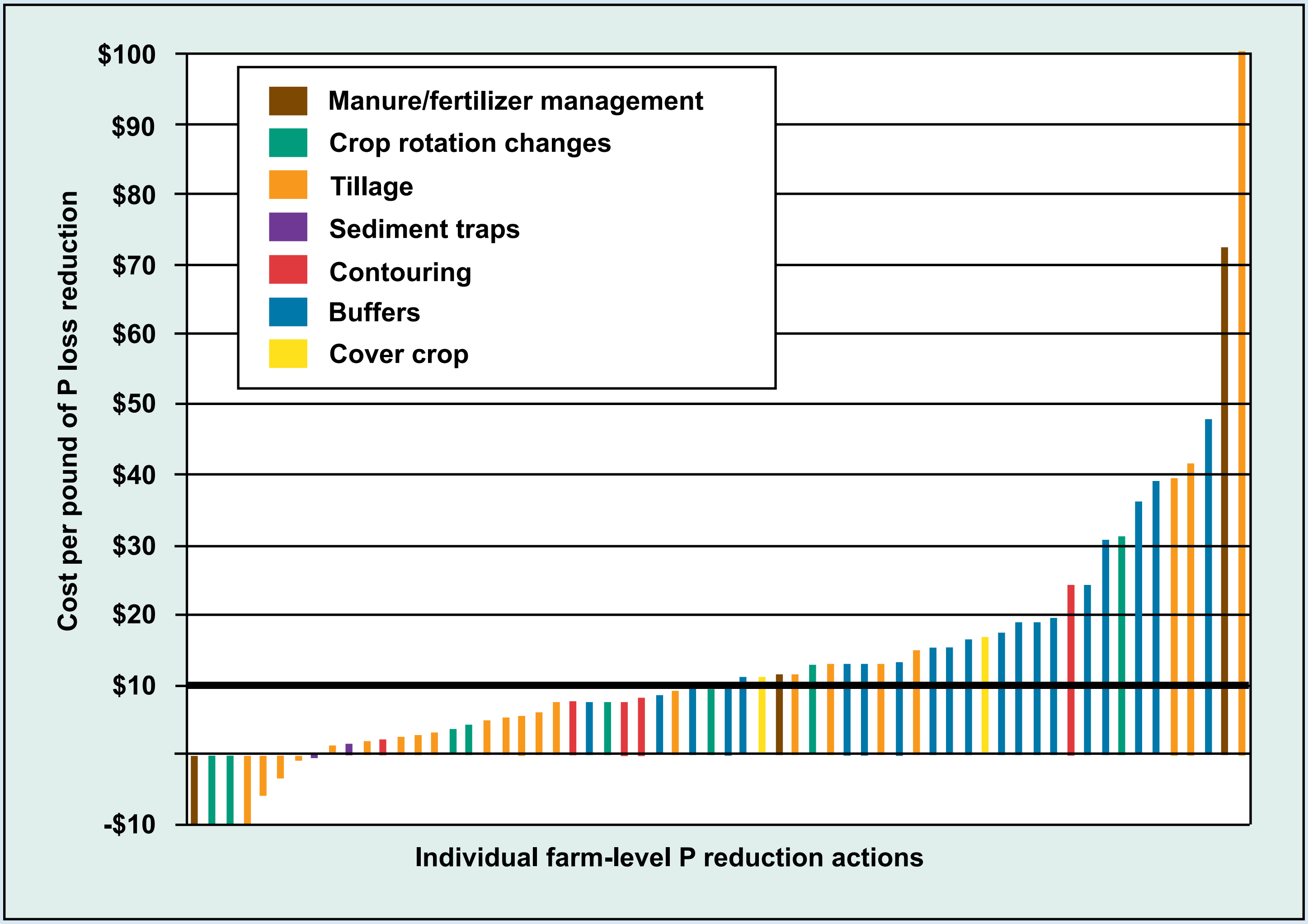


Figure 3. The cost-effectiveness of agricultural management practices in reducing phosphorus loss in a northeastern Iowa watershed.

Table 5. A performance incentive enrollment form as used in Coldwater-Palmer watershed of northeastern Iowa.

PERFORMANCE (outcome)-BASED FARM and WATERSHED
ENVIRONMENTAL MANAGEMENT PROGRAM: Coldwater/Palmer watershed
Please check activities you wish to complete. (Deadline April 1/first-come subject to funding).
[Payments near July 1 and early December will be prorated if participation exceeds $83,854].

NITROGEN PERFORMANCE (Cornstalk nitrate-nitrogen analysis).
_____$400 payment if the farm weighted average analyses does not exceed 1,700ppm.
_____$200 bonus if the weighted average (Max. 50 acres/field) is less than 1,300ppm.
_____$80 for two Cornstalk NO_3N samples analyzed and $30.00 for each additional test.
_____$80 for two Late Spring Nitrate Tests (LSNT) and $30.00 for each additional test.
_____$500 for side-dress nitrogen application.
_____$250 for moving N application from fall to spring, no fall application on watershed acres.
_____$200 bonus for a wetland impoundment or if drainage tile management of spacing and depth or treatment system is used to reduce N delivery.

PHOSPHORUS INDEX (PI) Maximum $10/Ac. See P-index explanation on back of this page.
_____$200 first year payment if the weighted whole farm P-index is less than a phosphorus loss risk of 3 (2-5 is medium risk). All field scores weighted by the field size and risk of P loss from each field to attain a weighted average farm P-index.
_____$100 bonus for each 0.1 reduction in reviewed P-index and for P-index less than 1.0 (VL).

SOIL CONDITIONING INDEX (SCI) Maximum $10/Ac.
_____$200 first year per 0.1 SCI above 0, based on acreage weighted average SCI of all fields.
_____$100 per 0.1 SCI for annual data and SCI review after the first year.
_____$400 paid for each 0.1 improvement in the annual SCI.
_____$400 for fall strip till or no-till corn,(no spring tillage), 20 acres minimum.

OTHER INCENTIVES
_____$200 For manure application calibration, manure analysis and nutrient Mgt. Demo..
_____$200 Grid sampling and variable rate fertilizer application (40 acres minimum).
_____$200 Install a manure settling basin and grass filter or pre-lot water diversion.
_____$200 Livestock Exclusion (stream fencing) or managed grazing (5 or more paddocks).
_____$500 For a nitrogen, manure, drainage, or tillage/planting replicated demonstration.
_____$200 Septic system up-grade. Low interest revolving fund loans available (515-242-6043).
_____$100 Farmstead Assessment (first time self assessment or changes-improved assessment).
_____$200 For farmable grass berms for diversion of water to ditches or waterways.
_____$100 Each up to three 40'X40' grass buffer area of concentrated flow, maintained for 3 yrs.
_____$0.60/ft., maximum 2,400 ft., waterways (no parallel row planting), headlands, or buffers, minimum 30' width.

WATERSHED ENVIRONMENTAL PERFORMANCE (add-on bonus).
_____$100 Bonus for each 10 percent increase above 20 percent of the land in the watershed enrolled in this Performance program. Payable to cooperators earning $1,000 or more watershed improvement incentives per farm operation.
_____$200 Three years of monitoring showing evidence of reduced contaminant delivery.

Name ______________________________ Address ______________________________

Phone ______________________________

most watershed residents rated the performance incentive program effective in: rewarding a conservation systems approach (100 percent); encouraging management changes (94 percent); and having a positive effect on the environment (86 percent).

Auction Bidding for Cost Share in Kansas

Interest in and use of market-based approaches for environmental management has increased partly because of their theoretical property of cost-effectiveness[1] and partly from their practical success in dealing with specific pollution problems, such as sulfur dioxide air emissions[21]. Such formalized markets also have been applied to water-borne pollutants from agriculture, with over 40 water quality trading (WQT) programs in place in the United States[2].

The auction allows the buyer to identify and purchase the most cost-effective environmental improvements for a specified budget.

In the Kansas BMP auction approach, bids are submitted to the agency by farmers and then ranked based on the quantity of soil erosion or nutrient reduction generated per dollar. For cropland auctions, each bid is evaluated by NRCS staff using RUSLE 2 soil loss baseline calculations. In livestock production auctions, SWAT and the Agricultural Policy/Environmental eXtender (APEX) models are used to evaluate bids. These baseline soil and nutrient losses are adjusted for the proposed BMP impact, and the bid amount is divided by the predicted quantity of soil or nutrient saved. Winning bids are awarded to farmers that can provide the most soil erosion reduction for the least cost. Awards are made until a predetermined minimum erosion reduction-to-price level is reached, although in most cases the funds are exhausted at higher reduction-to-price levels. The auction allows the buyer to identify and purchase the most cost-effective environmental improvements for a specified budget.

The allocation of cost-share funds to support the greatest nutrient/erosion reduction-to-price differs from traditional cost-share programs that simply limit the geographical area in which cost-share money can be spent. The auctions conducted in Kansas and Missouri were marketed to producers within targeted areas specified by SWAT and the EPA Spreadsheet Tool for Estimating Pollutant Loads (STEPL) models. They received direct marketing via mailings, and in some cases on farm visits, while broader marketing, such as radio interviews/advertisements and fliers posted in public places, serviced the entire watershed of interest.

Between 2007 and October 2009, five BMP auctions focusing on soil erosion and two focusing on livestock runoff were conducted in Kansas and western Missouri. Approximately 120 producers have submitted bids. The acceptance rate for bids is currently about 50 percent. The practices installed reduce annual soil erosion approximately 4,700 tons annually. The BMP auctions are relatively new but have been well received by agricultural producers and landowners. The cost-effectiveness of BMP auctions and other market based approaches have not yet been compared with that of traditional cost-share programs.

Summary

Goals of reducing water body contaminants from agricultural land have resulted in much change in management practices. These changes have generally been voluntarily implemented by farmers and farm managers, although often with the assistance of cost share and incentive programs. This publication addresses improvements of the cost-effectiveness of water quality protection. Alternative practices need to be easy for farmers and other land managers to adopt, and diverse factors affecting adoption need to be considered when selecting BMPs. The cost-effectiveness of BMPs has been estimated realizing that cost-effectiveness very much depends on particular situations. Watershed models and GIS can be useful in targeting and optimizing the selection of BMPs for different situations in a watershed. Innovative watershed programs have been implemented to improve the cost-effectiveness of water quality protection. They have provided lessons that are applicable in other watersheds. Integration of these various considerations, information, tools, and approaches can improve the cost-effectiveness of water quality protection.

Alternative practices need to be easy for farmers and other land managers to adopt, and diverse factors affecting adoption need to be considered when selecting BMPs.

Optimization schemes for evaluating cost-effective BMPs typically contain at least four components:

1) a multiobjective optimization algorithm,
2) a genetic algorithm,
3) a watershed scale simulation model, and
4) a BMP tool.

The first component is the logic and fitness assignment method of a multiobjective evolutionary optimization algorithm[5,16]. The second component is a publicly available C++ library of genetic algorithms, GALib[23] which provides the basis that is needed to implement an evolutionary search algorithm[14]. The third component is the water quality model, such as Soil and Water Assessment Tool (SWAT), Annualized Agricultural Non Point Sources (AnnAGNPS), or Hydrologic Simulation Program-Fortran (HSPF), which provides a framework to model the different conservation practices considered in a given study and their watershed level environmental impacts[14]. A fourth component is a BMP tool that is based on effectiveness data obtained from published BMP monitoring studies[10]. Such a database contains information about runoff, sediment, and nutrient load reductions, associated site and study characteristics, BMP classifications, and current BMP implementation expenses and expected lifetimes[6,10]. Figure 1A illustrates the basic steps of an optimization procedure for evaluating BMPs[22].

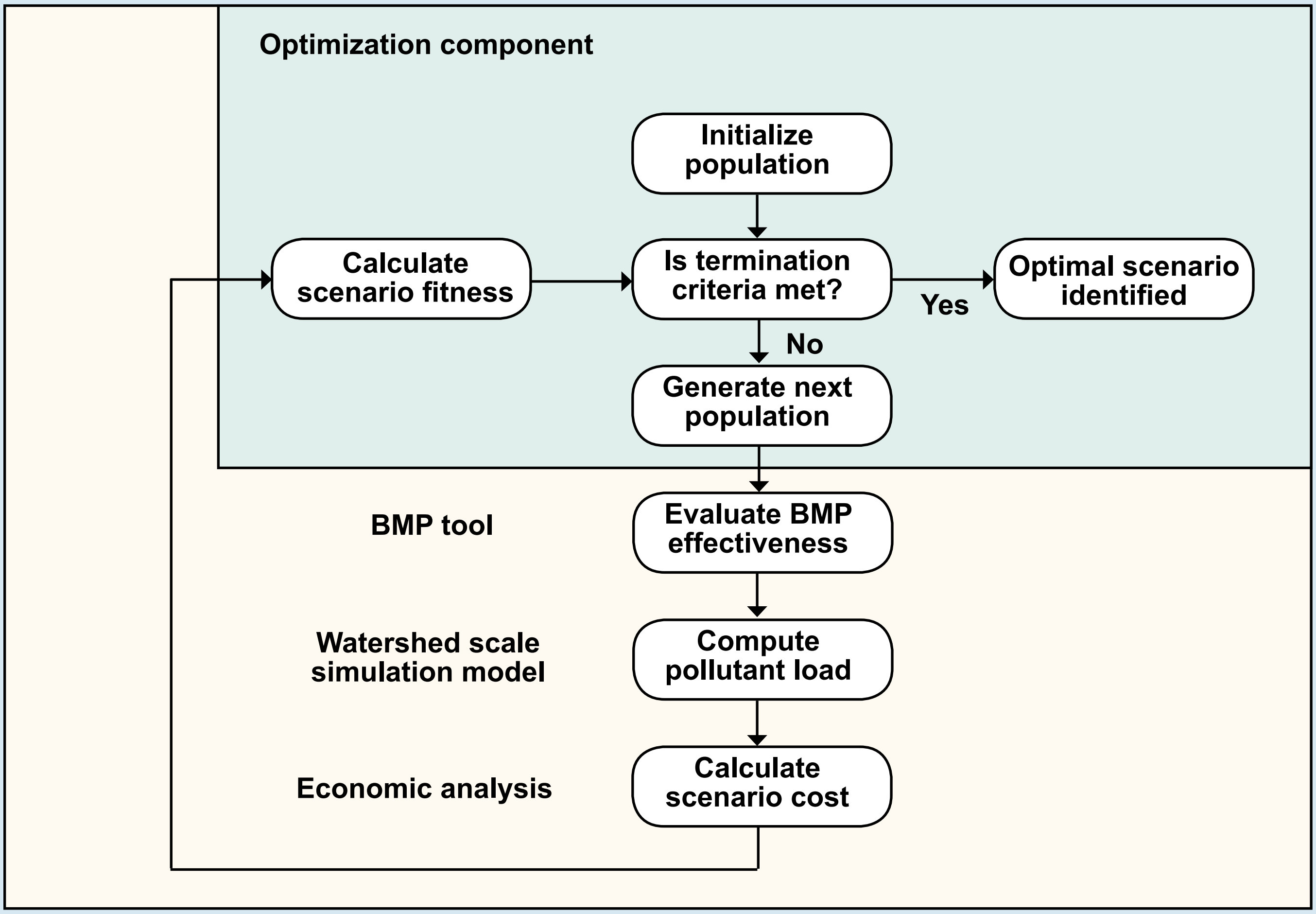


Figure 1A. Basics steps of an optimization procedure for evaluating BMPs[22].

References

1. Atkinson, S. and T. Tietenberg. 1991. Market failure in incentive based regulation: the case of emissions trading." Journal of Environmental Economics and Management 21(July 1991): 17-31.

2. Breetz, H.L., K. Fisher-Vanden, L. Garzon, H. Jacobs, K. Kroetz, and R. Terry. 2004 Water quality trading and offset initiatives in the United States: A Comprehensive Survey. Report for the EPA. Hanover, NH: Dartmouth College Rockefeller Center.

3. Cooke, R.A., G.R. Sands, and L.C. Brown. 2008. Drainage water management: A practice for reducing nitrate loads from subsurface drainage systems. Chapter 2 in *Final Report: Gulf Hypoxia and Local Water Quality Concerns Workshop*. American Society of Agricultural and Biological Engineers, St. Joseph, MI.

4. Czapar, G.F., J.M. Laflen, G.F. McIsaac, and D.P. McKenna. 2008. Effects of erosion control practices for nutrient losses. Chapter 9 in *Final Report: Gulf Hypoxia and Local Water Quality Concerns Workshop*. American Society of Agricultural and Biological Engineers, St. Joseph, MI.

5. Deb, K. 2001. Multi-Objective Optimization using Evolutionary Algorithm. New York: John Willey & Sons.

6. Degarmo, E.P., W.G. Sullivan, J.A. Bontadelli, and E.M. Wicks. 1997. Engineering Economy. Upper Saddle River, N.J.: Prentice Hall.

7. Devlin, D., K. Dhuyvetter, K. McVay, T. Kastens, C. Rice, K. Janssen, and G. Pierzynski. 2003. Water quality best management practices, effectiveness, and cost for reducing contaminant losses from cropland. KSU Agricultural Experiment Station and Cooperative Extension MF-2572.

8. Daggupati, P., A. Sheshukov, K. Douglas-Mankin, P. Barnes, and D. Delvin. 2009. Field targeting of cropland sediment yields using ArcSWAT. Presented at: 2009 5th International SWAT Conference. August 5-7, Boulder, CO.

9. Gedikoglu, H. and L.M.J. McCann. 2011. What Causes Farmers to Adopt Agricultural and Conservation Technologies and How Can We Use That Knowledge to Improve Policies, Programs, and Technologies?, pp. 109-127 in "Human Dimensions of Soil and Water Conservation: A Global Perspective," Ted Napier, Ed. Nova Science Publishers.

10. Gitau, M.W., T.L. Veith, and W.J. Gburek. 2004. Farm-level optimization of BMP placement for cost-effective pollution reduction. Transactions of the Society of Agricultural and Biological Engineers 47:1923-1931.

11. Goldberg, D.E. 1989. Genetic Algorithms in Searching, Optimization, and Machine Learning. Reading, MA: Addison Wesley.

12. Helmers, M.J., T. Isenhart, M. Dosskey, S. Dabney, and J. Strock. 2008. Buffers and vegetative filter strips. Chapter 4 in *Final Report: Gulf Hypoxia and Local Water Quality Concerns Workshop*. American Society of Agricultural and Biological Engineers, St. Joseph, MI.

13. Iovanna, R., S. Hyberg, W. Crumpton. 2008. Treatment wetlands: Cost-effective practice for intercepting nitrate before it reaches and adversely impacts surface runoff. Journal of Soil and Water Conservation 63:14A-15A.

14. Jha, M., S. Rabotyagov, and P.W. Gassman. 2009. Optimal placement of conservation practices using genetic algorithm with SWAT. Working Paper 09-WP 496. CARD, Iowa State University, Ames, IA.

15. Kaspar, T.C., E.J. Kladivko, J.W. Singer, S. Morse, and D.R. Mutch. 2008. Potential and limitations of cover crops, living mulches, and perennials to reduce nutrient losses to water sources from agricultural fields in the Upper Mississippi River Basin. Chapter 10 in *Final Report: Gulf Hypoxia and Local Water Quality Concerns Workshop*. American Society of Agricultural and Biological Engineers, St. Joseph, MI.

16. Maringanti, C., I. Chaubey, and J. Popp. 2009. Development of a multi-objective optimization tool for the selection and placement of best management practices for nonpoint source pollution control. Water Resources Research 45, WO6406: 1-15.

17. Mamo, M., D. Ginting, K. Schoengold, and C.S. Wortmann. 2009. Soil-Erosion Economic Decision Support Tool (SEE-DST) for land management in Nebraska. University of Nebraska Extension Circular EC169, University of Nebraska, Lincoln, NE (available online at URL *http://www.extension.unl.edu/publications/*.

18. Morton, L.W., J. Rodecap, S. Brown and G.A. Miller. 2006. Performance-based environmental management: The Hewitt Creek Model. Pm 2013. University Extension, Iowa State University, Ames, IA. 4 pp.

19. Randall, G.W. and J.E. Sawyer. 2008. Nitrogen application, timing, and forms. Chapter 6 in *Final Report: Gulf Hypoxia and Local Water Quality Concerns Workshop*. American Society of Agricultural and Biological Engineers, St. Joseph, MI.

20. Sawyer, J.E. and G.W. Randall. 2008. Nitrogen rates. Chapter 5 in *Final Report: Gulf Hypoxia and Local Water Quality Concerns Workshop*. American Society of Agricultural and Biological Engineers, St. Joseph, MI.

21. Stavins, R.N. 1998. What can we learn from the grand policy experiment? Lessons from SO2 allowance trading. Journal of Economic Perspectives 12:69-88.

22. Veith, T.L., M.L. Wolfe, and C.D. Heatwole. 2004. Cost-effective BMP placement: optimization versus targeting. Transactions of the Society of Agricultural and Biological Engineers 47:1585-1594.

23. Wall, M. 2006. GAlib: A C++ Library of Genetic Algorithm Components, ver. 2.4.6. Available at *http://lancet.mit.edu/ga*.

Applying knowledge to improve water quality

Heartland

Regional Water Coordination Initiative

A Partnership of USDA CSREES
& Land Grant Colleges and Universities