The impact of federal and state conservation programs on farmer nitrogen management

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Abstract: The U.S. federal government, as well as many state and local governments, operate a number of conservation programs aimed at ameliorating the environmental problems associated with agriculture. While motives and barriers to conservation program participation and adoption of conservation practices have been extensively studied, the direct impacts of programs on ongoing farm operations remains underexplored. To examine the effects of conservation programs on nitrogen management, an aspect of crop production with significant environmental impacts we conducted interviews with 154 corn producers in three Midwestern U.S. states with a range of program experiences. We found that programs shifted farmer N management behavior through three social processes: 1) engaging farmers in the conservation system by introducing them to the state and federal conservation agencies, 2) incentivizing trialing of specific N management practices, and 3) increasing

practice adoption through continued program engagement. Working lands programs were far more effective at shifting on-farm nutrient management practices than land retirement, certification, or outreach-based programs, though all programs had the indirect benefit of increasing farmer familiarity with conservation agencies and programs. Working lands programs directly motivated practice adoption; including soil testing regimes, implementing nutrient management plans, and splitting nitrogen applications to improving availability; by reducing producer risk and providing technical assistance, especially whole-farm planning. The additional benefits of all programs were moderated by participant selection bias, in particular that program participants were more predisposed to conservation efforts by existing stewardship and innovation attitudes.

Keywords: agriculture; agri-environmental programs; conservation practices; non-point source pollution; fertilizer

Introduction:

Agricultural lands produce a wide range of positive ecosystem services (primarily food, fuel, and fiber production) while also resulting in negative (and primarily unintended) outcomes (Robertson and Swinton 2009). These negative outcomes include surface and groundwater pollution (Rabalais et al. 2001; U.S. EPA 2009), degradation of wildlife habitat (Swinton et al. 2007), and contributions to climate change (Robertson and Vitousek 2009). Among the most critical and systemic environmental problems stemming from agriculture is excess nitrogen (N), primarily resulting from extensive fertilization of grain crops (Davidson et al. 2007; Millar and Robertson 2015). These environmental harms are among the most significant challenges to building a sustainable global agricultural sector (Robertson and Swinton 2009; Davidson et al. 2015).

Globally, governments have promulgated a wide range of policies over the past century to address environmental problems stemming from agriculture (Claassen et al. 2001; Baylis et al. 2008; Moon and Cocklin 2011). In the United States (U.S.), both federal and state governments have largely eschewed direct regulation of agriculture, focusing instead on voluntary and incentives-based policy tools (Batie 2009; Baylis et al. 2008). The U.S. federal government has invested significant financial resources into developing, promoting and incentivizing on-farm conservation practices (Dowd et al. 2009). The U.S. Department of Agriculture (USDA) operates numerous programs aimed at stimulating private conservation action, both by removing sensitive lands from production (land retirement) and encouraging adoption of conservation practices on active agricultural lands (working-lands programs). Despite decades of land retirement programs, environmental problems stemming from agriculture have persisted and in some areas intensified (Davidson et al. 2012). To address the ongoing environmental problems from agriculture, including excess N in the environment, the relative emphasis has shifted away from land retirement toward working-lands programs in the past two decades (Claassen 2014;

Dowd et al. 2009; Reimer 2015). Rather than addressing many of the underlying causes of environmental pollution, these policies have generally sought to incorporate new practices and technologies that reduce environmental harm from agriculture while maintaining the basic structure of the international agricultural sector (Reimer 2015).

As the policy emphasis at the federal level has shifted toward promoting conservation practice adoption on actively farmed land, especially through working lands programs that provide technical and financial incentives (Claassen 2014; Reimer 2015), there is a particular need to better understand how farmer participation in working lands programs affects on-farm practice use. Significant research effort has focused on understanding farmer conservation behavior, particularly the adoption of conservation or best management practices (Baumgart-Getz et al. 2015; Prokopy et al. 2008). While some research has explored farmer perceptions of and participation in conservation programs (Lambert et al. 2006; Lambert et al. 2007; McCann and Claassen 2014; Reimer and Prokopy 2014b), there remains a gap in understanding about how program participation influences on-going farm conservation efforts.

The research presented here explores how conservation programs influence farmer adoption of nutrient management practices through qualitative interviews with farmers in the U.S. Corn Belt (comprised of Illinois, Indiana, Iowa, Michigan, Minnesota, Ohio, and Wisconsin). Our focus is on federal conservation programs, which constitute the largest public investment in agri-environmental policy, though we do include some perspective on state and local policies, which also influence adoption. First, we provide an outline of U.S. agri-environmental policy, with an emphasis on recent shifts toward promoting sustainable farming practices in active production. We then present data from in-depth interviews with corn producers in the U.S. Midwest, a region of extensive corn production that relies heavily on external N fertilizer inputs. We present emergent themes from these interviews that highlight the influence of

conservation programs on agricultural N management, as well as factors that influence participation or non-participation in these programs.

U.S. Agri-Environmental Program Portfolio

Through the majority of the 20th century, U.S. agri-environmental programs focused on removing sensitive lands from production. Largely in response to the soil management crises of the 1930s Dust Bowl, the U.S. government created the Soil Conservation Service in 1933 as part of the USDA (Claassen 2014). The Soil Conservation Service focused on providing incentives to farmers to remove the most sensitive lands from production especially on so-called highly erodible lands with higher slopes and soils prone to surface erosion (Dowd et al. 2009). The Soil Bank Program (SBP) was a land retirement program created in the 1950s to address the dual purposes of ongoing soil erosion and controlling supply surpluses resulting from new production techniques (Helms 1985). The SBP also incentivized the establishment of conservation cover through the Conservation Reserve Program (CRP) (Helms 1985). In the 1980s, Congress revised conservation programming, ending the SBP while establishing the CRP as the primary land retirement program. The CRP has remained the largest agricultural conservation program since the 1980s, even after the most recent reorganization of the US federal conservation portfolio in 2014, with over 23 million enrolled acres in 2016 (Claassen 2014; Lubben and Pease 2014; USDA 2016). The Corn Belt contains nearly 20% (4.6 million acres) of the U.S. total CRP acreage, much of it in the western portion of this region (USDA 2016).

Since the 1990s, policy efforts at the federal level have shifted to changing production practices on actively farmed lands (Claassen 2003; Stubbs 2010). The primary goal of this shift was to address environmental issues beyond farm boundaries. While soil conservation remains a focus of many federal conservation efforts, working-lands programs were developed to address a wide range of environmental

issues, including landscape-scale wildlife habitat, water pollution, and air quality. As part of this shift in emphasis, the Soil Conservation Service was renamed the Natural Resources Conservation Service (NRCS) in 1994, and in 2014 there was an increase in funding for the working lands programs relative to CRP and other land retirement programs (Claassen 2014; Reimer 2015). The NRCS is the primary USDA agency responsible for managing the portfolio of conservation programs and providing technical assistance to farmers and landowners on conservation issues. It is important to note that federal conservation programs are often administered locally with the assistance of state and/or local conservation staff, most frequently local soil and water conservation districts. The ability to promote and disseminate information about programs has been shown to vary widely from state to state and even within states based largely on state and local governance capacity (Reimer and Prokopy 2014a).

The Environmental Quality Incentives Program (EQIP), was established in 1996 (Schertz and Doering 1999; Stubbs 2010), and is one of the two main working-lands programs administered by NRCS today. This program focused on providing cost-share and technical assistance to farmers to incentivize adoption of a wide range of conservation practices, including reduced tillage, in-field and edge-of-field structural practices (e.g. grassed waterways, drainage management structures), written nutrient management plans, and winter cover crops (Reimer and Prokopy 2014a). Because it is administered by the NRCS at the state level, EQIP allows for flexibility in which resource concerns and conservation practices will be the focus of the program. This flexible implementation results in a wide range of program outputs and outcomes from state to state. In some states, nutrient management is a significant focus of EQIP (Reimer and Prokopy 2014a).

In addition to EQIP, NRCS administers the Conservation Stewardship Program (CSP). This working-lands program focuses on holistic farm stewardship; rather than the adoption of single conservation practices

in exchange for cost-share and technical assistance farmers enroll farm acreage in CSP for a fixed-term (typically 5 year) contract. In exchange for an annual payment, participating farmers focus on a given resource concern, ranging from farmstead management to nutrient management, and install enhancements (including individual conservation practices such as written nutrient management plans and soil/plant tissue testing for nutrient management) that improve farm performance in that resource area. The CSP has grown quickly to become the third largest federal conservation program, after CRP and EQIP (Reimer 2015).

Some state and local governments have also been actively pursuing policies to reduce nutrient pollution related to agricultural practices in recent years. States vary widely in their efforts in this area, with large variation in how local soil and water conservation districts are organized and funded, as well as the funding and implementation of state-level programs. Similar to federal programs, most state-level programs use voluntary approaches, though some sub-federal programs often use other policy tools in addition to incentives. These include outreach and education efforts and certification programs (Dowd et al. 2009; Vollmer-Sanders et al. 2011). Several states in the U.S. Midwest have promulgated state nutrient reduction strategies as part of an effort to reduce nutrient (N and phosphorus) flows to the Gulf of Mexico (Rabotyagov et al. 2014). These state strategies use integrated watershed-based modeling to identify critical regions within a state that contribute to nutrient loading and target conservation efforts to those areas. For example, Iowa has recently expanded their state plan, the Iowa Nutrient Reduction Strategy, to reduce nutrient loading to waterways by 45% through the promotion of conservation practices (ISUEO 2014). Iowa state agencies work in conjunction with other public and private entities to target outreach and cost-share incentives to farmers in target watersheds throughout the state, with state funds directed through the Iowa Water Quality Initiative (IDALS 2015).

Farmer Adoption of Sustainable Nutrient Management Practices

Within the literature on farmer conservation behavior, determinants of conservation adoption have been shown to be wide-ranging and context-specific, including farmer demographics, farmer attitudes and values, farm financial and technical capacity, and characteristics of the practices in question (Baumgart-Getz et al. 2015; Prokopy et al. 2008). Researchers have used a variety of approaches to investigate farmer conservation behavior, including typologies that categorize farmers by shared values, attitudes, or behaviors (Maybery et al. 2005; Reimer et al. 2012), social-psychological explorations of attitudinal antecedents of practice adoption (Kaiser et al. 2005; Greiner and Gregg 2011; McGuire et al. 2013; Lincoln and Ardoin 2016), and analyses of farm-level variables contributing to conservation adoption and program participation (Lambert et al. 2006; Lambert et al. 2007; Shaible et al. 2015). Recent meta-analyses of this literature have found few factors that consistently predict conservation behavior across contexts (Baumgart-Getz et al. 2012; Prokopy et al. 2008). While farm- and farmer-level characteristics can significantly predict conservation behavior in some contexts, social-pyschological factors (e.g. attitudes, values, and social networks) are often important as well, and can be difficult to capture (Floress et al. 2018). One important thread in conservation adoption research has focused on the adoption of practices over time, which has been shown to follow a general trajectory of innovation adoption (Rogers 1983), in which conservation practices are initially adopted by a small cohort of early adopters, who tend to be more innovative and willing to undertake the risk of trying new practices (Coughenour 2003; Dunn et al. 2016). Other studies have focused on structural factors, such as national and international markets and policies, that constrain or incentivize certain on-farm behaviors. This literature has tended to identify contradictory incentives farmers face that can disincentivize investments in conservation, as markets and policies prioritize commodity production and other characteristics of food production (i.e. food safety) over sustainable land management (Stuart and Gillon 2013; Weis 2010). In certain commodity markets (e.g. seed corn), farmers are increasingly operating

under contracts with companies that constrain many of their choices, including in fertilizer management (Stuart and Houser 2018). Among the most complex decisions crop producers must make within their operation is nutrient management. Given the complexities of the decisions involved and the significant impact of N on both crop production and environmental quality, this study focuses primarily on N management.

In the context of N management, a number of conservation practices exist that have the potential to minimize loss of N from the cropping system to the environment (Robertson and Vitousek 2009). These practices are primarily focused on improving nutrient use efficiency (the amount of applied nutrients used directly by the crop). This can involve modifying fertilizer formulation, placement, timing, and more carefully assessing true crop need (Millar and Robertson 2015; Vollmer-Sanders et al. 2016). Commonly used practices include soil and plant tissue testing to assess current nutrient levels in soil or crops, use of additives designed to slow microbial degradation processes, applying N fertilizers post crop-emergence (when the crop has the greatest N demand) in a practice commonly known as sidedress application, and use of written nutrient management plans (Osborn et al. 2015; Robertson and Vitousek 2009).

Use of these nutrient management practices by many Midwestern farmers remains low: nearly one third of farmers in the Midwest apply the majority or all of their N fertilizer in the autumn (Ribaudo et al., 2011), creating significant potential for loss to the environment before crop demand peaks in June-July (Millar and Robertson, 2015). Weber and McCann (2015) analyzed USDA data on nutrient management and found that less than one quarter of farmers nationally conducted N soil tests, only 10% use inhibitor additives with N fertilizers, and only 7% use variable rate N application. Christianson et al. (2015) found farmers have positive perceptions of N management practices, including modifications to rates and timing, though these positive perceptions were not necessarily associated with practice adoption.

Rather, these practices were seen as the most compatible with the current farming system compared with more intensive water quality improvements, such as winter cover crop use and restoration of wetlands. Osmond et al. (2015) found that even when farmers do adopt N management practices, including written management plans and soil tests, they do not necessarily follow them. Ulrich-Schad et al. (2018) found high adoption rates of soil testing but low adoption of variable rate application, optimized application timing, and nutrient management plans, with few consistently predictive factors for adoption of these practices, though sources of information appeared to play a role for several of these practices.

Conservation programs can influence farmer behavior in multiple ways. The effectiveness of cost-share driven programs in part depends on their ability to incentivize behaviors that farmers would not otherwise undertake, a concept called *additionality* (Claassen et al., 2013). Conservation programs have varying levels of additionality, depending on the specific practices in question. Federal conservation programs generally appear to have higher levels of additionality for structural practices, which tend to be more expensive (both in direct costs and opportunity costs) and provide less direct on-farm benefits. Management practices, which often confer a financial or on-farm environmental benefit (e.g. conservation tillage provides cost savings in fuel and direct benefits to soil conservation), are less likely to be additionally motivated by payment programs (Claassen et al., 2013; Mezzatest et al., 2013). Low levels of additionality reflect program inefficiency, in the sense that participating farmers likely would have adopted the practice to some extent in the absence of cost-share assistance. In the case of nutrient management, Claassen et al. (2015) find mixed evidence for program effectiveness in terms of additionality. The USDA data these authors rely upon do not include many common management practices, but do find that conservation programs have high additionality for written management plans but little effect on limiting fertilizer applications or increasing the use of sidedress application.

Public policies, in the form of federal and state conservation programs, have the potential to impact farmer N fertilization practices both directly, through cost-share and technical assistance, and indirectly, through promotion and education of efficiency practices. While programs incentivize and promote a wide range of nutrient management practices, it remains unclear what impact these programs are having on farmer adoption of these practices. More in-depth information from crop producers and program participants is needed to better understand the ways in which conservation programs influence farmer nutrient management. To this end, we explored the following overarching research question: how does participation in conservation programs impact farmer N management behaviors, including adoption and continued use of N efficiency practices? Within this broad question, we examined two specific questions: 1) how do conservation programs influence nutrient management, in particular the additionality of program participation; 2) what motivates farmers to pursue nutrient management through conservation programs?

Methods:

As part of a larger study on N management in the U.S. Corn Belt, we collected comprehensive data on nutrient management from corn growers in three states: Indiana, Iowa, and Michigan. Michigan was chosen due to the research team's location in Michigan and increasing water quality concerns within the state. Iowa was selected due to its status as the top corn producing state and Indiana, also a leader in corn production, was selected due to concerns surrounding pollution in the Mississippi Basin and Lake Erie. In addition, these states were selected because they reflect a range of biophysical, agronomic, and social conditions found in the Corn Belt. We focused on three states which allowed for a more in-depth and comprehensive understanding of each state, rather than dispersing our limited resources across the entire Corn Belt region. Because our research questions pertain to *how* and *why* nutrient management

252 decisions are made and the effects of conservation programs, we collected qualitative data to
253 understand the range of influences, motivations, and barriers.
254
255 Multiple researchers conducted 154 semi-structured interviews with corn producers in three U.S.
256 Midwestern states: 53 interviews in Iowa (IA), 51 in Indiana (IN) and 50 in Michigan (MI). Our sample
257 selection criteria were non-organic, commercial corn producers who grew at least 100 acres of corn in
258 2014. Participant recruitment varied by state. In IA, participants were identified through the Iowa State
259 University Extension (23% of the sample), county Soil and Water Conservation District offices (23%),
260 Practical Farmers of Iowa (a farmer-led organization focused on promoting on-farm research and
261 information sharing) (6%) at events, such as field days (4%), and through snowball sampling (45%). In
262 Indiana, Purdue University Extension was the primary source of the contacts (59%), followed by those
263 obtained through snowball sampling (33%) and via other relevant organizations (8%). In Michigan, most
264 of the contacts were made through Michigan State University Extension (64%). We used snowball
265 sampling to identify the majority of the remaining contacts (24%), with some additional contacts made
266 through lists of Michigan Agriculture Environmental Assurance Program (MAEAP, a state-level farm
267 stewardship certification program) participants (12%).
268
269 It should be noted that based on these methods of recruitment participants may be more likely to have
270 been exposed to conservation programs and practices. This sample is ideal to better understand what
271 conservation program factors most encourage or discourage farmers from adopting nutrient
272 management practices. Due to our selection process, our quantitative data regarding the percent of
273 participants enrolled in specific programs is likely higher than a random sample; however, these
274 descriptive statistics are still important to report to understand the extent that this particular interview
275 sample was involved in conservation programs.

It is also important to note that our sample selection process resulted in a sample that is 100% white and male, with ages ranging from approximately 20-70. These demographics are largely representative of the farming population in these states; farm operators in the study states are overwhelmingly white (99% in IA and IN, 97.5% in MI) and male (about 70% in each state) (USDA-NASS 2016). As an exploratory study of Midwest corn growers' nitrogen management practices and perceptions of conservation programs, "farmer" in our study included anyone growing conventional (non-organic), commercial-grade corn who produced at least 100 acres of corn in 2014. Based on our specific research questions, we did not make explicit efforts to broaden participation in our study through specifically targeting non-white and female farmers. Future research could seek to expand definitions of who is a farmer and capture broader perspectives, particularly from demographic groups not traditionally represented in agricultural research.

The majority of the interviews were conducted in-person, with a small number of telephone interviews, between May and December 2014. Interviews were audio recorded with the permission of the participant and transcribed verbatim (two participants were not comfortable with recording so researchers kept extensive notes of these interviews). The interviewers used a semi-structured interview guide, with general questions and prompts for select questions to ensure that topics of interest were covered in the interview. The interview guide included questions on a range of topics related to N management in the farmer's operation, including: operational characteristics (farm size, rotation, etc.), N application practices (formulation, timing, rate, placement); sources of information about nutrient practices; influence of policies, programs, and markets on fertilizer decisions; and perceptions of environmental and climate impacts related to fertilizer management.

Interview data were analyzed using two stages of coding. Data were initially coded into broad categories based on the interview guide structure (*a priori* specific coding). Following this stage, sections of the interviews that were policy-relevant were selected (especially questions pertaining to participation in conservation programs and use of N management practices) and analyzed using a hierarchical axial coding approach. This involved an open coding step, wherein the data were read and broad themes generated from the data, followed by axial coding, where the themes were refined and connections between the themes were established (Corbin and Strauss, 1990). To enhance reliability of the analysis, initial coding was independently conducted by multiple researchers, with subsequent axial coding modified based on discussion (Braun and Clarke, 2006). In the Results section, we present a description of our sample, followed by the major emergent themes from our interviews which highlight the three primary processes through which conservation programs influence N management behaviors. In the Discussion section, we describe how these processes intersect with the existing motivations farmers have for undertaking conservation actions, along with some concluding thoughts about the implications for policy design.

Results:

Sample Description

Most of the farmers we interviewed grew corn in rotation with other crops (especially soybeans, and wheat in Michigan). Fourteen farmers also had livestock operations (3 hog operations, 1 dairy, and 10 with beef cattle). Interviewees ranged in operation size from a few hundred acres of cropland to over 9,000 acres (mean = 1700 acres). The majority of farmers interviewed for this study had participated in a conservation program at some point in their careers. Out of 151 farmers, 74 (49%) of the total sample had participated in or were currently participating in CRP, while 61 (40%) had or were currently participating in EQIP, and 48 (32%) had or were currently participating in CSP. A number of interviewees

participated in multiple programs. Fifteen farmers (10% of our sample) participated in all three major conservation programs, while 40 others (26%) were participating in two programs. Only 33 producers (22%) had never participated in a federal conservation program. We included the responses of non-participants in our analysis, especially to elucidate deterrents to program participation and compare N management behaviors of participants and non-participants.

Table 1. Commonly used practices by sampled farmers participating in CRP, EQIP, and CSP (Note: numbers do not sum to total participants in each program due to multiple practices being covered by the same program)

CRP (N=74)	EQIP (N=61)	CSP (N=48)
Filter strips/field borders (N=42)	Cover crops (N=14)	Nutrient management (stalk nitrate testing, equipment upgrades, inhibitor use, variable rate application) (N=34)
Grassed waterways (N=7)	Terraces/in-field erosion control structures (N=15)	Cover crops (N=8)
Wildlife habitat (N=2)	Nutrient management (written management plans, soil testing, plant/tissue testing, application equipment upgrades) (N=14)	Pest management (N=5)
	Livestock/pasture management (N=12)	
	Manure management (N=6)	

Program participants were engaging in a variety of practices through conservation programs (table 1). Filter strips were overwhelmingly the most common practice adopted by CRP participants, with a few

participants installing in-field structures, such as grassed waterways. A few participants noted that their practices were primarily designed for providing wildlife habitat, including specific plantings in field borders or filter strips designed to promote upland game bird (quail) habitat. The range of practices farmers were adopting through the EQIP and CSP programs was much wider. A number of farmers we interviewed had used EQIP cost-share funds for livestock-related practices, including upgrades to livestock and manure-management facilities, pasture fencing, and rotational grazing. Several farmers had adopted winter cover crops on at least part of their operation with EQIP funds. Others had engaged in nutrient management practices through EQIP, including composing written nutrient management plans, implementation of soil or plant tissue sampling procedures, soil mapping, and upgrades to application equipment (e.g. new sprayer nozzles). The majority of farmers who were participating in CSP were adopting similar nutrient management practices to EQIP participants. In addition to nutrient management, CSP participants were also using winter cover crops and pest management practices, while a few were engaged in livestock management practices.

Operation size did not seem correlated with conservation participation among our sample; non-participants had an average of about 1,500 acres under cultivation, while current and past program participants averaged 1,750 acres. There was significant variation in operation size between the two groups as well, with some non-participants having some of the largest operations in our sample. There was also significant variation in adoption of conservation practices and N management practices between the program participants and non-participants. Some respondents without a history of program participation were no-till farmers and at least two of the 33 non-participants had experimented with cover crops recently, while some active program participants used conventional tillage (e.g. deep disking).

Program impact on nitrogen management

We found that programs had mixed impacts on farmer N management, depending on program goals and structure as well as farmer perspectives. We found that programs shifted farmer N management behavior through three social processes: 1) engaging farmers in the conservation system by introducing them to the state and federal conservation agencies, 2) incentivizing trialing of specific N management practices, and 3) increasing practice adoption through continued program engagement. In the following subsections, we will elaborate upon how these processes function to influence nutrient management and in particular the additionality of these various program approaches (the first research question guiding this analysis).

Farmer Engagement

While many farmers in our sample had participated in at least one conservation program, the level of engagement and practices conducted through these programs varied considerably. Land retirement programs, especially CRP, and state programs with low barriers to participation appear to serve a crucial role in putting farmers in contact with conservation agencies and increasing awareness of other programs. While these programs had limited direct impacts on N management practices, they have indirect impacts on farmer conservation efforts overall. Below we detail the indirect impacts each of these program types have on farmer engagement in conservation programs.

Land retirement programs: More farmers in our sample had participated in the CRP and other land retirement programs than working lands programs. Respondents most commonly used funds to install physical structures, such as field buffers and filter strips along waterways and agricultural ditches. When asked how these practices impacted on-farm N management, nearly all farmers indicated it had no direct impact on how they made N decisions, though a few noted that these practices could keep

nutrients from entering waterways. A Michigan farmer noted: "*I know filter strips, the water structures, the cover crops are all… maintaining my fertilizer here on the farm rather than losing it.*"

Among the farmers we interviewed land retirement programs appeared to have weak indirect impacts, mainly by giving farmers confidence in edge-of-field control of surface loss of nutrients. However, land retirement programs, especially CRP, served as an entry point for some farmers into the conservation program system by putting them in contact with federal and local conservation agencies. A Michigan farmer said: "*They [conservation agencies] constantly keep working with you. They don't badger you but they follow up all the time and make you aware of these practices that you continue or can they help you with any suggestions to improve it.*"

For many program participants, CRP served as a first experience that provided familiarity with conservation agents, program terminology, and exposure to other programs. Over half of EQIP participants (31/61) and CSP participants (25/48) we interviewed had participated in CRP. For CSP participants, EQIP served a similar role, with 20 of the 48 participants having EQIP experience. A few CSP participants specifically mentioned their EQIP experience leading them to CSP. Previous research has shown that awareness of programs among farmers is generally low and the terminology and administrative requirements associated with programs can serve as barriers to participation for many farmers (Reimer and Prokopy 2014). Farmers must become aware of program benefits, learn program requirements and agency jargon, and develop relationships with conservation staff before they will apply for programs. By providing experience with conservation agencies, our interviewees indicate CRP can ease the transition into programs with more complex administrative structures, such as EQIP and CSP.

Previous research has demonstrated the importance of social connections and access to relevant information on practice adoption. Farmers are more likely to adopt practices if they have strong social connections with other adopters and more frequent contacts with conservation agencies (Manson et al. 2016; Ulrich-Schad et al. 2018). In the N management context, the sources from which farmers seek information has been shown to be important for practice adoption, with private sector advisors increasingly playing an active role in N management (Stuart et al. 2018; Ulrich-Schad et al. 2018). Farmer engagement in the governmental conservation system is an important aspect of the portfolio approach to conservation systems, particularly given low levels of information about programs among farmers (Reimer and Prokopy 2014). Land retirement programs, which have limited direct effects on N management practice adoption, still serve a function of promoting farmer engagement.

State programs: While federal conservation programs were the primary focus of our interview questions, state level programs also serve an important role in developing connections between farmers and agencies. State programs often utilize different policy mechanisms than federal programs and offer an informative example of how programs can engage farmers with the conservation policy system. In contrast to the cost-share based federal conservation programs, the Iowa Nutrient Reduction Strategy (NRS) is a state-level effort based on identifying sources and causes of nutrient pollution, providing technical assistance and promotion of conservation practices aimed at reducing this pollution. To encourage voluntary action by farmers and landowners, this program is based on partnerships between state agencies, local conservation districts, universities, producer groups, and community watershed groups (ISUEO 2014). The NRS served as a source of information for several farmers in Iowa about nutrient management practices, as well as opportunities for cost-share through federal and state conservation programs. One Iowa farmer put it this way: "*Its Iowa's nutrient reduction strategy that focuses on educating people in certain watersheds. It sure seems like it. Maybe I'm just imaging that, but*

it sure seems like we've got a lot of information about it." Seven Iowa farmers described the watershed-based approach of the program, where certain high-priority watersheds were identified and targeted for outreach and limited cost-share for practice adoption. While not all farmers fell within these target watersheds, the program in general raised awareness of the focus on nutrient pollution reduction. As one Iowa farmer described it: *"The nutrient reduction strategy that is coming out will make payments to do things, that's tended to more what you haven't done already, so I think you'll see that, it's coming because the voluntary approach to reduce nutrients will be important."*

Seven out of 50 Michigan farmers we interviewed had participated in the Michigan Agriculture Environmental Assurance Program (MAEAP), which sets standards for environmental performance on a wide range of farm operations, including crop production, livestock operations, and farmyards (physical infrastructure). The program offers technical assistance to farmers for implementing a range of best management practices. In addition, the program puts farmers in contact with local, state, and federal conservation agencies, increasing their opportunities to learn about other conservation programs. In exchange for meeting certification requirements, farmers receive signage they can display indicating that they are MAEAP certified (Vollmer-Sanders et al. 2011). Research on farm certification programs, including MAEAP, have demonstrated mixed impact on environmental performance. A review of certification (including ecolabeling) and supply chain programs in a wide range of agricultural contexts found their effects to be limited and often unrealistic (Waldman and Kerr 2014). Some research on MAEAP in particular found some positive environmental impacts among livestock producers who participated in the program (Vollmer-Sanders et al. 2011), while the impact on crop producers' nutrient management efforts in particular was found to be minimal (Stuart et al. 2014b).

Most MAEAP participants we interviewed did not need to significantly change practices to become certified, indicating low additionality of this program, in line with previous research on the program (Stuart et al. 2014b). For example, one respondent shared: "*When I came and signed up for CSP I literally didn't have to do anything; I didn't have to change anything in our operation. We already were doing all the things USDA thinks that they want farmers to do. I mean, it's kind of like when I went for my MAEAP verification, literally the only thing I was lacking was the tube on the mailbox*." Other farmers indicated that the MAEAP was an easy program to participate in, as they did not have to change many practices to participate. One participant indicated that he was already doing certain practices and MAEAP offered a way to "get credit" for these practices: "*I was already [doing] the filter strips . . . so I said well, might as well be certified, and get recognized as the MAEAP program*." MAEAP participants were more likely to reference knowing local conservation staff than non-participants, indicating the potential importance of the program as a mechanism for generating contacts between farmers and agencies. MAEAP certification is a one-time process, so this program likely represents a more shallow level of engagement than a program that takes place over a multi-year contract (i.e. EQIP).

Trialing Nitrogen Management Practices

Working lands programs primarily influenced nutrient management through incentivizing farmer experimentation and trialing of new practices. These programs were seen as a valuable source of cost-share funds that allowed farmers to try practices with some risk protection provided by cost-share. Farmers participating in EQIP and CSP had implemented nutrient management practices with cost-share and technical assistance. Of the 61 farmers with current or past experience in EQIP, 14 had implemented nutrient management practices including written nutrient management plans, soil testing, and upgraded application equipment (e.g. more precise spray nozzles) or facilities (e.g. fertilizer storage). Others had implemented manure management practices through EQIP (6) or cover crops (14).

Among the 48 CSP farmers, 34 had implemented nutrient management practices (two farmers had implemented cover crops in addition), with another six adopting cover crops through the program.

The financial support available through cost-share programs allows farmers the ability to trial practices, an especially important consideration for potentially risky practices. For cost-share programs, NRCS revises cost-share and program payments annually. Within EQIP, these cost-share rates take into account the cost of materials and labor as well as the opportunity costs of practice adoption (i.e. land conversion). These rates differ from state-to-state to account for varying practice costs (Stubbs 2010). Many conservation practices also require financial investments, and technical expertise and knowledge of how to implement the practice within the existing farm management system. Nitrogen management practices in particular often require substantial trialing and experimentation. Farmers indicated that working lands programs provided valuable experience with practices. A Michigan farmer put it this way: "*It kind of helps offset some of the costs of learning those type of things. Well, in some respects if you're making money through the CSP program, well then you can afford to make a mistake or two and you say, well, it's still worthwhile, I'm learning how to do this*." Cover crops, a practice with potential N management impacts through improved soil structure and tightened nutrient cycling, has been noted as a perceived high-risk practice (Arbuckle and Roesch-McNally 2015). Cost-share incentives through conservation programs appear to be particularly important for risky practices, including cover crops. One Indiana farmer described his experience with EQIP and cover crops:

> *"EQIP, they're kind of promoting some funds for cover crops stuff. That takes a lot of risk, the sting, out of it. This year we had a really hard winter, and it hurt the cover crops some. They didn't do quite as well. But we had a little bit of cost sharing going. My cost was a little lower than normal, which took some of the sting out of it. I think they did a nice job with some of these*

new concepts to try to get people to participate. . . . They're helping you try them . . . you can try stuff and learn about stuff. I like that. It's a good thing. That's what the government is for."

As described above, conservation cost-share programs offered an opportunity for farmers to try practices they were curious about or may otherwise have trialed on their farms. A Michigan farmer said this about his experience with CSP: "*It does make me change a few things that I was doing, or at least make me consider and try a different way that I wouldn't maybe normally… You know, I wouldn't even consider it. It wouldn't even be brought to my attention, but through the CSP programs it's like 'yeah, all right, oh, all right I'll try it.*'" For other farmers, working lands programs were an opportunity to receive cost-share on practices they were already using. For example, one Michigan farmer said: "*We've always had CSP . . . I can't remember what all things we were signed up for, but it seemed like all the split applications of nitrogen and the soil sampling and those sorts of things, but most of the time those were things that we were doing anyway, and we just kind of added them to our program, but it didn't help… I mean, it kind of just reinforced what we were already doing*." For farmers with this perspective, the program does not provide substantial additionality, instead simply promoting practice adoption among those farmers who had already adopted practices, or were already likely to do so without program support.

In contrast to land retirement and most state-level programs, EQIP and CSP target specific ongoing agricultural management through practice cost-share and technical assistance. Despite their designed potential to influence nutrient management, their impact on the farmers we interviewed was limited by lack of participation. Among our interview participants, fewer than half had participated in a working lands program, and some participants had practices that do not directly affect nutrient management (e.g. farmstead or livestock facilities practices outside of manure management). The farmers who had

526 participated in EQIP or CSP to implement nutrient management practices used the two programs in
527 different ways, reflecting the divergent design and purpose of those programs. EQIP provides cost-share
528 and technical assistance to farmers for individual practices for a relatively short time period. Many of
529 the EQIP participating farmers we interviewed reflected that the program cost-share payments allowed
530 them to trial practices and develop valuable knowledge and skills with reduced personal risk. Trialing
531 with cost support (and technical assistance) from conservation agencies allows a farmer to develop
532 critical knowledge and skills as it pertains to the practice, or as one farmer put it: "*you can afford to*
533 *make a mistake or two*." For some farmers, the availability of EQIP funds was an important motive in
534 adoption, while others indicated that they likely would have adopted the practice anyway (though the
535 financial support was appreciated). Six farmers indicated that EQIP funds were critical factor in getting
536 farmers to try cover crops, a practice with significant cost and perceived risk (Reimer et al. 2012;
537 Arbuckle and Roesch-McNally 2015). EQIP may have higher additionality for practices with significant
538 perceived risks but lower additionality for practices with high apparent on-farm benefits (such as
539 farmstead improvements or soil testing).
540
541 *Increasing Conservation Efforts through the Conservation Stewardship Program*
542 While programs, especially working lands programs, promote changes in individual practice, the
543 portfolio approach to programs serves an important role in ratcheting up farmer conservation efforts
544 over time. Participants saw CSP in particular as an important program for enhancing current practices,
545 including changing multiple aspects of nutrient management. Whereas EQIP participants were generally
546 using a small number of practices, and adopting them one or two at a time, CSP participants were
547 making more substantial changes; 34 of 48 farmers in CSP were directly engaged in nutrient
548 management enhancements and nearly all of these farmers were implementing multiple practices
549 under this enhancement (especially soil and plant tissue testing, written management plans, and rate

limitations). CSP participants were generally very positive about the program, and many were on a second or third contract cycle. These farmers were continuing to add new practices with each new contract, as well as maintaining the practices they had previously adopted. As one Michigan farmer put it: "*It's kind of like when I came in for my renewal on my CSP, what thing I'm going to add and it's kind of like well, I've already got everything on your list when we started out; we're doing the cover crops, we're doing the no-till, we're doing the conservation, we're doing the filter strips*."

In addition to providing cost-share for various practices, CSP also sets nutrient management standards for farmers to adhere to while under contract for nutrient management enhancements. These standards constrained farmer behaviors, including setting limits on N application rates or prohibiting fall application of N. When asked if anything constrained his N management, one Iowa farmer who was currently enrolled in the CSP said: "*My nutrient management plan, I was assisted in that by the soybean association here in Iowa. Taking into consideration what our plan is and what our limits are, because there are upper limits, we cannot go above so many units of N, P and K to stay within our management plan*." While these were limits imposed by programs, the farmer chose which practices and enhancements to pursue, making them voluntary for the set length of the contract.

For some farmers, their experiences with nutrient management practices through programs changed their long-term management. One Michigan farmer described how CSP promoted his use of stalk nitrate testing.

> *"One of the questions they [NRCS] asked 'would you continue to do this [stalk nitrate testing] as a practice?' And I said I'm fairly confident where we are at this point in time, but I wouldn't hesitate to use it again if something changed; if a new variety of corn came out that was somehow different, that we had to feed it differently, well that would be one of the resources I'd*

go to and say okay, let's start doing some stalk nitrate testing and see what we've got out there."

For this farmer, his experience with the practice adopted through CSP left a positive attitude toward the practice and confidence in his ability to use it in the future. Another Iowa farmer expressed a similar sentiment, explicitly saying he would continue to use practices despite lack of program funds: "*I think there probably won't be any payments from the USDA for them. But we'll keep doing what we're doing, because we're incorporating that into our operation anyway. What we're doing is taking the fall stalk nitrate tests and using that to make recommendations, for our decisions on nitrogen.*" For many working lands program participants, the program technical assistance was just as important as the cost-share assistance, as it allowed farmers to generate critical skills and experience to incorporate new practices into their operation, not just through the covered practice but through related aspects of management.

Cost-share programs sometimes incentivize farmers to either continue practices they had already tried or would have tried on their own, limiting their additionality. While many participants were already engaged in conservation practices on their farm, CSP appeared to have higher levels of additionality than EQIP, with most participants indicating that the program had had a substantial influence on their long-term nutrient management strategy. An Iowa farmer indicated that CSP was different from other programs in this respect: "*So it's kinda an interesting program [CSP], they try to get you to do more than what you've done instead of paying you for what you're already doing. Because in the past, that's the way most government programs are, they pay you for doing something if you haven't done already, so they reward the people who have done the worst job in the past, so the guy who has already put up terraces and no till and all that, then we don't get any*." CSP encourages participation among those farmers who were already implementing some conservation practices, while also pushing them to go further. While additionality is considered a measure of program effectiveness, a program that awards

598 farmers already using conservation practices can also encourage them to adopt additional conservation
599 practices in the future. Additionality is an important factor to consider in program design, but also
600 remains difficult to assess and understand in the long-term (Claassen et al. 2013).
601
602 ***Discussion and Conclusions***
603 We approached this analysis with two specific questions: 1) how do federal and state conservation
604 programs influence farmer N management; and 2) what motivates farmers to pursue nutrient
605 management practices through conservation programs? Based on our interviews with Midwestern corn
606 growers, working land programs have more direct impacts on N management practice adoption than
607 land retirement, certification, or outreach-based programs. While land retirement and outreach
608 programs have small indirect benefits associated with building farmer familiarity with conservation
609 agencies and programs, working lands programs are more effective at incentivizing practice change over
610 time. Working lands programs, particularly the CSP, encourage farmers to adopt nutrient management
611 practices through financially supporting farmers to trial practices and make mistakes as they learn how
612 to use them successfully. While the additionality of these programs appears to be low for some N
613 management practices, as a set of policies, these programs serve as an important motivator to
614 experiment with practices and engage in more holistic conservation, including nutrient management.
615 While program structure and approach are important factors influencing participation decisions, farmers
616 have other motives that may influence their decisions as well. In our interviews, program participants
617 and non-participants spoke to two key motives: stewardship attitudes and avoidance of regulation.
618
619 *Stewardship attitudes:* Conservation programs often tap into existing stewardship attitudes held by a
620 subset of producers. Strong stewardship attitudes were an important motivator among program
621 participants and programs appeared to activate these stewardship attitudes. These stewardship

attitudes were often complex and mixed with other motives for participation. One farmer in Michigan expressed both stewardship and self-interest motivations: "*I'm a conservationist, and I want to do as much as I can to do things correctly, and I don't like to be the one that puts nitrates or phosphates into the river and goes to Lake Erie. So it's just… No, I want to keep all my stuff. If I pay for it I want it; I don't want to lose it.*" This attitude reflects the dual nature of conservation activities, which are especially evident with nutrient management practices. Efficient management of nutrients can generate both on-farm benefits through input cost savings and off-farm benefits through environmental protection. These dual motivations have been demonstrated in other agricultural contexts, with farmers often engaging in practices to achieve multiple goals simultaneously, including on-farm soil conservation, agronomic benefits, and natural resource protection (Sheeder and Lynne 2011; Reimer et al 2012).

Previous research on farmer conservation behavior has highlighted the wide diversity in farmer values and attitudes towards stewardship (Maybery et al. 2005; Greiner and Gregg 2011; Reimer et al. 2012). Strong stewardship attitudes do appear to play a role in farmer decisions to participate in programs (Reimer and Prokopy 2014b; Thompson et al. 2015), though these are not the only motivations at play. Farmers' attitudes toward conservation programs are complex and can be viewed as a complex assemblage comprised of interacting social, environmental, political and temporal systems (O'Connell and Osmond 2018). Our findings indicate that decisions to participate in conservation programs are highly individualistic and depend on context. Some producers seemed highly motivated to participate based on their stewardship attitudes, while others emphasized more direct or tangible benefits to their operation. Some program non-participants were engaged in highly sophisticated and intensive N management and expressed strong stewardship motivations for their adoption of practices. For programs such as CSP, which has been a smaller and more targeted program, participants seem more

likely to be motivated by underlying stewardship interests, as well as being more oriented toward experimenting with new practices and approaches.

Avoiding regulations: More than a quarter of the farmers we interviewed, spread across our study states, discussed the possibility of future regulation of farm activities generally or related to nutrient management specifically to protect environmental quality. These producers saw voluntary actions to reduce the environmental impacts of agriculture as the best way to avoid government regulation, which they generally regarded as harmful or burdensome. One Michigan farmer expressed this sentiment by saying: "*And that's why it's important [conservation practices], because we can do it voluntarily our way, or we cannot do anything and wait for the government to tell us how to do it, and we're not going to like how the government tells us to do it, because the government doesn't know what they're doing.*"

A few farmers (less than 10% of those interviewed) discussed direct forms of regulation and government action already impacting their decision making, including taxes on fertilizers and limits on nutrient application near urban areas or wellhead areas. Most farmers however did not perceive of any direct government regulations or programs limiting their current application behaviors. Rather, it was the avoidance of unspecified future regulation that motivated many farmers to adopt conservation practices in general and to participate in conservation programs specifically. This was especially true of many state conservation programs. Several farmers in Iowa discussed their state's NRS as a voluntary approach specifically designed to avoid direct regulation. An Iowa farmer put it this way: *"I think that's a very important approach this reduction strategy to try and be proactive for growers, because otherwise they're gonna get regulated."* Many farmers who participated in these programs acknowledged the larger role conservation programs, and their own actions by adopting practices through these programs, played in improving the environmental performance of cropping systems in the Midwest. The MAEAP

669 program in Michigan, with the emphasis on public promotion of environmental certification, was also
670 seen as a voluntary hedge against potential regulation. Previous research on MAEAP found that
671 avoidance of regulation was a strong motivation for livestock producers to participate in the program
672 (Chantorn 2013; Vollmer-Sanders et al. 2011). These programs then serve a larger role in signaling
673 stewardship and responsibility to society in general. While not the primary motive for most farmers, this
674 industry-level benefit served an important role for some participants.
675
676 *Conservation program design:* Conservation programs are structured to meet a wide range of
677 environmental goals and appeal to farmers for different reasons, including the opportunity to trial
678 practices and pursue stewardship goals within their operations. Yet farmers, both program participants
679 and non-participants, also perceive conservation programs to be an important mechanism for
680 promoting voluntary action and avoiding more onerous government regulation. While not all farmers
681 were positive about government programs (dislike or distrust of government was a critical barrier for
682 some farmers), the majority of those we interviewed were generally positive about the goals of
683 conservation programs. Throughout the interviews, most producers spoke about the complexity and
684 importance of managing nutrients appropriately and viewed nutrient stewardship as an important part
685 of farming. Working lands programs in particular were viewed as an important policy through which
686 government can support farmers in their nutrient stewardship, both directly through financial and
687 technical support and indirectly through promoting whole-farm conservation planning and social
688 support for voluntary stewardship. Conservation programs also serve an important role in signaling
689 responsible stewardship for the agricultural industry as a whole, helping farmers to avoid potential
690 direct regulation in the future.
691

692 Farmer motivations intersect with program design by allowing different types of farmers to pursue their
693 goals through multiple avenues. For example, the CSP appeared to target a different type of farmer than
694 EQIP: the early adopter or conservation-oriented farmer. A majority of the CSP participating farmers we
695 interviewed across our study states said the program was valuable primarily in that it provided a source
696 of program payments to reward conservation-oriented farmers. Participant self-selection moderates the
697 additionality of the program to some extent by primarily drawing on farmers actively engaged in
698 conservation in their operations, though many participating farmers also indicated that the participation
699 in the program had also spurred them to make additional changes to their operations. Unlike EQIP,
700 which funds a wide range of practices (including many with little direct impact on nutrient
701 management), many farmers participating in CSP were focused primarily on improving their N practices.
702 In addition, CSP emphasizes whole farm resource planning and management; many CSP participants we
703 interviewed reflected that they were taking a systems approach to their N management, rather than
704 focusing on individual practices. The holistic planning structure of CSP may lead to more efficient use of
705 nutrients overall (as opposed to individual practices), as nutrient management is complex and use
706 efficiency affected by multiple factors interacting together (Johnston and Bruulsema 2014). CSP is the
707 only current program that incentivizes the most conservation-oriented farmers to go further in their
708 conservation.
709
710 The ultimate outcomes of federal and state conservation programs on N management are complex;
711 while programs do appear to have some tangible impact on the adoption of nutrient best management
712 practices, for some farmers these programs do not appear to significantly shift overall management
713 toward more sustainable practice. Other farmers have not chosen to participate in programs but have
714 adopted nutrient management practices, including variable rate application and grid sampling, on their
715 own. The complexities of conservation decisions make evaluating the additionality of individual

programs and the conservation system as a whole difficult. While our research focused on N management, this aspect of farm management is particularly difficult to track and assess. On-farm N management is dynamic and highly variable, both temporally and spatially. There is a need for greater monitoring and assessment of N management, both through conservation programs and at the cropping system level. The findings presented here add to this complex picture by identifying specific mechanisms through which programs influence ongoing management with potentially significant environmental impacts. Further research is needed to more broadly quantify the impacts of these programs on the efficiency of N management over time. In addition, future research is needed to evaluate the indirect impacts of programs, including the social influence of various program approaches on community norms and attitudes, a theme that farmers addressed in our interviews.

Our findings emphasize the need for a diverse range of approaches to conservation. Programs have different goals and use different incentives to achieve those goals. Due to the diversity in stewardship attitudes, views of government, and capacities among farmers, a portfolio approach to conservation is best suited to achieving the overall aim of improving the environmental performance of agriculture. Conservation programming should also emphasize the social benefits of stewardship for agriculture as an industry to promote programs among producers with lower internal motivation to engage in stewardship practices.

The largest current limitation to farmer conservation through government programs appears to be the low levels of awareness of programs and the agencies that administer them. Federal conservation policy should use a robust portfolio approach to appeal to the diversity of farmer motives and account for the social learning necessary to engage farmers in continued improvement through different programs. This portfolio would include programs with low barriers to entry, such as basic environmental performance

certification and targeted small-scale land retirement (e.g. field buffer programs). These programs would serve a conservation purpose but would also build awareness of the conservation system and develop farmer familiarity with conservation agencies. As our findings demonstrate, these types of programs are important in building relationships between farmers and agencies and play a role in encouraging future program participation. Practice-focused cost share programs such as EQIP serve an important function in encouraging practice trialing and experimentation. At the top is the CSP program, which focuses on whole-farm natural resources planning and sustained improvement over time. More emphasis should be put on trying to move farmers up the "ladder" of programs by building farmer familiarity with conservation agencies and programs, and particularly with the CSP program.

Modern agricultural systems face many challenges to not only environmental sustainability, but also social and economic sustainability (Swinton et al. 2007). Addressing these challenges will require substantial changes to crop and livestock production systems. Nutrient management provides a key example of the complexities associated with on-farm decisions and their impact on production and environmental outcomes. Cost share programs are an important mechanism by which society shares in the risks associated with changing agricultural practices. As our research findings demonstrate, these programs also serve an important role in building farmer technical knowledge and experience, as well as confidence in being able to incorporate changes to their production systems. Conservation policy should continue to not only provide financial support to defray some of the risks to individual farmers, but also provide a robust system of technical and social support that encourages improvements in farm sustainability.

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