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ADAPTIVE TARGETING: ENGAGING FARMERS TO IMPROVE TARGETING AND ADOPTION OF AGRICULTURAL CONSERVATION PRACTICES[1]

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ABSTRACT: Targeting of agricultural conservation practices to cost-effective locations has long been of interest to watershed managers, yet its implementation cannot succeed without meaningful engagement of agricultural producers who are decision makers on the lands they farm. In this study, we engaged 14 west-central Indiana producers and landowners in an adaptive targeting experiment. Interviews carried out prior to targeting provided rich spatial information on existing conservation practices as well as producers' preferences for future conservation projects. We targeted six of the most accepted conservation practices using the Soil and Water Assessment Tool and spatial optimization using a genetic algorithm approach. Fairly optimal conservation scenarios were possible with even the most limiting constraints of farmer-accepted practices. We presented in follow-up interviews a total of 176 conservation practice recommendations on 103 farm fields to 10 farmers whose lands were targeted for conservation. Primary findings indicated producers were interested in the project, were open to hearing recommendations about their lands, and expressed a high likelihood of adopting 35% of targeted recommendations. Farmers generally viewed the interview process and presentation of results quite favorably, and the interviews were found to build trust and make the targeting process more acceptable to them.

(KEY TERMS: watershed management; optimization; best management practices (BMPs); nutrients; public participation; conservation practice adoption; interviews.)

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INTRODUCTION

Watershed managers have long supported strategic placement of conservation practices in the landscape, also known as targeting (e.g., Duda and Johnson, 1985; Hession and Shanholtz, 1988; Crumpton, 2001; Veith *et al.*, 2004; Heathwaite *et al.*, 2005; Diebel *et al.*, 2008, 2009; Tuppad *et al.*, 2010). In the United States (U.S.), a variety of policy incentives encourage agricultural producers to implement conservation practices (Harrington *et al.*, 1985), but these incentives alone may not produce economically efficient solutions since they are not based on the true magnitude of pollutant reduction (Helfand and House, 1995). Generally, incentives are available to all on a "first come, first serve" basis, and enrollment is voluntary even though this is not considered the most effective way to reduce pollution. Nonpoint source pollution often originates in hotspots or critical

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source areas on a small portion of the landscape, which can be targeted for maximum efficiency (Carpenter *et al.*, 1998; Pionke *et al.*, 2000; Qiu *et al.*, 2007; White *et al.*, 2009; Kovacs *et al.*, 2012). Not only are certain locations more vulnerable to nonpoint source pollution but individual conservation practices may be more or less suitable in those locations within a given watershed (Tomer *et al.*, 2013). Targeting the most effective conservation practices to locations with the greatest potential for water quality improvement can decrease the cost of implementation to meet a particular water quality goal (e.g., Veith *et al.*, 2004). The approach that we used in this study involves spatial optimization of conservation practice placement to minimize both cost and water pollution (e.g., Gitau and Veith, 2006; Maringanti *et al.*, 2011; Kalcic *et al.*, 2015b).

Theoretically, targeted conservation practices should increase effectiveness of a conservation program. To achieve this effectiveness under current voluntary conservation programs, however, land managers would need to actually adopt these practices on their lands. Managers of high priority lands may choose to reject targeted recommendations for many reasons, such as a perception that the practice is not applicable on the lands they farm, or a distrust of the results (Kalcic *et al.*, 2014). Even when these managers agree to implement conservation projects, they may fail to properly use and maintain them over time (Jackson-Smith *et al.*, 2010; Grady *et al.*, 2013). An adaptive, iterative targeting approach that involves land managers can minimize these barriers to cooperation and produce greater cost effectiveness than a program that does not consider stakeholder input (Kalcic *et al.*, 2014).

Adaptive watershed management not only involves iterative testing and learning about the natural environment but it also requires stakeholder engagement to understand the surrounding culture and enhance social learning as well (Allan *et al.*, 2008). Ahnstrom *et al.* (2008) conclude their review on farmers and conservation by recommending that conservation programs be flexible, seeking to fulfill the aims of the program creatively, and allowing for local adaptations. Reimer *et al.* (2012a) suggest that successful targeting of conservation requires outreach to landholders managing the most vulnerable lands, and they caution that a one-size-fits-all approach will not succeed. Kaplowitz and Lupi (2012) demonstrated that landowner preferences for conservation should be taken into account in watershed planning. Furthermore, Piemonti *et al.* (2013) highlighted the importance of considering stakeholders and incorporating sociological data into spatial optimization of conservation practices, concluding there is a need for more efforts in this direction.

Stakeholder participation in decision making is commonly viewed positively for normative reasons such as increasing democracy or fairness, as well as for practical reasons such as contributing to wiser and more efficient solutions to complex natural resource management issues (Tuler and Webler, 1999; Lauber and Knuth, 2000; Beierle, 2002; Dietz and Stern, 2008). Although some have argued that mandatory controls are needed for agricultural pollution (e.g., Epp and Shortle, 1985), most conservation in the U.S. still relies on voluntary enrollment. Since nonpoint source pollution control is primarily in the hands of the producers and not an external regulator, it is important that any plan for conservation be flexible, tailoring the approach to producers (Carpentier *et al.*, 1998). Building good relationships and trust between producers and conservation programs is more likely to lead to adoption and corresponding reductions in nonpoint source pollution. These targeting programs should take into account producers' needs and desires so that they have the highest chance of adoption in agricultural landscapes.

Engineering targeting solutions guided by the human dimensions of watershed management can make the approach practical and relevant to individual land managers. The overall goal of our study was to demonstrate an adaptive targeting approach using spatial optimization of agricultural conservation practices in two watersheds. We developed an adaptive optimization framework that engages farmers and landowners in the process of optimizing the spatial locations of conservation practices at the watershed scale. While the adaptive approach is not entirely new to the field of watershed management, its implementation with real stakeholders in a spatial optimization context has not previously been undertaken. The intention of this work was to make the optimization acceptable to farmers and thereby encourage adoption of targeted conservation in the watershed.

This optimization framework is adaptive in a number of aspects. First, it considers the scale at which land managers make decisions. Many researchers have identified and found creative solutions to a disconnect in scaling between watershed models and farm fields (Gitau *et al.*, 2004; Veith *et al.*, 2005, 2008; Ghebremichael *et al.*, 2008, 2010, 2013; Daggupati *et al.*, 2011; Pai *et al.*, 2012). Similarly, in this adaptive optimization we define the watershed model's smallest spatial units by farm field boundaries (Kalcic *et al.*, 2015a). This optimization also incorporates farmer feedback on current conservation and management practices in their lands. In addition, it seeks to deliver only field-scale targeted recommendations that each farmer previously identified as acceptable. Finally, it solicits farmer feedback on the approach to permit ongoing adaptation.

MATERIALS AND METHODS

Adaptive Targeting Approach

We developed an approach we refer to as "adaptive targeting" that includes a multidisciplinary process of engaging farmers and running a model to develop targeted conservation recommendations, which are hypothetically the best, producer-accepted practices for critical source areas. We describe the process briefly here and in greater detail in the following sections.

First, we engaged farmers and landowners through initial interviews about existing conservation practices on their farms as well as their interest in future conservation efforts. Farmer interviews provided detailed farm and farmer-specific information about as many farm fields in the study areas as possible. We selected 11 conservation practices to include in interviews based on their prevalence in the watersheds and likelihood of improving water quality. From these 11, 6 practices were most palatable to farmers and have previously been represented in the watershed model (Arabi *et al.*, 2008; Waidler *et al.*, 2009; Kalcic *et al.*, 2015b), and we used these in the targeting experiment.

Second, we used a coupled watershed model and spatial optimization approach to determine targeted conservation recommendations. The watershed model we employed was the Soil and Water Assessment Tool (SWAT) (Arnold *et al.*, 1998) because it is capable of simulating agricultural watersheds, including conservation practices and management operations, and it is commonly used to predict the influence of land management on water quality and crop growth. For spatial optimization we used an evolutionary algorithm approach to determine optimal placement of conservation practices in the watersheds. We adapted and evaluated the optimization using varying degrees of farmer information on current conservation and future conservation preferences as constraints.

Finally, we conducted follow-up interviews with farmers to transfer targeted recommendations and determine their reactions and intentions to adopt these practices. These interviews enhanced our learning about how the adaptive process was successful and what could be improved.

Application to Two Study Watersheds

We applied the adaptive targeting approach for six years (2007-2012) following a three-year warm-up period to the Little Pine Creek and Little Wea Creek watersheds in west central Indiana (Figure 1), where three years (5/2009-5/2012) of daily streamflow and weekly nitrate, phosphorus, and sediment concentrations were available at watershed outlets (Haas *et al.*, 2014a, b, c). Relatively small watersheds at 56 and 45 km^2 in size, respectively, Little Pine and Little Wea have approximately 90% of land in corn and soybean crops, 70-80% of cropland drained by subsurface tiles, and fairly flat topography with an average slope of 1-2%. Farms owned by Purdue University cover 13% of the Little Pine watershed. Local conservation planners, such as those from the Natural Resources Conservation Service (NRCS) and the Soil and Water Conservation District, are active in the watershed, and a recent regional watershed management plan identified these two watersheds to target with conservation practices, and federal funds were obtained to do so (Wabash River Enhancement Corporation, 2011).

Initial Farmer Interviews

We developed a farmer interview guide to investigate farm management and farmer preferences for future conservation. First, we asked farmers to identify farm fields they owned or rented within or near the study area. Then we asked farmers about their past use, current use, and future potential use of 11 conservation practices (Table 1). Farmers identified existing conservation practices on the map, then placed each practice in one of four preference piles:

1. Yes: farmer is interested in implementing this practice in the future;
2. Maybe: farmer may be interested in using this practice;
3. No: farmer has no interest in using this practice;
4. Not applicable: farmer considers the practice not applicable to his/her lands.

Finally, we asked farmers about their views on the benefits of conservation and gauged their response to targeting as a theoretical concept as well as a practical approach. The interview guide was approved by Purdue University's Institutional Review Board.

We contacted farmers and landowners by mail and by phone based on publicly available parcel information for those owning at least 20 ha of land in the study watersheds. All farmers reached by phone accepted the interview. In addition, we asked two landowners who had previously farmed and were still involved in the farming operation on their lands to participate in the interview, and they accepted. A total of 14 farmers and landowners participated in interviews during winter of 2012, including 8 farmers

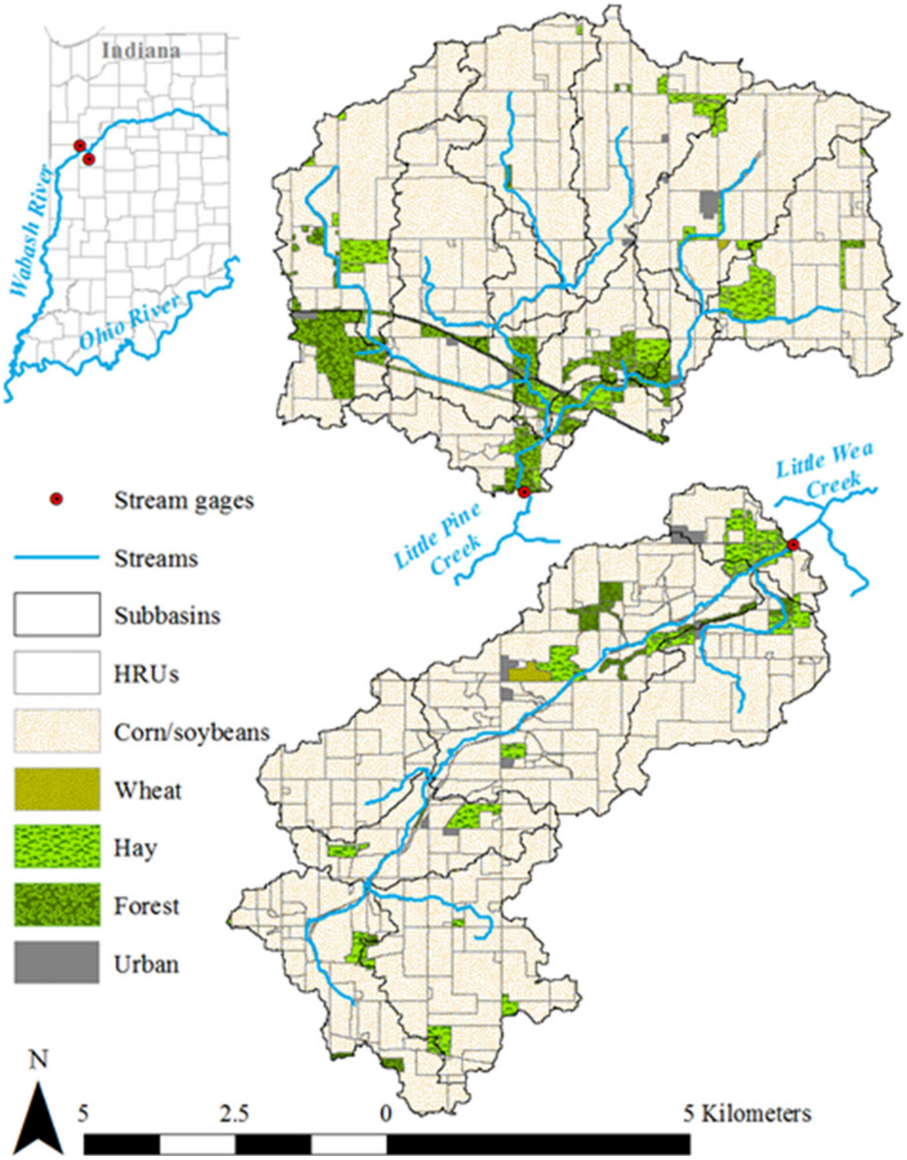

FIGURE 1. Study Watersheds within Tippecanoe County, Indiana: Little Pine Creek Watershed (top) and Little Wea Creek Watershed (bottom). Watersheds are not located as near to each other as shown above (Graphic from Kalcic *et al.*, 2015b).

in Little Pine, of which 2 worked with the Purdue research farms, and 4 farmers and 2 landowners who were retired from farming in Little Wea. Farmer interviews provided data on land covering 34% (1,900 ha) of Little Pine watershed and 32% (1,440 ha) of Little Wea. Most of this land was owned by farm operators, although a portion of it was rented (7% of interviewed lands in the Little Pine watershed and 17% in the Little Wea watershed). Farmers operating over the remaining lands in the study watersheds could not be determined, and we think they may be rented by farmers who do not own at least 20 ha of land in either watershed and thus were not contacted. Most farms produced primarily corn and soybean crops, though some farmers had small or large beef cattle or hog operations. All farmers were male, Caucasian, had farmed an average of 36 years, and were on average 62 years old, although some of the older interviewees were no longer actively involved in the farming operation. Farmer age, sex, and race corresponded well to those for the state of Indiana from the 2012 U.S. Census of Agriculture (USDA NASS, 2014), although the size of farming operations among those interviewed was generally in the top 7% of Indiana farms and the sample had a higher proportion of livestock operations as well.

Watershed Modeling

We used the SWAT (Arnold *et al.*, 1998) for watershed modeling of the two study areas because of

TABLE 1. Conservation Practices Discussed in Interviews.

Conservation practice (NRCS number)	Description of practice, and how it was simulated in the SWAT model (or reason why it was not simulated). More details on practice simulation can be found in Kalcic (2013)
None	Rotation with corn (chisel and disk plow) and soybeans (no-tillage planting)
No-tillage (329)	Using no tillage to manage crop residues on the soil surface. No-tillage planting of corn and soybeans and 2 point reduction in HRU curve number
Cover crops (340)	Planting crops for seasonal cover. Cereal rye was planted October 15, following harvest of corn and soybeans, and killed April 15
Filter strips (393)	Vegetated strips intended to filter contaminants from surface runoff. The SWAT filter strip routine was used, sized at 2.5% HRU area, 50% of the HRU draining to the most concentrated 10%, and no fully channelized flow
Grassed waterways (412)	A shaped strip of grass intended to prevent gully erosion from overland flow. SWAT grassed waterway routine used with 10 m width and $HRU^{0.5}$ length
Drainage water management	Varying the depth of tile drainage outlets throughout the year using a water control structure. Not simulated due to low farmer interest and lack of current ability to model in SWAT
Nutrient management (590)	Altering the amount and form of fertilizer applications to maintain high yields while minimizing the water quality impacts. Not simulated due to difficulty predicting current farmer nutrient management
Waste utilization (633)	Ensuring agricultural wastes (e.g., manure) are used in a way that protects the environment. Not simulated due to difficulty predicting existing practices
Restoration and management of rare or declining habitats (643)	Conserving biodiversity by providing habitat for rare and declining species. Considered "habitats" and assumed to be tall grass prairie for cost calculations and targeting recommendations. Modeled as filter strips
Upland wildlife habitat management (645)	Conserving biodiversity by managing upland habitats to create connectivity of landscapes. Considered "habitats" and assumed to be tall grass prairie for cost calculations and targeting recommendations. Modeled as filter strips
Two-stage ditches	Designing drainage ditches after stable natural streams, with a channel and adjacent floodplains. Not modeled due to low farmer interest and lack of ability to model in SWAT
Wetland creation (658)	Creating a wetland to filter contaminants from agricultural runoff. Modeled as headwater wetlands using SWAT's wetland routine

its ability to model land use and land management, including agricultural conservation practices, as well as implement "what if" scenarios (Arnold *et al.*, 1998). Within the study area watersheds, SWAT delineates subwatersheds using elevation data and, optionally, hydrography. Subwatersheds are further divided into hydrologic response groups (HRUs), which are lumped regions with similar soil type, land use, and slopes. SWAT version 622 was used for this work because of its updated subsurface tile drainage routine based on the Hooghoudt and Kirkham tile drain equations and its ability to simulate nitrate and dissolved phosphorus travel through tiles (Moriasi *et al.*, 2013a, b).

This approach differed from usual SWAT practice in the definition of HRUs by a common land unit (CLU) layer, which divides land based on ownership and land use (Kalcic *et al.*, 2015a). It was important to show farmers the targeted recommendations for specific crop fields, rather than for HRUs that may be dispersed throughout the subwatersheds. HRU definition by CLU resulted in 418 HRUs and 320 cropped (corn and soybean) HRUs in Little Pine, and 396 HRUs and 311 cropped HRUs in Little Wea.

The SWAT models were not calibrated, as the models were generally able to predict daily flow (coefficients of determination above 0.6 and Nash-Sutcliffe efficiencies above 0.5) and average daily nutrient and sediment loading at the watershed outlets fairly well, and annual crop yields were within a reasonable range. This approach was similar to Chaubey *et al.* (2011) in which authors argued that when input data collected represented actual watershed conditions and the default model outputs were reasonable, a detailed calibration of SWAT model was not necessary to evaluate effectiveness of conservation practices. We are unaware of studies that quantify what level of model agreement is necessary for assessing the relative effectiveness of conservation alternatives, so we used standard acceptability coefficients in evaluating model performance. A detailed summary of model setup and evaluation can be found in Kalcic *et al.* (2015b).

Spatial Optimization of Conservation Practices

To identify optimal locations for conservation practices we employed a spatial optimization approach (Kalcic *et al.*, 2015b) using a genetic algorithm, the nondominated sorting genetic algorithm (NSGA-II) (Deb *et al.*, 2002). Genetic algorithms use evolutionary concepts of reproduction and selection to improve populations or solutions over time. A population consists of a number of individuals, and at each generation that population is changed through crossover, mutation, replication, or die-off.

In this study, each individual represented one scenario of conservation practices spread throughout the cropland HRUs in a watershed. We used a generation of 50 scenarios, and in each generation half were crossed to generate new offspring, and all mutated at a low rate of 0.001 chance of gaining or removing a practice per HRU. We estimated fitness, or effectiveness, of every scenario in each generation by running the SWAT model for each scenario and processing HRU-level outputs. Those scenarios with greatest fitness passed on to the next generation, while the NSGA-II algorithm attempted to maintain a good spread of solutions across the optimization front. The optimization was entirely automated within MATLAB scripts (MATLAB; The MathWorks Inc., 2012). For the purpose of visualizing a smooth and complete Pareto optimal front, we selected a fairly evenly spaced set of 50 scenarios from all generations.

Conservation practices included in the optimization were no-tillage, cereal rye cover crop, filter strips, grassed waterways, created wetlands, and restored prairie wildlife habitats. We implemented each in the SWAT model, allowing every practice to be placed in any cropped HRU, with the potential for multiple practices in a given HRU. In SWAT, headwater wetlands are considered to be placed at the subwatershed-level rather than the HRU-level, and therefore wetlands were modeled at the subwatershed outlet. Possible wetland locations were located generally following a placement method based on contributing area (Kalcic *et al.*, 2012), totaling 22 wetlands in Little Pine and 25 wetlands in Little Wea. The wetland contributing area identified as part of the placement method was divided by the subwatershed area to determine a fraction of subwatershed draining to it.

Objectives: Simultaneously Minimize Water Pollution and Cost of Conservation

We quantified performance of individual conservation practice scenarios, which specifies those who pass on to the next generation, using two objective functions, which are detailed in Kalcic *et al.* (2015b). The first objective was to minimize conservation costs, including yield changes due to taking land out of production or changes in crop management. Cost of materials, equipment, installation, and labor for the implementation of each conservation practice over one decade were estimated from the NRCS Field Office Technical Guide for the state of Indiana (USDA, NRCS, 2012), which is detailed in Kalcic *et al.* (2015b). No-tillage and cover crops can either raise or lower crop yields, and we used the SWAT model to estimate such changes. Foregone yield (or yield increases) for the six-year simulation was estimated as the model's change in yield for each HRU by subtracting the baseline scenario in which no conservation exists in the watershed. The practices that occupied no spatial area in SWAT — filter strips, grassed waterways, wetlands, and habitats — were assumed to cause yield decreases in proportion to the calculated physical area and the average yield of that HRU. Cost of foregone yield (or profit for increased yields) was calculated from the five-year average grain costs from 2008-2012, which was $232/tonne for corn grain and $442/tonne for soybeans.

The second objective was to minimize the water quality impacts of farming, defined as a normalized average of total nitrogen, total phosphorus, and sediment reaching the watershed outlets. Each water quality indicator — total nitrogen (TN), total phosphorus (TP), and sediment (Sed) — was normalized by dividing the baseline simulation's pollutant load over the six-year simulation (2007-2012), and a Water Quality Index for the watershed was calculated as the equally weighted sum of these three indicator values. Water Quality Index value of 0 means reduction of water quality pollutants to 0, while Water Quality value of 1 means no reduction in pollutants compared to the baseline simulation.

Using Farmer Information to Develop Optimization Constraints

We ran four separate optimizations for each study area to determine the effect of current conservation and future preference constraints on targeting conservation practices:

1. No constraints: An unconstrained optimization determined the most efficient conservation practice scenarios for the watershed.
2. Current conservation: An optimization constrained to current conservation practices but not future preferences.
3. Future constraints (maybe): An optimization constrained to both current conservation and future conservation constraints, using somewhat limiting future preferences by including "yes" and "maybe" categories.
4. Future constraints (yes): The most limiting optimization including current conservation and most limiting future preferences by including only the "yes" category.

We developed constraints from existing conservation practices and future preferences provided in farmer interviews. We digitized existing conservation practices in ArcMAP (ESRI, 2010), and HRUs containing or adjacent to these conservation practices were given these as current conservation constraints. We implemented the future constraint by tagging each field to the farmer, and only practices for which that farmer had answered "yes" or "maybe" for future preferences were permitted on those fields.

The same structure was used to implement both current and future conservation practices in the optimization code, such that any individual scenario of conservation for the watershed was forced to meet constraints. We applied constraints after scenarios underwent propagation to the next generation, so that mutation would not create scenarios violating those constraints, and any violations to the constraint were corrected through addition or subtraction of that practice. This is not a usual practice for applying constraints, and we could have instead created many more offspring and removed any that violated the constraints. Future conservation preferences for lands for which the farmers were not interviewed were randomly assigned the preferences of another farmer interviewed in that study watershed. This provided a more realistic estimate of conservation that could be obtained in the entire watershed.

Farmer Follow-Up Interviews and Stated Adoption Intention

We reconfigured the SWAT model and optimization after farmer interviews with improvements in fertilization assumptions and a more recent version of SWAT, so the targeted set for the watershed and the subset brought to farmers does not exactly match the updated spatial optimization results presented in this article. The following methods were implemented using the previous version of optimization results.

Determination of targeted conservation practice recommendations to bring to farmers in follow-up interviews was not as simple as choosing one individual scenario from the final generation in the spatial optimization. We considered all scenarios in the final generation to determine those practices that occurred most frequently in the final generation. This was done using a count of the number of times each conservation practice was seen in each HRU over the entire optimal front (defined at that time as the final generation in the simulation). For each HRU we selected zero, one, or two practices that occurred in at least 25% (for Little Wea) or 50% (for Little Pine) of the scenarios in the final generation. For example, to determine if there was a targeted recommendation for HRU 1, the frequency of no-tillage, cover crops, filter strips, grassed waterways, wetlands, and habitats in HRU 1 would be counted in the final generation. If any practices occurred in at least 50% of the final generation, we would select the most frequently occurring practice as a first choice recommendation, and if the second-most occurring practice was also above the 50% threshold it would be included as a second choice. We ran the SWAT model again with these final recommendations, and cost and water quality benefits were calculated for each HRU. In summarizing the recommendations brought to farmers, HRUs smaller than 10 ha were generally excluded to focus the discussion on more significant conservation projects.

Farmers who operated in those lands were then consulted in follow-up interviews during the spring of 2013. We contacted by phone the 11 farmers who had targeted recommendations, and 10 were available for the interview. The one remaining farmer responded to the contact and intended to schedule an interview, but was unable to find the time before the busy planting season. We created interview documents to clearly convey these recommendations to farmers. The interview began by reminding farmers about the study, the modeling process, the objectives of the optimization, and the conservation practices considered. Then farmers were presented with a table of targeted practice costs (in $) and removal of nutrients (in lb/acre) and sediment (in ton/acre) provided by that practice, along with a map identifying which farm fields had targeted recommendations.

To gauge farmer interest in recommended practices, we asked farmers three questions for each practice:

1. Whether they considered that practice to be optimal for that field, based on their local knowledge of field conditions. Farmers were encouraged to think outside of their current management constraints to decide whether practices would be ideal for those locations. For instance, a farm operator could agree that a recommendation is optimal on rental land even though it is not currently feasible, given the views of the landowner. This is referred to as "stated optimality" throughout the article.
2. Whether they see themselves implementing that practice on that field in the next five years. Those practices for which farmers said yes, they plan to implement it within five years, are referred to as "adoption intention" throughout the article.
3. What reasons they had for these plans and opinions.

Finally, we asked farmers about their views on the adaptive targeting approach, how it felt to receive targeted recommendations on their lands, how the interviews may influence their land management decisions, and what suggestions they had for improving the approach.

We adjusted targeted recommendations following interviews to remove those that farmers stated were already implemented or were not on cropland, and in a few cases, were too small to find on the map. Rates of adoption intention and stated optimality of targeted recommendations were calculated as a percentage of adjusted results. We categorized farmers' qualitative responses and compared them to studies of conservation practice acceptance.

RESULTS AND DISCUSSION

Current and Future Conservation Efforts

Current and past adoption of each conservation practice by interviewed farmers, as well as future adoption preference, is shown in Table 2. The number of conservation practices present on a given farm varied from one practice to seven, with an average of 3.9 and standard deviation of 2.0. Every farm contained grassed waterways, though some likely needed reconstruction, as acknowledged during several interviews. No-tillage had been attempted by all but two farmers in the sample, and four of those farmers had abandoned it for various reasons, mostly related to soil compaction. Filter strips were present on all but three farms containing open waterways. Three of the eight farmers who had used cover crops in the past had abandoned it, and yet there was some willingness to try cover crops again, as reflected by the future adoption preferences. While grassed waterways and filter strips were common among the farmers, six farmers who had adopted grassed waterways did not prefer to implement more, and three farmers who had adopted filter strips believed they had enough of these already. Both innovative conservation practices — two-stage ditches and drainage water management — were not yet in use in the study area, and generally farmers had little to no familiarity with these practices. Farmers were shown one page of information about each practice in the initial interview, which briefly defined the practice, provided a visual aid, and detailed its primarily purpose as well as the conditions where it may apply. Farmers expressed some interest in trying out these practices, despite having little prior knowledge of them or their effectiveness. Aside from the innovative practices, only no-tillage and cover crops elicited interest from more farmers than the number currently implementing such practices. Wetlands were unique in their high level of "maybe" responses, perhaps revealing farmer ambivalence about incorporating these into their farms.

Current adoption of conservation practices in farmland managed by farmers we interviewed (Table 3) shows that grassed waterways dominate in both

TABLE 3. Current Adoption of Conservation Practices in Farmlands Managed by Interviewed Farmers for Each Study Watershed, Listed as a Percent of HRUs and Percent of Cropland Covered by Interviews That Is Protected by the Practice. Wetlands were not included, although two exist in Little Pine.

	Little Pine Interviews		**Little Wea Interviews**	
	% of HRUs	**% of Cropland**	**% of HRUs**	**% of Cropland**
No-tillage	5	2	22	18
Cover crops	0	0	16	14
Filter strips	21	22	12	17
Grassed waterway	17	36	38	46
Wildlife habitats	3	1	2	4
No practices	43	33	36	27

TABLE 2. Past and Current Conservation Practice Adoption by 14 Farmers, As Well As Future Conservation Interests Expressed in Initial Interviews.

			Future Adoption Preference			
	Past Adoption	**Current Adoption**	**Yes**	**Maybe**	**No**	**Not Applicable**
No-tillage	12	8	10	2	2	0
Cover crops	8	5	8	3	3	0
Filter strips	10	10	4	4	1	5
Grassed waterway	14	14	11	0	1	2
Drainage water management	0	0	2	3	7	2
Restoration and management of rare or declining habitats	6	6	5	3	6	0
Upland wildlife habitat management	7	7	4	3	7	0
Two-stage ditch	0	0	2	5	6	1
Created wetland	4	4	1	8	5	0

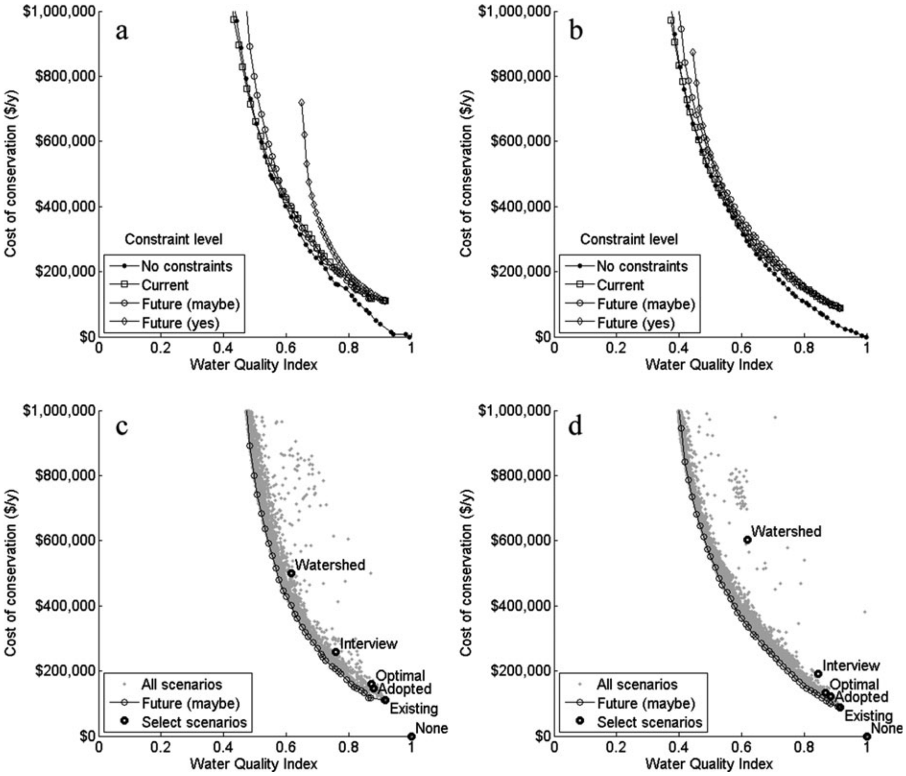

FIGURE 2. Optimal Fronts Developed from 1,000 Generations for Little Pine (a, c) and Little Wea (b, d). Each line in (a) and (b) depicts an optimal front determined from a different level of constraint to farmer practices and preferences. The Future (maybe) optimization result is shown in (c) and (d) alongside the full set of scenarios for every generation. Select scenarios are highlighted for comparison against the targeted set, which appears suboptimal as it was determined in a previous modeling scheme. "Watershed" is set of targeted recommendations for the watershed, "Interview" consists of those targeted solutions brought back to farmers in follow-up interviews, "Optimal" are those practices the farmers considered to be optimal, and "Adopted" are those farmers intend to adopt, "Existing" are those practices found to exist in the watershed through interviews, and "None" shows the baseline condition of no conservation in the watershed.

watersheds, filter strips are more common in Little Pine, and no-tillage more common in Little Wea. No fields operated by these farmers exceeded two existing practices per HRU in Little Pine or four in Little Wea. Note that some no-tillage and cover crops may have been under represented in Little Pine on Purdue farmland, due to the complexity of crop rotations and management discussed in interviews. Also, farmers may have neglected to mention some conservation practices, especially filter strips or habitats located adjacent to but not within farmland, as discovered in follow-up interviews. While farmers may have used many conservation practices on their farm, these practices were not dispersed uniformly across farmland. In both watersheds, nearly one-third of the farmland lacked any of the conservation practices we considered in this study.

Evaluating Method through Optimization Comparison

Optimizations based on four levels of current conservation and future preference constraints showed similar patterns for the two study watersheds (Figure 2). The optimal curve constrained by current conservation shows the cost and benefit of existing practices — although these practices are already in place and funded by farmers or subsidies, their cost was included in this work to provide an estimate of how much all conservation in the watershed would cost, rather than merely new projects. Addition of current conservation practices shifted the optimal curves to a slightly higher cost, suggesting that current conservation is suboptimal on this scale of cost and Water Quality Index. If the Water Quality Index was formulated with different weighting of contaminants, for instance greater emphasis on sediment reductions, existing conservation may have appeared more optimal.

Future conservation preferences were much more limiting in the Little Pine watershed than in Little Wea, especially for the most limiting "yes" future preferences. Spread of the optimal front shows that if farmers only implement targeted recommendations they are most interested in, the watershed may only be capable of achieving a 30-50% reduction in water pollution. If no constraints are considered, water-

TABLE 4. Process of Obtaining Adjusted Targeted Results from the Set of Targeted Recommendations Presented to Farmers in Follow-Up Interviews.

Conservation Practice	Initial Targeted Results	Results Already Implemented	Additional Results Removed	Adjusted Targeted Results Presented to Farmers
No-tillage	3	0	0	3
Cover crops	60	1	6	53
Filter strips or wildlife habitats	79	9	3	67
Grassed waterways	56	3	3	50
Wetlands	4	1	0	3
Total	202	14	12	176

sheds could achieve a 60% pollution reduction at a greater cost. Overall, it may be encouraging that the optimal fronts for nearly all levels of constraint lie within a similar range, suggesting the watershed can realistically achieve near-optimal conservation if farmers adopt targeted recommendations that already interest them. A main reason for the similarity of these fronts is that six practices were considered, which are capable of intercepting the same pollutants, and this redundancy permitted adaptation of targeted practices to meet each farmer's preferences. Even a farmer who is unwilling to use four or five of the six practices may be able to achieve near-optimal simulated results with the remaining practice that holds his interest.

Farmer Intention to Adopt Targeted Conservation

A single set of targeted recommendations for each watershed was determined by the most frequently occurring practices in each HRU in the final generation of the optimization. The cutoff threshold for frequency of a practice in a given HRU was chosen to be 50% of the final generation in Little Pine, and 25% of the final generation in Little Wea, because these thresholds provided a reasonable number of recommendations to bring to farmers in follow-up interviews.

We brought a total of 202 targeted conservation practice recommendations on 125 farm fields to ten farmers in follow-up interviews (Table 4). Twelve of these practices were removed, primarily due to many small parcels modeled as cropland that were not in fact cropland caused by errors in the NASS land use data. An additional 14 targeted recommendations had already been implemented in those lands, but their presence had not been conveyed in the initial interviews. At least one of these had been implemented in the time between the initial interview and the follow-up interview, and one farmer mentioned that it would have been desirable to have checked back with farmers immediately prior to optimization to obtain the latest information. Some other practices that had not been communicated in the initial interview the farmer referred to as degraded filter strips or grassed waterways, and perhaps they simply had not thought they were worth mentioning at the time. The remaining 176 adjusted targeted recommendations on 103 farm fields were used to assess farmer response to targeted conservation (Table 4).

Most targeted conservation recommendations were filter strips or wildlife habitats, cover crops, and grassed waterways (Table 5). Only three instances of no-tillage were present in targeted recommendations brought to farmers, as the model generally found no-tillage reduced all three water quality constituents less efficiently than the other practices. We recommended creation of only three wetlands to farmers, due in part to the small number of farmers who would consider creating wetlands on their farms and in part to the limited number of locations for placement of wetlands; study watersheds yielded only 47 possible wetland locations but 631 corn and soybean HRUs where other conservation practices could be placed. A fourth wetland recommended to a farmer was found to already exist adjacent to the field it was targeted for, and the farmer remarked that the suggested wetland area was near to the size of that existing wetland, which serves as anecdotal confirmation of the wetland placement method.

When we asked farmers if they considered a particular practice to be optimal on that land, some were unsure how to answer the question. When they asked "optimal by what measure?" the interviewer responded by the measures used in this study: cost and water quality improvement. Some understood "optimal" to indicate practicality of use on their farm, and when they asked for clarification, the interviewer replied that "optimal" means a best practice for the land regardless of practicality to the farm, since practicality would be captured by the adoption question. Because of this difference of opinions on the meaning of optimal, these results indicate a measure of goodness of fit, but by a variety of measures. Nevertheless, rates of adoption intention and stated optimality clearly tracked with one another (Table 5).

TABLE 5. Farmer Intention to Adopt Practices and Their Statement of Practice Optimality upon Receiving Targeted Recommendations through Follow-Up Interviews.

Conservation Practice Name	Adjusted Targeted Results	Adoption Intention Rates: Farmers Plan to Implement Targeted Conservation within Five Years — Number of Targeted Results: Yes	Maybe	No	N/A*	Stated Optimality Rates: Targeted Conservation Farmers Considered to Be Optimal on Their Lands: Yes	Maybe	No	N/A*
No-tillage	3	0	0	2	1	0	0	2	1
Cover crops	53	30	15	5	3	37	11	2	3
Filter strips or wildlife habitats	67	13	5	48	1	20	6	40	1
Grassed waterways	50	19	5	25	1	25	5	20	0
Wetlands	3	0	0	3	0	0	0	3	0
Totals	176	62	25	83	6	82	22	67	5

*N/A indicates those results that were unclear.

Farmers considered certain conservation practices more optimal than others, and they generally expressed an intention to adopt them in proportion to their stated optimality (Table 5). A few farmers receiving recommendations of no-tillage and wetlands consistently considered these practices to be nonoptimal and did not intend to adopt them, yet they were recommended in so few cases that this result is not generalizable to the watershed.

Cover crops had the highest stated optimality rate (70%) and the highest adoption intention (57%), which was initially surprising, since no-tillage and grassed waterways had higher farmer preferences in initial interviews. However, in the year between initial interviews and follow-up interviews, the study area had seen growing interest in and adoption of cover crops. Indeed, one farmer who had previously given cover crops a “no” for future adoption preference (Table 2) stated multiple times during the follow-up interview that he had expected cover crop recommendations. His interest in cover crops was also surprising as he had no adoption intention for any of the targeted recommendations in that interview. Following the interview, we explained that cover crops had not been placed on his lands due to his view one year prior, and agreed to send him updated results including cover crops in the optimization for his lands. Such a shift in views on cover crops is likely due to greater adoption by neighbors (which this farmer mentioned), education about growing cover crops, and the severe drought in 2012.

Grassed waterways were the second most accepted practice, at 50% stated optimality and 38% adoption intention, including many existing grassed waterways that required reconstruction (these existing grassed waterways were not removed as “results already implemented” because farmers agreed they needed reconstruction). Filter strips and wildlife habitats were combined in the interviews because the first interviews showed that farmers were not comfortable with the suggestion of filter strips on lands lacking open waterways, and as they were simulated the same in SWAT, it made sense to combine them to provide greater flexibility to the farmer. Farmers considered only 30% of these filter strips to be optimal on targeted lands, and expressed an intention to adopt only 19%.

Some farmers received many more recommendations than others. The farmer who received the fewest recommendations was given just three results on three fields; the farmer who received the most was given 44. This discrepancy was due primarily to the constraint of future preference; those farmers who were unwilling to implement many practices had few options and their land was less likely to be targeted in this adaptive process. Another factor was variability in farm size. Some operations were as small as 30 ha in the study watersheds and others as large as 600 ha. Six farmers considered at least 50% of adjusted targeted recommendations to be optimal, while the two farmers who received the fewest recommendations thought none were optimal. At least one farmer who adopted few recommendations shared that he viewed the practices to be infeasible because as a manager of a research farm he was not always at liberty to make decisions on removing land from production, changing tillage practices, and cover cropping that would interfere with researchers’ goals. Farmer-specific adoption intention rates varied from 0% adoption intention, with 100% in the “no” category, to 71% adoption intention (17 of 24 targeted practices). Seven farmers had greater than 10% adoption intention. Farmers were also given the option to suggest a conservation practice that was more optimal for a given farm field than the recommendation. Farmers suggested cover crops would be more optimal than the recommendation on nine fields, grassed waterways would be more optimal on three fields, and filter strips on one field.

TABLE 6. Net Cost and Water Quality Improvement of Baseline and Targeting Scenarios.

	Cost	Water Quality Improvement	Nitrogen Removal	Phosphorus Removal	Sediment Removal
Baseline scenarios	($/yr)	(Pollutant removal compared with no conservation*)			
Little Pine Baseline: Existing conservation from Little Pine interviews	$110,000	8%	1%	8%	16%
Little Wea Baseline: Existing conservation from Little Wea interviews	$89,000	8%	2%	8%	15%
Little Pine targeting scenarios	($/yr over baseline)	(Pollutant removal as % of Little Pine baseline with existing conservation**)			
Watershed: Targeted conservation in Little Pine	$390,000	33%	13%	33%	57%
Interview: Adjusted targeted results for follow-up interviews	$150,000	17%	5%	17%	32%
Optimal: Targeted conservation considered optimal (Yes) by farmers	$51,000	5%	3%	5%	8%
Adopted: Targeted conservation farmers intend to adopt (Yes)	$36,000	4%	2%	4%	6%
Little Wea targeting scenarios	($/yr over baseline)	(Pollutant removal as % of Little Wea baseline with existing conservation**)			
Watershed: Targeted conservation in Little Wea	$510,000	33%	11%	37%	53%
Interview: Adjusted targeted results for follow-up interviews	$100,000	8%	2%	9%	12%
Optimal: Targeted conservation considered optimal (Yes) by farmers	$44,000	5%	1%	6%	9%
Adopted: Targeted conservation farmers intend to adopt (Yes)	$33,000	3%	1%	4%	6%

*Pollutant removal = 100% × $(1 - \text{Pollutant index})$

**Pollutant removal = 100% × $\left(1 - \frac{\text{Pollutant index}}{\text{Baseline pollutant index}}\right)$

While farmers agreed to adopt 35% of targeted recommendations (Table 5), it is relevant to assess the cost and water quality impacts of these conservation practices, as shown in Figure 2. Targeted recommendations for both study watersheds no longer lie on the optimal curve because the watershed modeling approach was modified after farmers were interviewed. At the time that targeted recommendations were determined, they did appear along the Future (maybe) optimal curve constrained to farmer-preferred practices. Given the previous modeling approach, those practices brought to farmers through follow-up interviews were also near-optimal, and farmer assessment of which practices were optimal resulted in a smaller yet more optimal set of practices. Farmers' adoption intention mirrored targeted results they believed were optimal. These adopted practices would be cost-effective as they lay on the optimal front.

We estimated that current conservation efforts improve water quality by an average of 8% in each watershed at an annual cost of $89,000 in Little Wea and $110,000 in Little Pine (Table 6). Water quality mitigation by existing practices is proportionately greater for sediment than phosphorus, and much greater than nitrogen. This finding could indicate that farmers placed greater value on soil erosion prevention than nutrient losses, which is further supported by the fact that targeted conservation is somewhat less disproportionate in water quality improvement of each constituent (Table 6). However, given this set of six practices, the model more readily reduces sediment than phosphorus, and phosphorus than nitrogen (Kalcic *et al.*, 2015b), in large part because tile drainage serve as conduits for dissolved nutrients to bypass conservation measures.

If farmers and landowners implemented targeted conservation practices throughout each watershed these efforts could be expected to cost an additional $390,000-$510,000/yr and deliver pollutant removal of approximately 33% over the baseline scenario. In all scenarios, sediment and phosphorus were reduced more readily than nitrogen, likely due to the high nitrate loading through subsurface tile drainage that is not treated by conservation practices intended to intercept overland flow (e.g., grassed waterways, filter strips, and habitats). Selecting targeted recommendations on only lands covered by interviews reduces the additional cost and water quality impact to $100,000-$150,000/yr and 8-17%, respectively, with greater improvement seen in the Little Pine than the Little Wea. Targeted recommendations farmers considered to be optimal in their lands further reduced the water quality improvement to only 5% over existing conservation efforts. Those practices which farmers agreed to adopt would achieve a 3-4% average reduction in pollutants in the watersheds at an annual cost of $33,000-$36,000.

While practices farmers agreed to adopt may be cost-effective, they would make a fairly small difference in water quality compared to the baseline of 0 (no conservation) and the existing practices. If they

TABLE 7. Reasons and Justifications Farmers Gave for Choosing to Adopt ("Yes" or "Maybe") or Not to Adopt ("No") Targeted Conservation Practices.

Reasoning or Justification	**No-tillage**	**Cover Crops**	**Filter Strips/ Wildlife Habitats**	**Grassed Waterways**	**Wetlands**	**Total**
	Count of farmers giving reason for *choosing to adopt* a targeted practice					Sum of all practices
Already in plans	0	4	2	2	0	8
Requires reconstruction	0	0	1	2	0	3
Presence of soil erosion	0	1	1	1	0	3
Convenience	0	1	1	1	0	3
Land is rented	0	1	0	0	0	1
Presence of open ditches	0	1	0	0	0	1
Absence of open ditches	0	0	0	1	0	1
	Count of farmers giving reason for *choosing not to adopt* a targeted practice					Sum of all practices
Absence of soil erosion	0	1	4	6	0	11
Inconvenience	0	1	4	2	0	7
Current conservation is sufficient	0	0	3	2	1	6
Land is rented	0	0	2	1	1	4
Absence of open ditches	0	0	1	0	0	1
Uncertainty of performance	0	1	0	0	0	1
Cost is a barrier	0	0	1	0	0	1

were implemented throughout the watershed it would be difficult to detect any change through monitoring at the watershed scale. Indeed, if farmers throughout the Midwest think similarly, the watershed-scale nitrogen and phosphorus reductions of 1-6% are not nearly sufficient to achieve the nearly 50% reductions required to achieve the goals for the Gulf of Mexico hypoxia (Scavia and Donnelly, 2007). Plots in Figure 2 show that for little additional expense, much more improvement could be realized at the watershed scale. If practices farmers have already adopted, and are willing to adopt in the future, are not sufficient for the needs of society, a new policy model or increased regulation may be needed.

Farmer Adoption Reasoning

Adoption of conservation should depend on the type of conservation practice, as farmers will perceive practices as having different relative advantage on their farm (Pannell *et al.*, 2006; Prokopy *et al.*, 2008; Reimer *et al.*, 2012b). Overall, Greiner *et al.* (2009) found that major barriers to conservation practice adoption included insufficient time/staff, lack of incentives, loss of productivity, absence of recommended best practice standards, uncertainty about land tenure, impractical/complicated property management, and the belief that conservation practice is not necessary to improve the environment. Reimer *et al.* (2012b) used interviews and qualitative analysis to understand farmer motivations for adoption of particular conservation practices in two Indiana watersheds similar to the ones studied here. In their work, motivations for adoption and nonadoption of grassed waterways included soil conservation, perception of need, and land tenure. Filter strip adoption and nonadoption depended on loss of productive land and lack of land ownership. Conservation tillage was adopted for soil conservation and input savings (e.g., fertilizer, labor), while barriers included yield losses and no perceived need for the practice. Cover crops were adopted to improve soil fertility and crop yields, while cost, labor, and time increases were barriers to their use in the watersheds, as was a lack of knowledge; many farmers did not fully understand the benefits of cover crops.

In this work, farmer reasons for not adopting a practice were coded into the following categories based not on previous studies but wholly on farmers' statements made in the interviews (Table 7): presence/absence of soil erosion or corresponding water control issues (includes slope and water control considerations); problems associated with convenience or compatibility of the practice with the farming operation (e.g., not wanting to break up large, square fields with conservation practices); barriers related to land that is rented (e.g., a landowner who is unwilling to use conservation practices though the renter is willing); uncertainty regarding how an untested practice would work in their lands (e.g., not knowing yet if cover crops will grow sufficiently given plant date and weather conditions); presence or absence of surface drainage (e.g., belief that filter strips are unsuitable unless an open waterway needs protecting); belief that current conservation efforts are sufficient on the field; and difficulties related to the cost of conservation. The dominant categories tracked well with certain conservation practices. A total of 56 (67% of) responses for adoption and nonadoption intention were categorized out of 83 total nonadoption responses, and no clear reasoning was provided for the remaining responses. Categorized results are shown in Table 7.

Similar to Reimer *et al.* (2012b), absence of soil erosion was the leading reason for not implementing conservation, especially with regards to grassed waterways and filter strips, while presence of erosion was a major driver for choosing to adopt these practices (Table 7). Grassed waterways were primarily seen as remedies to soil erosion problems. Lack of convenience, issues related to farming rented lands, absence of open ditches, and a belief that current conservation was sufficient, were frequently given as reasons for not adopting conservation, especially filter strips. In particular, one farmer firmly believed that filter strips did not belong on a farm that lacked open ditches, even though wildlife habitats were combined with filter strips in most interviews. Filter strips and habitats were most often viewed as inconvenient, because they required breaking up fields or changing management practices. One farmer did not intend to adopt many filter strips because he knew his landlord would not permit it, and he preferred to use cover crops in this situation because they would not take land out of production. Relatively few reasons were given for adoption or nonadoption of no-tillage and nonadoption of cover crops, while two of the three recommended wetlands were not adopted due to lack of land ownership or belief that they are not needed.

Surprisingly, cost was given as a barrier to implementing targeted recommendations only once, despite being mentioned at many other times in the interviews (Table 7). This aligns with other works finding that farmers may stress the economics of conservation more in early interviews than later ones, where they begin to articulate other reasoning (Ahnstrom *et al.*, 2008). Reasoning involving rental land, however, may indirectly imply financial issues. For instance, farmers may be less willing to invest in long-term conservation on rental land if their contract lacks a long-term commitment. Perhaps even more relevant in these interviews was the problem of reaching landowner agreement on implementing conservation that affects the farm's bottom line, especially through conversion of productive cropland to filter strips and grassed waterways.

Farmer Response to Adaptive Approach

Nine of the ten farmers in follow-up interviews agreed that conservation practices coming from model results were applicable to their lands. Emphasis was again placed on the reasons categorized in Table 7, such as already planning to adopt a number of the targeted practices, identifying practices needing repair, and preventing topsoil erosion. The one farmer who did not find the targeted recommendations applicable to his lands was one of only two who did not intend to adopt any of the practices. He had conveyed a limited set of future interests in the first interview, and consequently only three targeted results had been brought to him in the follow-up interview.

When asked about their expectations for the project and how well those expectations had been met, farmers communicated that they had understood that their information would be applied to a modeling study, and most of them — including those who had no interest in adopting the recommendations — stated that the study had met or exceeded their expectations. Many suggested that the information provided to them was practical, useful, and would be helpful for them in making farm decisions. At least two farmers expressed surprise by the targeted recommendations, either the types of practices (e.g., expecting a recommendation of no-tillage) or their locations (e.g., expecting to see targeting practices along ditch banks rather than upland areas). When asked how targeted recommendations might impact their farm management decisions, eight farmers shared that the results would be influential, either because they aligned with — and provided justification for — their current plans, or because they provided the farmers with new information and ideas to think about.

Finally, when asked how it felt to be given recommendations about which conservation practices may be most optimal on their lands, many farmers emphasized their open-mindedness and willingness to receive recommendations, and two specifically appreciated having "another pair of eyes" to look into conservation on their lands. One contrasted the approach with regulations — he likes to be presented with "options, not requirements," and another said "I don't feel compelled to do it," but affirmed his interest in the study. Some spoke in detail of the specific targeted results, while others took a more global view:

> It's a reminder to think about conservation. Conservation takes more management, and it's not easy to implement. It takes planning, dedication, and continual learning.

Farmer Recommendations for the Approach

We asked participants if there was anything else they would have liked to see in the follow-up interview, and what recommendations they would have if another adaptive targeting study was conducted. Recommendations for additional information in the follow-up interview, when offered, were quite specific and different for each interviewee: presenting filter strips and wildlife habitats separately in results; presenting cost and nutrient loads on a per acre basis for enhanced comprehension; providing more information on how costs were calculated; and providing estimates of wind erosion on soils. One expressed surprise that increased subsurface tile drainage was not recommended. At the conclusion of many interviews, the interviewer agreed to email the farmer some additional follow-up information, usually any updated results including additional current conservation practices.

Recommendations for the study and interview approach differed for each farmer as well, including: ensuring that the latest data are used; reinterviewing farmers immediately before running the final model optimization to be certain to include all of the latest conservation practices; including more conservation options such as bioreactors, drop boxes, and minimum tillage; and presenting farmers with more information on how they may save nitrogen by using cover crops. Five farmers had no recommendations for improving the approach, and one affirmed the approach was "clear, straightforward, easy to understand, and objective." Overall, the recommendations do not converge on one or two main themes, but refer to the plethora of decisions that were made in the modeling and displaying of targeted recommendations. If there were readily apparent issues in the approach, we hoped they would have been mentioned by at least two of the participants. If targeting had been performed in the absence of initial interviews, there would have clearly been poorly made decisions about model setup, current conservation practices, options for targeted conservation practices, and the display of results. Involving farmers in the early stages of the project and being willing to correspond with them even after follow-up interviews were crucial to providing farmers with usable information. Farmer satisfaction of the adaptive targeting approach clearly relates to the level of involvement and adaptation of the research to the participants' needs.

Limitations of the Approach

The tools we chose to use in this targeting experiment have several limitations. While the SWAT model has been used extensively to test conservation scenarios in agricultural lands, the representation of many conservation practices within the model requires assumptions as to the size and performance of practices. In addition, some conservation practices have not been modeled in SWAT previously, or could not be modeled without detailed information from farmers (e.g., nutrient management and waste utilization), and therefore were not considered in this study. The two watershed models had reasonable prediction of flow and water quality yet as with any model, simulated water quality improvements are somewhat uncertain. A limitation of the spatial optimization was the Water Quality Index used to assess performance of conservation scenarios. Within that index, all three pollutants were reduced to one objective function, so there are many ways to achieve each Water Quality Index value by trading off nitrogen, phosphorus, and sediment reductions. If water quality goals existed for each pollutant, or each pollutant was weighted differently, we could have used a different formulation of the Water Quality Index.

It is worth asking whether the value of this adaptive targeting approach justified the time spent engaging farmers and performing optimization. The entire process — from designing farmer interviews through conducting follow-up interviews — lasted approximately 15 months, and required one researcher's full attention through much of that period. However, much of that time was spent on activities that could be abbreviated or removed from the process in future projects, including: (1) developing an appropriate interview guide, (2) transcribing interviews verbatim, and (3) carefully studying interviews to evaluate the approach and pull out themes related to farmer perceptions of targeting. If the approach developed here was replicated in other watersheds, the most time-intensive activities are likely to be performing initial farmer interviews (~2 h per interview), setting up the SWAT model and spatial optimization (weeks), running the optimization, preferably through parallel computing (days to weeks of computer time), choosing a final set of targeted recommendations (days), and conducting follow-up interviews (~1 h per interview).

One of the greatest difficulties in the stakeholder engagement approach was identifying and attempting to contact all farmers in the study area. Targeting the most vulnerable lands requires reaching all or most farmers in the watershed, and this study missed many operators, especially those renting land in the watershed. We expect that our approach may have missed some younger farms and those with smaller operations. Ideally, teams leading future targeting efforts would have access to farmer contact information and trusted networks through which to establish communication with farmers, such as the Soil and Water Conservation Districts. Additionally, continued follow-up and adaptation of the approach could not be demonstrated in this single research project, while adaptive targeting efforts led by these trusted networks could continue the adaptive cycle, responding more meaningfully to farmer feedback.

While there is some evidence that farmers are receptive to the targeting approach based on economic and environmental efficiency (Arbuckle, 2013; Kalcic *et al.*, 2014), there may be times when such an approach will fail to produce the necessary social change to maintain conservation over time. Brown writes that there are "missing links in targeting that only citizen participation can supply" (2011, p. 252) and argues that a better approach consists of land managers prioritizing practices in their own operations through sufficient education and a changing social norm. In a truly adaptive approach, there may be times the concept of targeting is abandoned entirely. We think that in this adaptive targeting approach, building relationships and actively involving land managers in the targeting process provides some of that necessary education and encouragement.

SUMMARY AND CONCLUSIONS

Adaptive targeting through spatial optimization and farmer interviews can help scientists and agencies learn from farmers, display complex results in an appropriate and usable manner, and utilize computer models to target multiple conservation practices to farm fields. Detailed spatial understanding of existing conservation practices was gained through interviews with 14 farmers covering one-third of lands in two study watersheds. Farmers already used many conservation practices, though up to one-third of agricultural lands they operated in lacked any form of conservation considered in our study. Grassed waterways were the only practice present on all farms. Existing conservation efforts in lands covered by interviews were estimated to cost between $89,000 and $110,000 per year in each watershed, and model simulations estimated these practices improve average water quality by 8%, with particular effectiveness in reducing sediment and phosphorus loading to surface waters. Model simulations predicted fairly low nitrogen removal rates by conservation practices, partly due to how conservation practices are modeled in SWAT such that extensive subsurface tile drainage that permits export of high nitrate loads directly to surface waterways, short-circuiting entirely the filtering process of grassed waterways, filter strips, wildlife habitats, and upland wetlands. In reality, some of these practices (especially wetlands) should reduce nitrate loads (Kalcic *et al.*, 2015b).

We conducted watershed modeling and spatial optimization in such a way to promote incorporation of farmer data and to make the results more usable by farmers through defining HRUs according to farm field boundaries. The final set of targeted recommendations brought to interviews covered 125 farm fields with 202 practices, which we brought to 10 farmers in follow-up interviews and pared down to 176 adjusted targeted results on 103 farm fields. Farmers' view of the optimality of targeted practices was confirmed through follow-up interviews in a number of ways: (1) farmers generally stated that recommendations were optimal for their lands; (2) in choosing to adopt targeted recommendations, many farmers shared that they already planned to implement those practices in those locations; and (3) a number of targeted recommendations were found to already exist in the watershed, though this had not been communicated in the first interview.

Farmers intended to adopt 35% of targeted recommendations within the next five years. Cover crops, which had increased in popularity between the two sets of farmer interviews, had the highest level of adoption intention with 30 farm fields and a 57% adoption intention rate. If farmers adopt the practices they anticipate implementing, it would entail an estimated annual cost of nearly $68,000 over both watersheds ($6-7/ha of watershed area), and produce water quality improvements in the range of 1-2% total nitrogen, 4% total phosphorus, and 6% sediment loading. Practices farmers were willing to adopt under the current farm policies are not sufficient to reach water quality goals, such as the need to reduction nutrients by up to 50% to remediate hypoxia in the Gulf of Mexico (Scavia and Donnelly, 2007), suggesting a different policy model or greater regulation may be needed.

Soil erosion played a crucial role in convincing farmers to adopt — or not to adopt — conservation practices; many farmers who chose to adopt targeted recommendations were motivated by the desire to prevent soil erosion, while some who chose not to adopt targeted conservation did so because they did not think the recommended practices would affect erosion. Grassed waterways were seen as particularly useful in addressing erosion issues. Farmers used a variety of reasons to justify nonadoption of conservation practices, particularly filter strips, including inconvenience, land tenure, the absence of open waterways on their land, and their perceptions that current conservation efforts were sufficient.

If this adaptive targeting approach were scaled up to larger watersheds there may be challenges in both the targeting method and the stakeholder engagement process. If watershed modeling were conducted to target practices as we have done, it would require time and resources to build a model, and available water quality data to calibrate it. In this project, we were able to define SWAT's HRUs by farm field boundaries, but in larger watersheds such high resolution methods may be computationally infeasible. Yet the method we lay out can be flexible in the targeting tools used as the stakeholder engagement approach did not depend on them.

Interviews were a critical part of this approach, and farmers were generally quite pleased with the interview process and presentation results, including those who chose not to implement any targeted conservation. Farmers were receptive to hearing about targeted conservation, and the interviews may have served to build trust as well as make targeting more practical prior to presenting results in the follow-up interviews. Yet in a larger watershed it may not be feasible to interview every farmer. In scaling up this approach, alternative methods for learning about existing conservation practice could be developed such as Grady *et al.* (2013), and surveys could be used to obtain information on future conservation preferences, similar to what has been done by Kaplowitz and Lupi (2012) in determining landowner preferences for conservation practices. Interviews still may be required to build trust and encourage farmer consideration of targeted results, however. From this work it can be expected that some farmers will choose not to adopt any targeted practices, and may have little interest in future conservation. But these farmers may be willing to conduct interviews, and may view the interviews positively. It is possible that the interview process was beneficial in turning low-adopting farmers' thoughts toward conservation and preparing them to consider farm management changes.

Overall, our work in engaging 14 farmers demonstrates a promising approach for targeting conservation in agricultural lands. Though this work was limited to two watersheds, and farmers for two-thirds of the land could not be determined because they rented land in the watershed or contact information was not available, those who were reached by phone almost unanimously agreed to participate. Initial interviews provided extensive spatial information used to improve the watershed model, and farmer preferences used to adapt the model constraints in order to place on a given farmer's land only those practices acceptable to that farmer. Spatial optimization results showed that even when farmer preferences are considered, near-optimal targeted scenarios could be achieved in the watershed. Farmer response in follow-up interviews was positive, and farmers plan to adopt a considerable portion of targeted results.

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LITERATURE CITED

Ahnstrom, J., J. Hockert, H.L. Bergea, C.A. Francis, P. Skelton, and L. Hallgren, 2008. Farmers and Nature Conservation: What Is Known about Attitudes, Context Factors and Actions Affecting Conservation? Renewable Agriculture and Food Systems 24(1):38-47.

Allan, C., A. Curtis, G. Stankey, and B. Shindler, 2008. Adaptive Management and Watersheds: A Social Science Perspective. Journal of the American Water Resources Association 44(1): 166-174.

Arabi, M., J.R. Frankenberger, B.A. Engel, and J.G. Arnold, 2008. Representation of Agricultural Conservation Practices with SWAT. Hydrological Processes 22:3042-3055.

Arbuckle, J.G., 2013. Farmer Attitudes Toward Proactive Targeting of Agricultural Conservation Programs. Society and Natural Resources 26(6):625-641.

Arnold, J.G., R. Srinivasan, R.S. Muttiah, and J.R. Williams, 1998. Large Area Hydrologic Modeling and Assessment: Part I. Model Development. Journal of the American Water Resources Association 34(1):73-89.

Beierle, T.C., 2002. The Quality of Stakeholder-Based Decisions. Risk Analysis 22(4):739-749.

Brown, S.S., 2011. Building Citizen Capacity. *In*: Pathways for Getting to Better Water Quality: The Citizen Effect, L.W. Morton, and S.S. Brown (Editors). Springer Science & Business Media, Springer, United Kingdom, pp. 247-255, doi: 10.1007/978-1-4419-7282-8_19.

Carpenter, S.R., N.F. Caraco, D.L. Correll, R.W. Howarth, A.N. Sharpley, and V.H. Smith, 1998. Nonpoint Pollution of Surface Waters with Phosphorus and Nitrogen. Ecological Applications 8(3):559-568.

Carpentier, C.L., D.J. Bosch, and S.S. Batie, 1998. Using Spatial Information to Reduce Costs of Controlling Agricultural Nonpoint Source Pollution. Agricultural and Resource Economics Review 27(1):72-84.

Chaubey, I., L. Chiang, M.W. Gitau, and S. Mohamed, 2011. Effectiveness of Best Management Practices in Improving Water Quality in a Pasture-Dominated Watershed. Journal of Soil and Water Conservation 65(6):424-437, doi: 10.2489/jswc.65.6.424.

Crumpton, W.G., 2001. Using Wetlands for Water Quality Improvement in Agricultural Watersheds; the Importance of a Watershed Scale Approach. Water Science and Technology 44(11-12):559-564.

Daggupati, P., K.R. Douglas-Mankin, A.Y. Sheshukov, P.L. Barnes, and D.L. Devlin, 2011. Field-Level Targeting Using SWAT: Mapping Output from HRUs to Fields and Assessing Limitations of GIS Input Data. Transactions of the ASABE 54(2):501-514.

Deb, K., A. Pratap, S. Agarwal, and T. Meyarivan, 2002. A Fast and Elitist Multiobjective Genetic Algorithm: NSGA-II. IEEE Transactions on Evolutionary Computation 6(2):182-197.

Diebel, M.W., J.T. Maxted, P.J. Nowak, and M.J. Vander Zanden, 2008. Landscape Planning for Agricultural Nonpoint Source Pollution Reduction I: A Geographical Allocation Framework. Environmental Management 42:789-802.

Diebel, M.W., J.T. Maxted, D.M. Robertson, S. Han, and M.J. Vander Zanden, 2009. Landscape Planning for Agricultural Nonpoint Source Pollution Reduction III: Assessing Phosphorus and Sediment Reduction Potential. Environmental Management 43:69-83.

Dietz, T. and P.C. Stern, 2008. The Promise and Perils of Participation. *In*: Public Participation in Environmental Assessment and Decision Making, Thomas Dietz and Paul C. Stern (Editors). The National Academies Press, Washington, D.C., pp. 33-74.

Duda, A.M. and R.J. Johnson, 1985. Cost-Effective Targeting of Agricultural Nonpoint-Source Pollution Controls. Journal of Soil and Water Conservation 40(1):108-111.

Epp, D.J. and J.S. Shortle, 1985. Agricultural Nonpoint Pollution Control: Voluntary or Mandatory? Journal of Soil and Water Conservation 40(1):111-114.

ESRI (Environmental Systems Resource Institute), 2010. ArcMap 10.0. ESRI, Redlands, California.

Ghebremichael, L.T., T.L. Veith, and J.M. Hamlett, 2013. Integrated Watershed- and Farm-Scale Modeling Framework for Targeting Critical Source Areas While Maintaining Farm Economic Viability. Journal of Environmental Management 114:381-394.

Ghebremichael, L.T., T.L. Veith, J.M. Hamlett, and W.J. Gburek, 2008. Precision Feeding and Forage Management Effects on Phosphorus Loss Modeled at a Watershed Scale. Journal of Soil and Water Conservation 63(5):280-291.

Ghebremichael, L.T., T.L. Veith, and M.C. Watzin, 2010. Determination of Critical Source Areas for Phosphorus Loss: Lake Champlain Basin. Vermont. Transactions of the ASABE 53 (5):1595-1604.

Gitau, M.W. and T.L. Veith, 2006. Quantifying the Effects of Phosphorus Control Best Management Practices. *In*: Modeling Phosphorus in the Environment, D.E. Radcliffe, and M.L. Cabrera (Editors). CRC Press, Boca Raton, pp. 351-382.

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 ASAE 47(6):1923-1931.

Grady, C.A., A.P. Reimer, J. Frankenberger, and L.S. Prokopy, 2013. Locating Existing Best Management Practices within a Watershed: The Value of Multiple Methods. Journal of the American Water Resources Association 49(4):883-895.

Greiner, R., L. Patterson, and O. Miller, 2009. Motivations, Risk Perceptions and Adoption of Conservation Practices by Farmers. Agricultural Systems 99:86-104.

Haas, M., S. Peel, and R. Turco, 2014a. Biological, Chemical and Flow Characteristics of Five River Sampling Sites in the Wabash River Watershed Near Lafayette, Indiana — 2009, doi: 10.4231/R7CC0XM3.

Haas, M., S. Peel, and R. Turco, 2014b. Biological, Chemical and Flow Characteristics of Five River Sampling Sites in the Wabash River Watershed Near Lafayette, Indiana — 2010, doi: 10.4231/R77P8W9J.

Haas, M., S. Peel, and R. Turco, 2014c. Biological, Chemical and Flow Characteristics of Five River Sampling Sites in the Wabash River Watershed Near Lafayette, Indiana — 2011, doi: 10.4231/R73X84K6.

Harrington, W., A.J. Krupnick, and H.M. Peskin, 1985. Policies for Nonpoint-Source Water Pollution Control. Journal of Soil and Water Conservation 40(1):27-32.

Heathwaite, A.L., P.F. Quinn, and C.J.M. Hewett, 2005. Modelling and Managing Critical Source Areas of Diffuse Pollution from Agricultural Land Using Flow Connectivity Simulation. Journal of Hydrology 304:446-461.

Helfand, G.E. and B.W. House, 1995. Regulating Nonpoint Source Pollution under Heterogeneous Conditions. Journal of Agricultural Economics 77(4):1024-1032.

Hession, W.C. and V.O. Shanholtz, 1988. A Geographic Information System for Targeting Nonpoint-Source Agricultural Pollution. Journal of Soil and Water Conservation 43(3):264-266.

Jackson-Smith, D.B., M. Halling, E. de la Hoz, J.P. McEvoy, and J.S. Horsburgh, 2010. Measuring Conservation Program Best Management Practice Implementation and Maintenance at the Watershed Scale. Journal of Soil and Water Conservation 65(6): 413–423.

Kalcic, M., I. Chaubey, J. Frankenberger, and E. Kladivko, 2012. A Geospatial Approach to Targeting Constructed Wetlands for Nitrate Removal in Agricultural Watersheds. Applied Engineering in Agriculture 28(3):347-357.

Kalcic, M., I. Chaubey, and J. Frankenberger, 2015a. Defining Soil and Water Assessment Tool (SWAT) Hydrologic Response Units (HRUs) by Field Boundaries. International Journal of Agricultural & Biological Engineering 8(3), doi: 10.3965/j.ijabe.20150803.951.

Kalcic, M.M., 2013. Adaptive Targeting: Engaging Farmers to Assess Perceptions and Improve Watershed Modeling, Spatial Optimization, and Adoption of Agricultural Conservation Practices. Doctoral Dissertation, Purdue University, West Lafayette, Indiana.

Kalcic, M.M., J. Frankenberger, and I. Chaubey, 2015b. Spatial Optimization of Six Conservation Practices Using SWAT in Tile-Drained Agricultural Watersheds. Journal of the American Water Resources Association, doi: 10.1111/1752-1688.12338.

Kalcic, M.M., L.S. Prokopy, J. Frankenberger, and I. Chaubey, 2014. An In-Depth Examination of Farmers' Perceptions of Targeting Conservation Practices. Environmental Management 54(4):795-813.

Kaplowitz, M.D. and F. Lupi, 2012. Stakeholder Preferences for Best Management Practices for Non-Point Source Pollution and Stormwater Control. Landscape and Urban Planning 104:364-372.

Kovacs, A., M. Honti, M. Zessner, A. Eder, A. Clement, and G. Blöschl, 2012. Identification of Phosphorus Emission Hotspots in Agricultural Catchments. Science of the Total Environment 433:74-88.

Lauber, T.B. and B.A. Knuth, 2000. Citizen Participation in Natural Resource Management: A Synthesis of HDRU Research. HDRU Series No. 00-7, The Human Dimensions Research Unit (HDRU) in the Department of Natural Resources at Cornell University, Ithaca, New York. http://www2.dnr.cornell.edu/hdru/pubs/HDRUReport00-7.pdf

Maringanti, C., I. Chaubey, M. Arabi, and B. Engel, 2011. Application of a Multi-Objective Optimization Method to Provide Least Cost Alternatives for NPS Pollution Control. Environmental Management 48:448-461.

Moriasi, D.N., P.H. Gowda, J.G. Arnold, D.J. Mulla, S. Ale, and J.L. Steiner, 2013a. Modeling the Impact of Nitrogen Fertilizer Application and Tile Drain Configuration on Nitrate Leaching Using SWAT. Agricultural Water Management 130:36-43, doi: 10.1016/j.agwat.2013.08.003.

Moriasi, D.N., P.H. Gowda, J.G. Arnold, D.J. Mulla, S. Ale, J.L. Steiner, and M.D. Tomer, 2013b. Evaluation of the Hooghoudt and Kirkham Tile Drain Equations in the Soil and Water Assessment Tool to Simulate Tile Flow and Nitrate-Nitrogen. Journal of Environmental Quality 42(6):1699-1710, doi: 10.2134/jeq2013.01.0018.

Pai, N., D. Saraswat, and R. Srinivasan, 2012. Field_SWAT: A Tool for Mapping SWAT Output to Field Boundaries. Computers & Geosciences 40:175-184.

Pannell, D.J., G.R. Marshall, N. Barr, A. Curtis, F. Vanclay, and R. Wilkinson, 2006. Understanding and Promoting Adoption of Conservation Practices by Rural Landholders. Australian Journal of Experimental Agriculture 46:1407-1424.

Piemonti, A.D., M. Babbar-Sebens, and E.J. Luzar, 2013. Optimizing Conservation Practices in Watersheds: Do Community Preferences Matter? Water Resources Research 49(10):6425-6449, doi: 10.1002/wrcr.20491.

Pionke, H.B., W.J. Gburek, and A.N. Sharpley, 2000. Critical Source Area Controls on Water Quality in an Agricultural Watershed Located in the Chesapeake Basin. Ecological Engineering 14:325-335.

Prokopy, L.S., K. Floress, D. Klotthor-Weinkauf, and A. Baumgart-Getz, 2008. Determinants of Agricultural Best Management Practice Adoption: Evidence from the Literature. Journal of Soil and Water Conservation 63(5):300-311.

Qiu, Z., M.T. Walter, and C. Hall, 2007. Managing Variable Source Pollution in Agricultural Watersheds. Journal of Soil and Water Conservation 62(3):115-122.

Reimer, A.P., A.W. Thompson, and L.S. Prokopy, 2012a. The Multi-Dimensional Nature of Environmental Attitudes among

Farmers in Indiana: Implications for Conservation Adoption. Agriculture and Human Values 29(1):29-40, doi: 10.1007/s10460-011-9308-z.

Reimer, A.P., D.K. Weinkauf, and L.S. Prokopy, 2012b. The Influence of Perceptions of Practice Characteristics: An Examination of Agricultural Best Management Practice Adoption in Two Indiana Watersheds. Journal of Rural Studies 28:118-128.

Scavia, D. and K.A. Donnelly, 2007. Reassessing Hypoxia Forecasts for the Gulf of Mexico. Environmental Science and Technology 41:8111-8117.

The MathWorks Inc., 2012. MATLAB Version 7.14.0. The MathWorks Inc., Natick, Massachusetts.

Tomer, M.D., S.A. Porter, D.E. James, K.M. Boomer, J.A. Kostel, and E. Mclellan, 2013. Combining Precision Conservation Technologies into a Flexible Framework to Facilitate Agricultural Watershed Planning. Journal of Soil and Water Conservation 68(5):113A-120A.

Tuler, S. and T. Webler, 1999. Voices from the Forest: What Participants Expect of a Public Participation Process. Society & Natural Resources 12:437-453.

Tuppad, P., K.R. Douglas-Mankin, and K.A. McVay, 2010. Strategic Targeting of Cropland Management Using Watershed Modeling. Agricultural Engineering International 12(3):12-24.

USDA NASS, 2014. 2012 Census of Agriculture: United States Summary and State Data. Volume 1, Geographic Area Series, Part 51, AC-12-A-51. http://www.agcensus.usda.gov/Publications/2012/Full_Report/Volume_1,_Chapter_1_US/usv1.pdf, *accessed* August 2014.

USDA, NRCS, 2012. Field Office Technical Guide. National Resources Conservation Service. http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/fotg/, *accessed* June 2012.

Veith, T.L., A.N. Sharpley, and J.G. Arnold, 2008. Modeling a Small, Northeastern Watershed with Detailed, Field-Level Data. Transactions of the ASABE 51(2):471-483.

Veith, T.L., A.N. Sharpley, J.L. Weld, and W.J. Gburek, 2005. Comparison of Measured and Simulated Phosphorus Losses with Indexed Site Vulnerability. Transactions of the ASAE 48(2):557-565.

Veith, T.L., M.L. Wolfe, and C.D. Heatwole, 2004. Cost-Effective BMP Placement: Optimization Versus Targeting. Transactions of the American Society of Agricultural Engineers 47(5): 1585-1594.

Wabash River Enhancement Corporation, 2011. Region of the Great Band of the Wabash River Watershed Management Plan. http://www.wabashriver.net/region-of-the-great-bend/, *accessed* July 2014.

Waidler, D., M. White, E. Steglich, S. Wang, J. Williams, C.A. Jones, and R. Srinivasan, 2009. Conservation Practice Modeling Guide for SWAT and APEX. http://swat.tamu.edu/media/57882/Conservation-Practice-Modeling-Guide.pdf, *accessed* June 2011.

White, M.J., D.E. Storm, P.R. Busteed, S.H. Stoodley, and S.J. Phillips, 2009. Evaluating Nonpoint Source Critical Source Area Contributions at the Watershed Scale. Journal of Environmental Quality 38:1654-1663.