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Taking stock of voluntary nutrient management: Measuring and tracking change

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Abstract: The importance of nutrient management plans (NMPs) in mitigating the impact of farm-based nutrient applications on the environment is widely acknowledged. However, despite years of promotion by agencies, most farmers still have not developed a NMP. Those plans that have been developed vary in quality and in the degree to which they are actually implemented. Although effective tools have emerged to aid plan development, the planning process remains time and resource intensive. In addition, information about NMPs and actual nutrient application rates generally is not available to resource managers who address water quality issues. This study examines changes in nutrient management behaviors and perceptions among 259 farmers, who participated in a multisession educational workshop series focused on understanding and developing NMPs. Based on structured interviews with farmers before and again one to three years after the workshops, the study finds that farmers are developing NMPs, understanding their plans, and also changing nutrient application rates (both increasing and decreasing). After implementing their NMPs, a strong majority (69%) of the participants believe that their plan has saved them money with no negative effect on yield. Three main findings hold implications for broader water quality and land conservation programs: (1) NMP education courses can lead to changes in farmer nutrient management behaviors, not always toward reducing nutrients; (2) farmers acknowledge challenges in fully implementing their plans, yet a high percentage (82%) indicate that they follow their plan on most (>76%) of their land; and (3) there is a need for accessible approaches to measure and track nutrient management behaviors separate from NMPs and in cases where they do not exist.

Key words: adoption—behavior change—evaluation—nutrient management planning—program evaluation—workshops

Nonpoint source (NPS) pollution from agricultural nutrients is recognized as the largest contributor to poor water quality throughout many regions of the United States (USEPA 2009; USGS 2010). Nonpoint source pollution from rural and urban landscapes carries nutrients and other contaminants into surface water and groundwater and contributes to tainted drinking water supplies, degraded fish and wildlife habitat, and compromised recreational opportunities. For decades, numerous federal, state, and local agencies and nongovernmental organizations have provided technical assistance, funding, oversight, and expertise to enable landowners to use practices aimed at minimizing the impact of NPS (Osmond 2010; Duriancik et al. 2008). Despite those efforts, substantial challenges remain, and reducing agricultural nutrient loads is a central component for many water quality restoration and protection strategies (USEPA 2008; Thomas et al. 2007; Diebel et al. 2008; Jha et al. 2010).

Agricultural nutrient management plans (NMPs) provide a means for balancing crop nutrient needs with potential environmental quality impacts, and they are widely promoted. Plans vary in complexity, form, and level of detail. At their most basic level, NMPs document available nutrient sources on a farm and specify the amounts of manure and additional commercial nutrients to be applied on each field (Beegle et al. 2000; Shepard 2005). Developing a NMP involves soil testing, identifying environmentally sensitive areas, and calculating nutrient availability and crop needs. Application rates and timing are set to meet crop needs while reducing the potential for excess nutrients to enter streams, lakes, and groundwater. The USDA Natural Resources Conservation Service (NRCS) established the 590 Nutrient Management Standard to specify minimum requirements that NMPs must meet as a prerequisite for producers to enroll in related conservation programs. Developing and implementing plans is time and resource intensive (Weld et al. 2002; McCann 2009).

With exceptions for large concentrated animal feeding operations and special requirements in some states, agricultural nutrient management (NM) decisions and related conservation practices for addressing NPS—including NMPs—are voluntary for most agricultural operations in the United States. Despite years of promoting the development of plans as one way to encourage NM practices that improve farmer profits and benefit water quality, the conservation field still lacks clear information about what truly moves farmers to develop and then adhere to NMPs. While there is substantial literature focused on the reasons farmers adopt various conservation practices (e.g., Nowak 1992; Prokopy et al. 2008), consistent and accessible information about actual practice use is limited (Lambert et al. 2007). Although agency cost-share agreements with farmers provide one source of data, Jackson-Smith et al. (2010) found that conservation agency records (of cost-shared practices) do not accurately represent practice use. They also note that softer management practices (like NM) are more likely to be abandoned by farmers than practices involving physical structures. Unlike those structural practices that can be monitored for use and maintenance, NM is largely a set of behaviors that is difficult to observe. Even when NMPs are recorded with conservation agencies, producers face challenges implementing prescribed actions on their operations (Beegle et al. 2000; Cabot et al. 2006; Pierce et al. 2007). Conservationists recognize the need for better monitoring and tracking of practices and to combine social data with physical data to

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better understand impacts on environmental conditions (Ambs 2007; Jackson-Smith et al. 2010; Lambert et al. 2007; Nowak and Cabot 2004; Sylvester and Redman 2007).

Maryland's experience with mandatory planning suggests one model for systematically measuring and tracking NMP development and implementation. Prompted by NPS impacts in the Chesapeake Bay, the Maryland Water Quality Improvement Act of 1998 requires NMPs and annual reports for all farmers in the state. As of 2010, Maryland has achieved a 99.9% compliance rate for farms submitting plans (5,722 operations; 0.5 million ha [1.3 million ac]) (MDA 2011). Beyond tracking submission, Maryland conducts an intensive auditing program that employs agency staff to review approximately 400 plans each year for consistency with implementation requirements; reviews in 2010 found 62% of those plans in compliance for the initial audit (MDA 2011).

In contrast, Wisconsin's agricultural performance standards and prohibitions also require all producers to develop and implement NMPs, but the requirement is only enforceable if farmers are offered 70% cost sharing (Wisconsin Administrative Code NR151). With nearly 3.6 million ha (8.9 million ac) of harvested cropland and more than 54,000 operations (USDA NASS 2009), limited cost-share resources effectively make Wisconsin's program voluntary for most operations. Wisconsin also has limited resources available to track and review plans and relies primarily on county conservation agencies and private-sector planners reporting NMPs to the state. Additionally, Wisconsin annually assembles a team of public and private NM specialists to review the quality of an intentional sample of NMPs for compliance with state requirements. For over a decade, the review has highlighted strengths and deficiencies in the quality of those plans, such as extent of soil testing, fields meeting tolerable soil loss, and more recently, protection of concentrated flow areas (WDATCP 2010). However, estimates from 2010 state that only 15% of Wisconsin's harvested land is covered by NMPs, with no clear estimate of the percentage of actual farm operations and no consistent data for the remaining 85% of Wisconsin farmland (WDATCP 2010).

Wisconsin's estimates of low NMP use underscore the challenge of understanding NM practices on the vast majority of farmland and reinforce the need for additional information. Individual state water quality programs vary in their capacities to monitor NM where required on permitted operations, let alone for voluntary actions. Even so, federal and state laws direct US Environmental Protection Agency and state agencies to address NPS challenges and to encourage NMP use and nutrient reduction strategies where appropriate. With voluntary programs remaining the dominant policy approach for addressing NPS pollution and agricultural NM, there is a clear need to learn from initiatives promoting NM planning. Understanding the impacts of those voluntary program initiatives and using that understanding to improve program design and delivery remain significant policy and conservation challenges (Mickwitz and Birnbaum 2009; Wilbanks and Stern 2002; Genskow and Wood 2009). Those challenges are magnified in the current environment of increasing demands for accountability regarding conservation and water quality funding and continuing interest in numeric nutrient standards and the role of agricultural NM in nutrient trading and watershed restoration plans.

This study helps address the dual challenges of understanding use of NM practices and the impacts of training programs that seek to improve those practices. The purpose of this study is to identify behavioral changes and perceived impacts of NM among farmers following their participation in a NM educational workshop program. This article outlines the data collection and analysis methods used to identify changes, highlights characteristics of participants' agricultural operations, presents results of pre- and post-comparisons, and discusses implications for soil and water quality management efforts.

Materials and Methods

This study involved pre- and postworkshop interviews with Wisconsin farmers using a structured-interview questionnaire intended to document NM understanding and behavior. Interview questionnaires included farm-level questions regarding NM–related practices, focusing on commercial fertilizer and manure applications, crop rotations, manure and legume crediting, and related activities. Responses allow calculations for estimates of application rates for nitrogen (N) and phosphorus (as phosphate [P_2O_5]). The questionnaire also documents livestock and other general farm characteristics, as well as farmer perceptions about NMPs, including perceived barriers to implementation and impacts on farm operations and water quality.

The workshops utilized the Wisconsin Nutrient Management Farmer Education (NMFE) Program curriculum, developed and subsequently updated by a team of University of Wisconsin-Extension nutrient management educators and specialists (Frame and Kivlin 2001; Frame et al. 2010). The NMFE program included a series of modules conducted over multiple workshop sessions aimed at providing farmers with the scientific, economic, and policy rationale for managing nutrient practices on their farms. Instructors combined group learning sessions and on-farm visits to enable farmers to develop their own NM plans that met Wisconsin NMP requirements and to understand and implement those plans (or plans developed for them by others). Farmers also learned about state NM rules and regulations. University of Wisconsin Cooperative Extension maintains and supports the curriculum with biannual updates and distributes updates to instructors. The NMFE curriculum is used by extension educators, land conservation departments, and technical colleges.

Between 2000 and 2005 (the period for data in this study), 1,400 producers completed the series, representing over 171,315 ha (423,000 ac) in 34 of 72 Wisconsin counties. Nearly half (671) of those producers completed questionnaires before participating in the workshops, and of those farmers, 267 also completed follow-up questionnaires one to three years later. Those 267 farmers participated in 22 separate workshop groups in 15 Wisconsin counties. Workshop groups averaged 18 participants, ranging from 5 to 36 participants. Eight of the farmers expanded their livestock operations between their pre- and postinterviews, triggering the need for a concentrated animal feeding operations water quality permit and more stringent NMP; for the purposes of this study, those eight were removed from further analysis. The remaining 259 participants represent 70% of all of the farmers participating in those 22 workshop groups. Across those 22 groups, 29% to 100% of each group's participants completed both pre- and post-questionnaires (average 70%; median 76%).

Questionnaires were completed through personal interviews in which both the farmer and interviewer had copies of the

Table 1
Farm characteristics of participants (postworkshop).

	Average	Median	Minimum	Maximum
Farm size				
Tillable area (ac) (*n* = 259)	373	280	20	2,000
Number of fields (*n* = 253)	36	25	1	210
Herd size				
Dairy cattle (*n* = 218)	164	124	20	690
Hogs (*n* = 23)	75	40	5	300
Beef cattle (*n* = 75)	85	39	2	800
Poultry (*n* = 13)	2,435	50	1	16,000
Farm products as a percentage of income				
Dairy products (*n* = 257)	66%	80%	0	100
Livestock & cattle (*n* = 258)	17%	10%	0	100
Cash crops (*n* = 258)	13%	9%	0	100

questionnaire, and the interviewer recorded the responses. The interviews were intended to be brief, often lasting less than 30 minutes. Local workshop instructors administered the preworkshop questionnaire to project participants following a general interview protocol. Interviews were conducted in person before participation in the workshop (between 2000 and 2005) and then again one to three growing seasons after the workshop sessions were completed (between 2001 and 2006). Postworkshop questionnaires were completed by the instructor or another conservation professional. The period between measurements allowed the farmers time to incorporate NM practices into their purchasing decisions and crop rotation schedules. Pre/post comparison provided information about changes in perceptions, application rates, and practices reflective of NMFE Program goals. Statistical analyses for correlations and significance of differences were conducted with IBM SPSS Statistics software (version 19) using independent sample *t*-tests and Pearson's correlations.

The interview questionnaire collects data about nutrient application rates using a single representative cornfield as a proxy for other fields, rather than asking for detailed information on multiple fields (e.g., Shepard 2000, 2005). This allows farmers to recall nutrient application from memory without relying on their records. Each farmer identified the dominant soil texture, previous crop rotations, commercial nutrient sources, and manure applied for the representative field. For additional context, farmers were also asked if other fields received more, less, or about the same amount of nutrient sources as that field.

The study's nutrient estimates are calculated from responses provided. Resulting estimates of nutrient availability from crop history are conservative, erring toward producing lower values of residual crop-available nutrients in several ways: estimates exclude residual soil nitrate other than first-year legume nitrogen credits; they account for only first-year manure nitrogen credits; they assume manure was surface applied and not incorporated into the soil; and only the lowest values are used when a range is available for manure or legume credits. Credits for a first-year corn field coming out of a legume rotation were estimated following the University of Wisconsin guidelines (Kelling et al. 1998; Laboski et al. 2006) as a poor stand (0% to 30% alfalfa) with nitrogen values of 101 kg N ha^{-1} (90 lb N ac^{-1}) for medium- and fine-textured soils and 45 kg N ha^{-1} (40 lb N ac^{-1}) for sandy soils. For soybean rotations, first-year credits were 45 kg N ha^{-1} (40 lb N ac^{-1}) for medium- and fine-textured soils with no credits for sandy soils. First-year credits for peas were 22 kg N ha^{-1} (20 lb N ac^{-1}) for medium- and fine-textured soils with no credits for sandy soils, and for clover, first year credits were 81 kg N ha^{-1} (72 lb N ac^{-1}) for medium- and fine-textured soils and 36 kg N ha^{-1} (32 lb N ac^{-1}) for sandy soils.

Estimates of nutrients from manure were determined by asking farmers to specify field size, type of manure applied, type of manure spreader, and size and number of loads applied within 12 months prior to the last corn planting. The amount of plant-available N and P_2O_5 were estimated from University of Wisconsin guidelines (book values) based only on first-year nutrient availability (Kelling et al. 1998; Laboski et al. 2006). Nitrogen availability assumed 1.5 kg N Mg^{-1} (3 lb N tn^{-1}) for dairy cow manure (1 kg N Mg^{-1} [8 lb N 1,000 gal^{-1}] if liquid applied), 2 kg N Mg^{-1} (4 lb N tn^{-1}) for manure from beef cattle (0.6 kg N Mg^{-1} [5 lb N 1,000 gal^{-1}] if liquid applied), 3.5 kg N Mg^{-1} (7 lb N tn^{-1}) for hog manure (2 kg N Mg^{-1} [17 lb N 1,000 gal^{-1}] if liquid applied), and 10 kg N Mg^{-1} (20 lb N tn^{-1}) for poultry (1 kg N Mg^{-1} [8 lb N 1,000 gal^{-1}] if liquid applied). Estimates of available P_2O_5 assumed 1.5 kg P_2O_5 Mg^{-1} (3 lb P_2O_5 tn^{-1}) for dairy cow manure (1 kg P_2O_5 Mg^{-1} [8 lb P_2O_5 1,000 gal^{-1}] if liquid applied), 2.5 kg P_2O_5 Mg^{-1} (5 lb P_2O_5 tn^{-1}) for manure from beef cattle (0.6 kg P_2O_5 Mg^{-1} [5 lb P_2O_5 1,000 gal^{-1}] if liquid applied), 3 kg P_2O_5 Mg^{-1} (6 lb P_2O_5 tn^{-1}) for hog (1.2 kg P_2O_5 Mg^{-1} [10 lb P_2O_5 1,000 gal^{-1}] if liquid applied), and 15 kg P_2O_5 Mg^{-1} (30 lb P_2O_5 tn^{-1}) for poultry (0.7 kg P_2O_5 Mg^{-1} [6 lb P_2O_5 1,000 gal^{-1}] if liquid applied) (Kelling et al. 1998; Laboski et al. 2006). No other manures were applied.

Results and Discussion

Participant Farm Characteristics. Most of the 259 operations tracked for this study were in corn–soybean rotations with livestock. Table 1 highlights additional key characteristics. Ninety-two percent of operations had either dairy or beef animals as part of the operation. Eighty-four percent reported having dairy cows; dairy herd size ranged from 20 to 690 animals, with an average of 165 cows (milking and dry). Less than 10% had swine or poultry. Tillable land area ranged from 8 to 810 ha (20 to 2,000 ac), with an average of 151 ha (373 ac). Farms in this study averaged 36 fields, with a median of 25 fields; 5% of the farms had 100 fields or more. Eighty-seven percent of the producers reported operating in mostly silt or loamy soil, 9% reported operating in mostly clay, and 3% reported operating in mostly sandy soils.

All 259 farms used manure. Most (86%) managed the manure themselves. Forty-one percent of the farmers reported having one month or more of manure storage, 29% reported having six months or more of storage, and 10% had capacity to store manure for a full year. More than half (56%) put manure directly into their spreaders, and 49% hauled manure daily or frequently throughout the year. Just over one-third hauled mostly in the spring or mostly in the fall. Sixty-nine percent used a manure spreader, and 26% used a tank wagon. Fourteen percent had someone else haul manure for them, either following the farm's NMP or spreading on locations identified for the applicator by the farmer. Most of the manure managed by participants was applied to cornfields. In addition to corn and soybean fields, farmers applied manure to small grains, canning crops, alfalfa, clover, and pasture.

Postworkshop Changes: Nutrient Management Plans. Of the 259 producers, 248 (96%) had NMPs in place by the time postworkshop interviews were conducted. Of those 248 farmers, 198 (76%) developed a NMP following the workshop, and 50 (19%) reported already having some form of a NMP prior to the workshop and also had a plan after completing the workshop. Eight of the farmers (3%) had not yet completed a NMP at the time of the postworkshop interview, and three farmers (1%) discarded their preworkshop NMPs and had not yet completed a replacement plan. Most NMPs were created within one year of participation in the training program. Of the 50 farmers with plans prior to the workshops, 22 (44%) reported in the preworkshop interviews that their written plan met the NRCS 590 standard. Following the workshops, 133 (54%) of the farmers with plans reported that those plans met the standard. Many farmers reported not being able to determine whether their plans met the NRCS technical standard.

The NMPs were developed by a mix of public and private planners and farmers. Most workshop participants were closely involved in the plan development and stated that they understood their plans. Before the workshop sessions, the majority of those with NMPs had plans that were created by a private agronomist or crop consultant (57%); 32% had plans developed by public sector conservationists (county staff, university extension, or NRCS); and 11% had developed their own plans. Following participation in the training program, the majority of new plans (57%) were created by or with public-sector conservationists (including educators), 20% were created by private-sector consultants, and 22% were created by the farmers working independently. After the workshops, 61% of the farmers that worked on new plans with professionals reported being "very much" involved in developing their NMPs; another 30% felt "somewhat" involved. Ninety-eight percent reported that their personal recommendations were included in the final plan; 55% felt that their personal recommendations were "very much" included in the final plan. Among the 248 farmers with NMPs after the workshops, 70% indicated that they understood their plans "very well."

Table 2
Pre- and postworkshop nutrient application rates.

	Number of farmers (*n*)	Preworkshop average lb ac^{-1}	Postworkshop average lb ac^{-1}	Change lb ac^{-1}
Full group				
Total N	254	150	154	+4
Total P_2O_5	248	64	63	–1
Farmers decreasing application				
Total N	116	193	118	–75*
Total P_2O_5	106	91	45	–46*
Farmers increasing application				
Total N	127	110	189	+79*
Total P_2O_5	108	39	84	+45*
Differences between those increasing versus decreasing				
Differences in N		83*	71*	
Differences in P_2O_5		52*	84*	

Notes: N = nitrogen. P_2O_5 = phosphate. University recommendations for N ranged from 80 to 200 lb ac^{-1} based on soil organic matter, soil yield potential, and irrigation.
*$p < 0.001$

Farmers stated several reasons for developing NMPs. Sixty-seven percent were motivated to develop their plans because of a government program, specifically to stay ahead of regulations, as a prerequisite for constructing manure storage, and to meet requirements to apply manure from another farm. Other stated reasons included a desire to save money, improve manure and fertilizer management, and protect the environment.

Postworkshop Changes: Nutrient Application. As discussed previously, estimates of N and P_2O_5 application rates were obtained through direct interviews with farmers. Nitrogen sources included commercial (purchased) fertilizer, manure applications, and legumes from crop rotations. Phosphorus estimates included commercial and manure sources. Table 2 provides an overall summary of nutrient application rates before and after the workshops.

There were substantial and statistically significant changes in the application rates of N and P_2O_5 before and after participating in the NM program. Although not detectable when looking solely at the change in average application rates, further analysis of individual participants show significant shifts. Forty-seven percent decreased their N applications, with an average reduction of 84 kg N ha^{-1} (75 lb N ac^{-1}), 2% did not change their N rates, and 51% increased their N applications by an average of 89 kg N ha^{-1} (79 lb N ac^{-1}). Similarly, for P_2O_5, 46% decreased application rates by an average of 52 kg P_2O_5 ha^{-1} (46 lb P_2O_5 ac^{-1}), 7% did not change, and 47% increased their application rates by an average of 50 kg P_2O_5 ha^{-1} (45 lb P_2O_5 ac^{-1}).

Importantly, those who decreased their nutrient use and those who increased their nutrient use mostly began at very different levels of application before the workshops, and they largely changed from either excessively high or very low rates to rates closer to recommendations. The preworkshop N and P_2O_5 application rates were significantly different for those who increased their application rates versus those who decreased their application rates (table 2). Much of the increases in application rates came from farmers who were applying lower levels before the workshops, and much of the decreases in application rates came from farmers who were applying high levels of nutrients before the workshop. Average preworkshop application was 216 kg N ha^{-1} (193 lb N ac^{-1}) for those decreasing N, compared to 123 kg N ha^{-1} (110 lb N ac^{-1}) for those increasing it ($p < 0.001$). Similarly, for P_2O_5, those increasing had an average preworkshop rate of 44 kg P_2O_5 ha^{-1} (39 lb P_2O_5 ac^{-1}); those decreasing began with an average preworkshop rate of 102 kg P_2O_5 ha^{-1} (91 lb P_2O_5 ac^{-1}) ($p < 0.001$).

Beyond the group averages of farmers increasing versus decreasing, there is a statistically significant correlation between preworkshop nutrient application rates and the amount and direction of change. For both nutrients, high initial rates correlated

Table 3
Changes for farmers whose application rates were initially in the highest and lowest quintile groups.

	Nitrogen		Phosphorus	
	Initially in highest 20% group	Initially in lowest 20% group	Initially in highest 20% group	Initially in lowest 20% group
Rate (lb ac^{-1})				
Change in total application	–97	+84*	–68	+35*
Total rate pre (for group)	271	48*	144	17*
Total rate post (for group)	172	131*	76	53*
Percent (%)				
Moving to different quintile postworkshop	73	62	65	69
Increasing rate	10	84	12	83
Decreasing rate	90	10	82	14
Unchanged	0	6	6	3
With plan preworkshop	4	3	5	3
With plan postworkshop	96	96	98	96
With plan developed by public sector	39	56	54	62
With plan developed by private sector	24	20	15	19
Developing their own plans	37	24	30	13
Area (ac)				
Receiving manure pre workshop	115	145	117	100
Receiving manure post workshop	142	159	128	135

*$p < 0.001$

with larger decreases, and lower initial rates correlated with larger increases ($r = -0.605$ for change in N; $r = -0.712$ for change in P; for both $p < 0.01$). Farmers also increased the land area on which they applied manure (table 3). Changes were likely the result of reducing overapplications of fertilizer and manure, allocating nutrients to additional fields that had not traditionally received manure, and increasing rates to more closely match soil test recommendations.

Changes are especially pronounced when reviewing the subsets of farmers who were highest and lowest appliers before the workshops. Dividing the preworkshop N and P_2O_5 application rates into quintiles creates groupings of the highest and lowest 20%. Table 3 illustrates changes for farmers in those groups. In each case, 62% to 73% moved out of their original quintile groups (no longer a highest or lowest applier) by either increasing or decreasing their application rates after the workshops.

Farmers who applied at least 230 kg N ha^{-1} (205 lb N ac^{-1}) before the workshops made up the top quintile group (the highest 20% of N application rates). The average change for this group was a decrease of 109 kg N ha^{-1} (97 lb N ac^{-1}). Within the group, 90% of those highest appliers decreased their total N application rates by an average of 131 kg N ha^{-1} (117 lb N ac^{-1}), with a median of 124 kg N ha^{-1} (111 lb N ac^{-1}), and 10% of this group further increased their total application by an average of 90 kg N ha^{-1} (80 lb N ac^{-1}), with a median of 51 kg N ha^{-1} (45 lb N ac^{-1}).

Similarly, farmers in the top quintile for preworkshop P_2O_5 application rates all initially applied 108 kg P_2O_5 ha^{-1} (96 lb P_2O_5 ac^{-1}) or more. On average, this group of high appliers decreased their P_2O_5 application rates by 76 kg P_2O_5 ha^{-1} (68 lb P_2O_5 ac^{-1}). Digging deeper, 82% of those highest appliers decreased their application rates by an average of 92 kg P_2O_5 ha^{-1} (82 lb P_2O_5 ac^{-1}), with a median of 81 kg P_2O_5 ha^{-1} (72 lb P_2O_5 ac^{-1}). Six percent did not change their total P_2O_5 application rates, and 12% further increased their total application rates by an average of 36 kg P_2O_5 ha^{-1} (32 lb P_2O_5 ac^{-1}), with a median of 35 kg P_2O_5 ha^{-1} (31 lb P_2O_5 ac^{-1}).

More than 8 in 10 farmers beginning with very low application rates increased their rates. The bottom quintile (lowest 20%) for preworkshop N application included farmers applying less than 91 kg N ha^{-1} (81 lb N ac^{-1}) before the workshops. On average, this group of lowest appliers increased their applications by 94 kg N ha^{-1} (84 lb N ac^{-1}). Eighty-four percent of them increased by an average of 116 kg N ha^{-1} (103 lb N ac^{-1}), with a median of 99 kg N ha^{-1} (88 lb N ac^{-1}), to an average application rate of 168 kg N ha^{-1} (150 lb N ac^{-1}). Six percent of this lowest N applier group did not change, and 10% of the lowest quintile decreased further, on average by 36 kg N ha^{-1} (32 lb N ac^{-1}), with a median of 39 kg N ha^{-1} (35 lb N ac^{-1}).

Similarly, the lowest preworkshop P_2O_5 appliers (the bottom quintile group) used less than 28 kg P_2O_5 ha^{-1} (25 lb P_2O_5 ac^{-1}) before attending workshops. On average, this group of farmers increased application by 39 kg P_2O_5 ha^{-1} (35 lb P_2O_5 ac^{-1}). The increases came from 83% of this group, who increased by 54 kg P_2O_5 ha^{-1} (48 lb P_2O_5 ac^{-1}), with a median of 47 kg P_2O_5 ha^{-1} (42 lb P_2O_5 ac^{-1}), to an average of 73 kg P_2O_5 ha^{-1} (65 lb P_2O_5 ac^{-1}). Three percent did not change their application rates, and 14% further decreased their rates, on average by 7 kg P_2O_5 ha^{-1} (6 lb P_2O_5 ac^{-1}), with a median of 7 kg P_2O_5 ha^{-1} (6 lb P_2O_5 ac^{-1}).

Many of the initial low appliers who increased their N and P_2O_5 rates brought them closer in line with university recommendations for profitability and environmental protection. Beyond those changes, table 3 identifies the source of NMPs for farmers in those quintile groups. Those with the lowest initial rates relied more heavily on assistance from public-sector planners for support. Table 3 also illustrates that all groups increased the area receiving manure between the pre- and postinterviews. Across

Table 4
Farmer postworkshop perceptions of changes associated with a nutrient management plan (NMP).

Topic	Participants who agree		Average estimated change
Commercial nitrogen	**(%)**		**(lb ac^{-1})**
I decreased N with a NMP	65		decreased by 54
I had no change in N application	33		—
I increased N with a NMP	2		increased by 22
Commercial phosphorus	**(%)**		**(lb ac^{-1})**
I decreased P with a NMP	51		decreased by 32
I had no change in P application	47		—
I increased P with a NMP	2		increased by 27
Production costs	**(%)**		**($ ac^{-1})**
I had no change in production costs	24		—
A NMP saved money	69		saved me 18
A NMP cost money	2		cost me 27
I don't know	5		—
Corn yields	**(%)**		**(bu ac^{-1})**
There was no change in corn yield	74		—
A NMP increased corn yield	18		increased by 18
A NMP decreased corn yield	3		decreased by 16
I don't know	6		—
Impact	**Surface water (%)**	**Groundwater (%)**	
A NMP will have no impact	5	6	
A NMP will have a small, positive impact	53	54	
A NMP will have a major, positive impact	38	36	
I don't know	4	4	

Notes: NMP = nutrient management plan. N = nitrogen. P = phosphorus.

all groups, farmers increased the percentage of land receiving manure, from an average of 57% before the workshops to 79% afterwards. Median values increased from 33% to 37% of tillable land. This reallocation of manure over a larger area is consistent with training recommendations for decreasing nutrient concentrations to reduce risk of negative water quality impacts.

Postworkshop Changes: Farmer Implementation of Nutrient Management Plans. In addition to comparing calculated differences in application rates before and after the workshops, the study also asked farmers about their written plans and their NM changes. Of the 248 farmers with NMPs after the training, 86% indicated that their plans cover 76% or more of their croplands. Eighty-two percent indicated that they have been able to follow the recommendations in their plan on 76% or more of their acres, and 41% said they follow their plan on 100% of their acres.

Table 4 highlights perceived impacts of NMPs on the use of commercial nutrients, production costs, yields, and local water resources. Sixty five percent stated that they decreased commercial N with a NMP. Fifty-one percent decreased commercial phosphorus with a NMP. Sixty-nine percent stated that their NMPs saved them money. Seventy-four percent saw no change in corn yield. Fifty-three percent indicated that their NMPs will have a small, positive impact on surface water quality (54% on groundwater). Thirty-eight percent said that their NMPs will have a major, positive impact on surface water quality (36% on groundwater).

After the workshops, farmers had lower concerns about a number of barriers to NMP implementation that were predicted by the literature. Prior to the workshops, 27% were concerned or greatly concerned about the amount of time it would take to do NM planning; that dropped to 7% after the workshops. Twelve percent were initially concerned that the plan would not protect profits (13%) and yields (12%); those both dropped to 1% or less after the workshops. Only concerns about having too little manure to spread on all of the fields that were specified in the NMP increased following the workshops, from 10% before to 20% after. Concerns about having too much manure dropped from 11% to 5%. Before the workshops, those anticipating problems in moving manure to all of the fields specified in the plan ranged from 41% (due to inclement weather) to 29% (due to field location) to 26% (due to amount of time required). Those percentages decreased postworkshop to 30% (weather), 22% (location), and 14% (time) respectively.

As a final point, NMPs emphasize the importance of soil tests as a basic element of implementation. Postprogram data show that the number of farmers who test their soil every three to four years increased from 48% to 71%, while the number of farmers who test their soil every five years, never test soil, or have no pattern to soil testing all decreased. This behavioral change is promising and could be considered an important indication of progress. It confirms that a significant percentage of farmers changed their behavior, but that 3 out of 10 are still not following the recommended practice.

Summary and Conclusions

Changing Nutrient Management Through Training. This study suggests that the

Wisconsin NMFE Program, with its emphasis on multiple workshop sessions and direct farmer-educator interaction, is an effective approach for helping farmers understand NM and develop NMPs. All but a few participants developed plans (96%), and almost all participants stated that they understand their NMP. The study established that NM application rates changed following workshop participation and that soil testing frequency increased. Roughly half of the farmers increased their application rates following the workshops. Most of the highest appliers in the preworkshop assessment reduced their nutrient application rates substantially. Participants believe that their plans have saved them money and had no negative effects on yield. Issues that were initially perceived as obstacles to NM largely did not interfere with plan implementation.

These findings reinforce the importance of educational programs as components of a strategy for NM, and less directly, as components of water quality improvement efforts. While private sector agronomists and nongovernmental organizations have roles in developing and updating plans, ongoing funding and resource support for educational program development and delivery by the public sector is important.

Nutrient Management Implementation Challenges. Farmers in this study reported following their NMPs on most of their lands most of the time, but only 4 in 10 said that they follow the plan on 100% of their land area. More than double that amount (more than 8 in 10) are able to follow their plans on 76% or more of their land areas. This finding reinforces the need to look beyond the number of plans produced and to understand the extent to which producers are following sound NM practices in order to understand NMP use. Shepard (2005) noted this issue and the importance of a policy emphasis that includes a focus on building farmer understanding and implementation of NMPs. Quality reviews of plans and compliance audits further reinforce the point (e.g., WDATCP 2010; MDA 2011) and identify important issues for those writing and using NMPs.

Several researchers also point to the personal relationships developed between farmers and conservation professionals and one-on-one, personalized advice as important elements of NM education (Brant 2003; Nowak and Cabot 2004; Shepard 2005). In a recent contribution, Nowak (2011) argues for recognizing farmers as equal collaborators in the "conservation journey" and calls for additional resources to expand the network and capacity of local conservationists and educators to do this work. Training programs like the Wisconsin NMFE workshops help establish and build upon those relationships and allow conservationists and educators to understand and address the particular farming style and biophysical characteristics of individual farms to overcome NM implementation challenges. Group training and workshop models also support peer learning opportunities and can positively reinforce local norms for NM and related agricultural management practices.

Using Social Data. Nutrient management involves both behavioral and biophysical contextual components, and crafting workable approaches requires information about both (Brant 2003; Nowak and Cabot 2004). There are clear benefits to conducting more intensive, on-farm research to identify operational challenges in implementing NM (e.g., Cabot et al. 2006; Pierce et al. 2007; Weld et al. 2002), and findings from the USDA Conservation Effects Assessment Project studies illustrate the importance of incorporating social dimensions into that research (see Osmond 2010). Yet, beyond formalized research and comparative methodological approaches for NMP development (e.g., Sharpley et al. 2003; Weld et al. 2002), there is a need for complementary and accessible methods and measurement tools that incorporate socioeconomic and behavioral changes into use of NM and related voluntary practices, as well as a commitment to use them as part of a natural resource protection effort (Robertson et al. 2007; Genskow and Wood 2009; Prokopy 2011).

The comparative pre/post findings in this study would not have been possible by relying on NMPs for data. Participants did not have them before the workshops, and reviewing private NMPs for data rather than conducting interviews with farmers would have been less insightful and potentially more intrusive. It is worth noting that the ability to track the same participants at two points in time allowed for insights on individual NM changes in this study that would not have been evident if the results had relied solely on comparisons of two separate groups. This suggests value in targeting measures to include key groups or individuals of interest and contacting them at multiple points in time.

Incorporating spatial analysis with social data could help further understand connections to specific areas and potential environmental sensitivities (Lawley et al. 2009; Diebel et al. 2008). Information about NM behaviors and NMP implementation could readily support other efforts (e.g., Lambert et al. 2007; Prokopy et al. 2009) to learn more about various populations of farmers, their uses of practices, and their connections with environmentally sensitive areas. Such approaches provide information compatible with requirements for "measurable milestones" and progress indicators associated with US Environmental Protection Agency watershed management plans (USEPA 2008).

Just as adopting and implementing NMPs is a complex behavior, this study illustrates that understanding if, how, and why those changes are occurring is also complex and that it requires more than documenting the numbers of plans completed. There is a need for accessible approaches to measure and track NM behaviors—whether or not a NMP exists. Outreach, education, and individual consultation are important components in approaches to expand agricultural NM. In particular, this study suggests that educational workshops involving individual interaction with farmers in plan development supports changes in NM practices and ultimately may lead to more effective environmental and water quality efforts.

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References

Ambs, T. 2007. A state agency perspective. *In* Managing Agricultural Landscapes and Environmental Quality, ed. M. Schnepf and C. Cox, 178-180. Ankeny, IA: Soil and Water Conservation Society.

Beegle, D.B., O.T. Carton, and J.S. Bailey. 2000. Nutrient management planning: Justification, theory, practice. Journal of Environmental Quality 29(1):72-79.

Brant, G. 2003. Barriers and Strategies Influencing the Adoption of Nutrient Management Practices. Technical Report 13.1. USDA NRCS Social Sciences Institute.

Cabot, P.E., F.J. Pierce, P. Nowak, and K.G. Karthikeyan. 2006. Monitoring and predicting manure application rates using precision conservation technology. Journal of Soil and Water Conservation 61(5):282-292.

Diebel, M., J. Maxted, P. Nowak, and J. Vander Zanden. 2008. Landscape planning for agricultural nonpoint source pollution reduction I: A geographical allocation framework. Environmental Management 42:789–802.

Duriancik, L.F., D. Bucks, J.P. Dobrowolski, T. Drewes, S.D. Eckles, L. Jolly, R.L. Kellogg, D. Lund, J.R. Makuch, M.P. O'Neill, C.A. Rewa, M.R. Walbridge, R. Parry, and M.A. Weltz. 2008. The first five years of the Conservation Effects Assessment Project. Journal of Soil and Water Conservation 63(6):185A-197A, doi:10.2489/jswc.63.6.185A.

Frame, D., and P. Kivlin. 2001. Nutrient Management Farmer Education Program Curriculum. Madison, WI: University of Wisconsin-Madison College of Agricultural and Life Sciences.

Frame, D., P. Kivlin, and S. Sturgul. 2010. Nutrient Management Farmer Education Program Curriculum. Madison, WI: University of Wisconsin-Madison College of Agricultural and Life Sciences.

Genskow, K., and D. Wood. 2009. Measurement, learning, and adaptation in planning and implementing voluntary non-point source watershed programs. Journal of Planning Literature 24(2):137-154.

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, doi:10.2489/jswc.65.6.413.

Jha, M.K., K.E. Schilling, P.W. Gassman, and C.F. Wolter. 2010. Targeting land-use change for nitrate-nitrogen load reductions in an agricultural watershed. Journal of Soil and Water Conservation 65(6):342-352, doi:10.2489/jswc.65.6.342.

Kelling, K., L. Bundy, S. Combs, and J. Peters. 1998. Soil Test Recommendations for Field, Vegetable, and Fruit Crops. Publication A2809. Madison, WI: University of Wisconsin-Extension.

Laboski, C., J. Peters, and L. Bundy. 2006. Nutrient Application Guidelines for Field, Vegetable, and Fruit Crops in Wisconsin. Publication A2809. Madison, WI: University of Wisconsin-Extension.

Lambert, D., G.D. Schaible, R. Johansson, and U. Vasavada. 2007. The value of integrated CEAP-ARMS survey data in conservation program analysis. Journal of Soil and Water Conservation 62(1):1-10.

Lawley, C., E. Lichtenberg, and D. Parker. 2009. Biases in nutrient management planning. Land Economics 85(1):186-200.

McCann, L. 2009. Transaction costs of environmental policies and returns to scale: The case of comprehensive nutrient management plans. Review of Agricultural Economics 31(3):561-573.

MDA (Maryland Department of Agriculture). 2011. Maryland Nutrient Management Program: 2010 Annual Report. Annapolis, MD: Maryland Department of Agriculture.

Mickwitz, P., and M. Birnbaum. 2009. Key insights for the design of environmental evaluations. *In* Environmental Program and Policy Evaluation: Addressing Methodological Challenges, ed. M. Birnbaum and P. Mickwitz, New Directions for Evaluation 122:105-112.

Nowak, P. 1992. Why farmers adopt conservation technology. Journal of Soil and Water Conservation 47(1):14-16.

Nowak, P. 2011. The conservation journey. Journal of Soil and Water Conservation 66(3):61A-64A, doi:10.2489/jswc.66.3.61A.

Nowak, P., and P.E. Cabot. 2004. The human dimension of resource management programs. Journal of Soil and Water Conservation 59(6):128A-135A.

Osmond, D.L. 2010. USDA water quality projects and the National Institute of Food and Agriculture Conservation Effects Assessment Project watershed studies. Journal of Soil and Water Conservation 65(6):142A-146A, doi:10.2489/jswc.65.6.142A.

Pierce, F.J., P. Nowak, and P.E. Cabot. 2007. Coping with the data dilemma. *In* Managing Agricultural Landscapes and Environmental Quality, ed. M. Schnepf and C. Cox, 52-60. Ankeny, IA: Soil and Water Conservation Society.

Prokopy, L. 2011. Agricultural human dimensions research: The role of qualitative research methods. Journal of Soil and Water Conservation 66(1):9A-12A, doi:10.2489/jswc.66.1.9A.

Prokopy L., 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, doi:10.2489/jswc.63.5.300.

Prokopy L., K. Genskow, J. Asher, A. Baumgart-Getz, J. Bonnell, S. Broussard, C. Curtis, K. Floress, K. McDermaid, R. Power, and D. Wood. 2009. Designing a regional system of social indicators to evaluate nonpoint source water projects. Journal of Extension 47(2).

Robertson, G.P., L.W. Burger, C.L. Kling, R. Lowrance, and D.J. Mulla. 2007. New approaches to environmental management research at landscape and watershed scales. *In* Managing Agricultural Landscapes and Environmental Quality, ed. M. Schnepf and C. Cox, 27-50. Ankeny, IA: Soil and Water Conservation Society.

Sharpley, A.N., J.L. Weld, D.B. Beegle, P.J.A. Kleinman, W.J. Gburek, P.A. Moore, Jr., and G. Mullins. 2003. Development of phosphorus indices for nutrient management planning strategies in the United States. Journal of Soil and Water Conservation 58(3):137-152.

Shepard, R. 2000. Nitrogen and phosphorus management on Wisconsin farms: Lessons learned for agricultural water quality programs. Journal of Soil and Water Conservation 55(1):63-68.

Shepard, R. 2005. Nutrient management planning: Is it the answer to better management? Journal of Soil and Water Conservation 60(4):171-176.

Sylvester, K.M., and C.L. Redman. 2007. Integrating the biophysical and social sciences. *In* Managing Agricultural Landscapes and Environmental Quality, ed. M. Schnepf and C. Cox, 17-20. Ankeny, IA: Soil and Water Conservation Society.

Thomas, M.A., B.A. Engel, M. Arabi, T. Zhai, R. Farnsworth, and J.R. Frankenberger. 2007. Evaluation of nutrient management plans using an integrated modeling approach. Applied Engineering in Agriculture 23(6):747-755.

USDA NASS (National Agricultural Statistics Service). 2009. 2007 Census of Agriculture: United States Summary and State Data. Report AC-07-A-51. Washington, DC: USDA.

USEPA (US Environmental Protection Agency). 2008. Handbook for Developing Watershed Plans to Restore and Protect Our Waters USEPA 841-B-08-002. Washington, DC: USEPA.

USEPA. 2009. National Water Quality Inventory: Report to Congress, 2004 Reporting Cycle. United States Environmental Protection Agency publication EPA 841-R-08-001. Washington, DC: USEPA.

USGS (US Geological Survey). 2010. The quality of our Nation's waters—Nutrients in the Nation's streams and groundwater, 1992–2004: U.S. Geological Survey Circular 1350. Washington, DC: US Department of the Interior.

WDATCP (Wisconsin Department of Agriculture, Trade and Consumer Protection). 2010. Wisconsin Nutrient Management Update and Quality Assurance Team Review of 2010's Nutrient Management Plans. Madison, WI: Wisconsin Department of Agriculture, Trade and Consumer Protection.

Weld, J.I., R.L. Parsons, D.B. Beegle, A.N. Sharpley, W.J. Gburek, and W.R. Clouser. 2002. Evaluation of phosphorus-based nutrient management strategies in Pennsylvania. Journal of Soil and Water Conservation 57(6):448-454.

Wilbanks T., and P. Stern. 2002. New tools for environmental protection: What we need to know. *In* New Tools for Environmental Protection, ed. T. Dietz and P. Stern, 337-348. Washington, DC: National Academy Press.