FARMER RESPONSES TO A CLIMATE CHANGE-DRIVEN FERTILIZER OFFSETS PROGRAM: ECONOMIC INCENTIVES, WORLDVIEWS AND OPERATIONAL CONSTRAINTS

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ABSTRACT

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Greenhouse gas (GHG) reductions are an increasingly important point of emphasis in intensive agricultural systems. Nitrogen (N) fertilizer application reductions can play a key role in the mitigation of agriculture-related GHG emissions by reducing nitrous oxide (N_2O) emissions. However, implementing new strategies for these reductions often presents challenges to farmers whose N fertilizer management decisions are influenced by conflicting factors. Understanding the socio-economic influences of farmer decision-making regarding N fertilizer application is an important component in the effort to mitigate environmental impacts of intensive agriculture. This qualitative study explores the perceptions of 40 farmers and 6 agriculture company representatives in southwest Michigan regarding the associations of N fertilizer with environmental quality and the ability to reduce N application. The findings highlight a limited understanding of the associations between N fertilizer application and N_2O emissions. Farmers perceived their ability to reduce N fertilizer as limited but some respondents noted that economic incentives could be an effective mechanism to encourage practice changes. Worldviews, perceived risks, and structural influences were identified as barriers to participation in N fertilizer reduction programs. These findings provide insight for the continued efforts to balance agricultural production with environmental integrity.

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INTRODUCTION

Intensive agriculture systems are responsible for a variety of environmental impacts. While modern agriculture is credited for producing quantities of food, fiber, and fuel to support a growing population, this bounty comes at a cost. Water, soil, and biodiversity related problems due to modern intensive agricultural practices have been identified through water quality deterioration (e.g. Hansen et al., 2000; Bohlke, 2002), loss of soil productivity (e.g. Evans, 2005), and destruction of natural habitats (e.g. Buchs et al., 2003). In addition to these well-known environmental problems, it is now understood that intensive agriculture is an important contributor to greenhouse gas (GHG) emissions (IPCC 2001; Prinn, 2004; Robertson and Vitousek, 2009).

Fertilizer inputs are an integral part of intensive agriculture cropping systems. While synthetic fertilizers have greatly contributed to increased yields, their usage and corresponding byproducts are directly associated with environmental problems. Nitrogen (N) fertilizer has been found to contribute to nitrous oxide (N_2O) emissions (Snyder et al., 2009), with agriculture contributing almost 70% of N_2O emissions in the United States (USEPA, 2009). N_2O is approximately 300 times more effective at trapping heat than carbon dioxide (USEPA, 2010). In addition to harmful emissions, N fertilizer contributes to the impairment of water resources (Burow et al., 2010; Nolan et al., 1997; Rabalais, et al., 2007). Despite these associations, intensive agriculture continues to use large quantities of synthetic N fertilizer inputs.

Dating back to the 1970s, the majority of N fertilizer application recommendations in the U.S. have been based on yield goals (Stanford, 1973). Recent studies have found that N fertilizer application rates are often overestimated compared with plant uptake capabilities (Ju et al., 2009; Yadav et al., 1997). As N fertilizer application increases beyond crop uptake, N_2O emissions increase exponentially (McSwiney and Robertson, 2005). Alterations to previous yield goal formulas and advances in application technology have offered new tools for farmers to better manage N fertilizer inputs (Cherry et al., 2008). In addition, market mechanisms, similar to previous carbon trading efforts at the Chicago Climate Exchange, have been proposed as an additional mechanism to reduce excess N fertilizer application (Millar et al., 2010).

Farmers may face many challenges, however, that inhibit their ability to reflexively act in response to environmental concerns. It has been suggested that farmer adoption of conservation practices is related to awareness of, and attitude about, the environmental issue (Gould et al., 1989; Napier and Camboni, 1993; Warriner and Moul, 1992), the economic incentives for adoption of conservation practices (Saltiel et al., 1994; Somda et al., 2002), and structural constraints that limit adoption (Hendrickson and James, 2005; Stuart, 2009). Perceptions of the contemporary associations of N fertilizer and GHG emissions need further exploration. Understanding the farm-level decision process regarding N fertilizer application and the perceptions about corresponding environmental impacts are an essential component to support efforts to mitigate the adverse environmental consequences of intensive agriculture systems.

Statement of Problem

Human behavior has dramatically increased levels of biologically available and reactive N (Galloway et al., 2003). As global population increases so do the demands of our N-reliant food supplies, resulting in increased N_2O emissions. N_2O emissions due to human influences are increasing by 150 million metric tons of N each year (Mosier, 2002). The bulk of N_2O emissions from agriculture systems in the U.S. are related to intensive field cropping practices (CAST, 2004; USEPA 2008). Synthetic N fertilizers are a primary source of this increase with global consumption rising from 10 million metric tons in the 1950s to approximately 100 million metric tons of N in 2008 (Robertson and Vitousek, 2009). Currently, the U.S. is the third largest producer and consumer of N fertilizer (FAO, 2009). GHG emissions from increasing N fertilizer usage will have future climate change implications (IPCC, 2007).

A new approach for estimating N fertilizer rates, the Maximum Return to Nitrogen (MRTN) model (Iowa State University Agronomy Extension, 2004), is beginning to gain support in some regions of the country. This new estimating tool shows promise for reducing N fertilizer application rates without negatively impacting farm profit. The method uses regional N-rate recommendations based on multi-year and multi-location N-rate field trials specific to the state where the farm is located, and incorporates current corn and N fertilizer prices. In addition to this new method, timing, irrigation, crop selection, and tillage practices are responsible for altering emission levels (Parkin and Kaspar, 2006).

Although new nutrient management tools offer hope for increased efficiency, farmer decision-making about the adoption of these practices is highly individualized and variable. Limited information sources can inhibit awareness and/or attitudes about environmental risks (Camboni and Napier, 1993; Napier and Bridges, 2002), and mass media exposure can shape farmers' perceptions of problems (Jensen and Blok, 2008). In addition, farmers may overestimate their "stewardship" actions compared to assessments by other conservationists (Carr and Tait, 1991). Increased awareness and changing attitudes with respect to N fertilizer issues could be influential in increasing the effectiveness of mitigation strategies.

Similar to any other individual or business decision, economics plays an important role in shaping farming decisions. Farmers must make decisions amidst external pressures from markets, laws and regulations, and subsidy programs. Faced with these pressures, conservation practices can be sacrificed based on economic priorities (Cary, 1993). In addition, N fertilizer application reduction is often viewed as a high-risk behavior (Napier and Tucker, 2001), leaving farmers less likely to adopt such practices. Furthermore, economic analysis at the farm level is highly variable depending on individual characteristics (Osmond and Wossink, 2002), which offers additional challenges when developing standardized incentive programs. Despite these hurdles, financial mechanisms are crucial to help overcome perceived risks and increase adoption of conservation practices (Schneider and McCarl, 2006).

In addition to economic considerations, structural forces within the industry can influence management decisions. Market structures, production policies, and the influence of large agribusiness companies can limit the ability of farmers to explore alternatives (Hendrickson and James, 2005; Stuart, 2009). For example, competitive contracts in the seed sector offer financial incentives that often encourage excess N fertilizer application (Preckel, 2000). Furthermore, seed industry consolidation (Howard, 2009) limits the choices farmers have for crop production contracts. These structural barriers can reduce farmer efforts to address environmental impacts.

Background and Need

N fertilizer reduction represents one of the most effective strategies for climate change mitigation that farmers can adopt (Snyder et al, 2009). Reducing N_2O emissions can contribute to important climate changing benefits not realized by other practices such as afforestation or no-till management (Robertson, 2004). Unlike soil carbon sequestration, N_2O reductions are permanent and can be implemented across a great range of croplands at potentially low costs (ibid). In addition, N reduction offers a co-benefit of improved water quality: fertilizer management changes to reduce N_2O will also reduce water pollution related to N fertilizer application.

Current N_2O offsets program efforts are focusing on market-based mechanisms to attract farmers. As part of California's Global Warming Solutions Act (AB-32), regulations for enforceable caps of GHG emissions will begin in 2013 (CEPA, 2012). N_2O will be included as one of the capped emissions and it has been proposed that the accounting mechanism be based on MRTN approaches. This N fertilizer application estimator has been recommended for other regions of the U.S., including the Great Lakes region (Millar et al., 2010), and could spread to other areas of the country or world.

Large corporations have expressed interest in participating in the promotion of N fertilizer reduction practices. Walmart, Coca-Cola, Murphy-Brown, and Brown-Forman have begun discussing how their involvement can contribute to these efforts (personal communication, January 2012). Many of these companies have set aggressive goals for GHG emission reductions as part of their business objectives and are hoping to capitalize on agricultural N_2O emissions reductions through supply chain influence. The leverage of large retailers across the supply chain could be very influential in promoting farm-level conservation practices.

Despite growing interest and program development related to climate change mitigation through N fertilizer reduction, impacts depend on farm-level decision-making. Previous studies have examined farmer awareness of environmental issues and the corresponding response to conservation practice adoptions (Napier and Camboni, 1993; Saltiel et al., 1994; Soul, 2001). This study aims to gauge the awareness and attitudes of corn farmers regarding the use of N fertilizer, willingness to reduce application rates, and interest in participation in a market-based offsets program. An assessment of current farmer perceptions of N fertilizer application and corresponding environmental impacts may offer insight for effectively engaging farmers in the adoption of conservation practices and mitigation measures.

Purpose of Study

The purpose of this study was to explore farmers' perceptions about N fertilizer application and impacts to the environment, and to gauge the interest in, and challenges to participation in a N_2O offsets program. Focusing on corn farmers in southwest

Michigan, I conducted 40 farmer interviews between January 2011 and May 2011. Farmers were asked about their information sources regarding N fertilizer application, their understanding of the associations with N_2O and global warming, and their overall interest in a N_2O emission offsets program. Six key informants, representing seed companies and contractors, were also interviewed as part of this study. These interviews provide a context for understanding how the corn farmer community might receive an N fertilizer reduction program.

Research Questions

This case study began with a set of research questions that explored the associations between N fertilizer application and environmental quality. There was a particular emphasis on awareness and attitudes of farmers regarding these associations. In addition, this study sought to gauge farmer interest in participation in a proposed N_2O emissions offsets program. The following questions provided the basis for the study:

1. Do farmers associate nitrogen fertilizer with nitrous oxide emissions and/or global warming?
2. How do farmers perceive nitrogen fertilizer to impact water quality?
3. Are farmers willing to reduce nitrogen fertilizer in their operation?
4. What are the challenges/barriers to reducing nitrogen fertilizer application through an N_20 offsets program?

Limitations

As with any research, inherent limitations are present within this study. Personal interviews were the primary means of data collection. The resulting narratives provide detailed characteristics of individual perceptions, but are not easily replicable. Although steps were taken to eliminate potential researcher bias, the interpretation of the narratives is necessarily subjective, and could be viewed differently by others. It should also be noted that the results are particular to the sample and cannot necessarily be extended with certainty to the broader community. As the study progressed it is possible that previous respondents, or additional study efforts that were occurring parallel to the interviews, may have influenced respondents. In addition, responses from farmers who grew both seed and commercial corns may be difficult to separate. However, results were reported in an effort to most closely represent the views of the respondents.

CHAPTER 2: LITERATURE REVIEW

The environmental impacts related to intensive agricultural practices are widespread. Excessive nitrogen (N) fertilizer application significantly contributes to water quality degradation, as well as greenhouse gas (GHG) emissions that affect global climate change (Robertson and Vitousek, 2009). Conventional corn production systems are particularly characteristic of high N fertilizer application rates (Halvorson and Reule, 1994), resulting in increased N loss vulnerability (Hilton et al., 1994). When farmers make fertilizer input decisions, they take a variety of factors into account. Understanding the socio-economic influences of farmer decision-making is a crucial component of efforts that aim to mitigate the environmental impacts of intensive agriculture production.

Based on in-depth interviews of 40 corn farmers and 6 agricultural industry representatives in southwest Michigan, this study sought to understand the socio-economic aspects of fertilizer decision-making, and how reduction efforts might best be directed. The interviews explored how farmers associate nitrogen fertilizer with environmental impacts, how farmers perceive their ability to reduce nitrogen fertilizer, and what challenges or barriers may inhibit participation in a nitrous oxide (N_2O) offsets program.

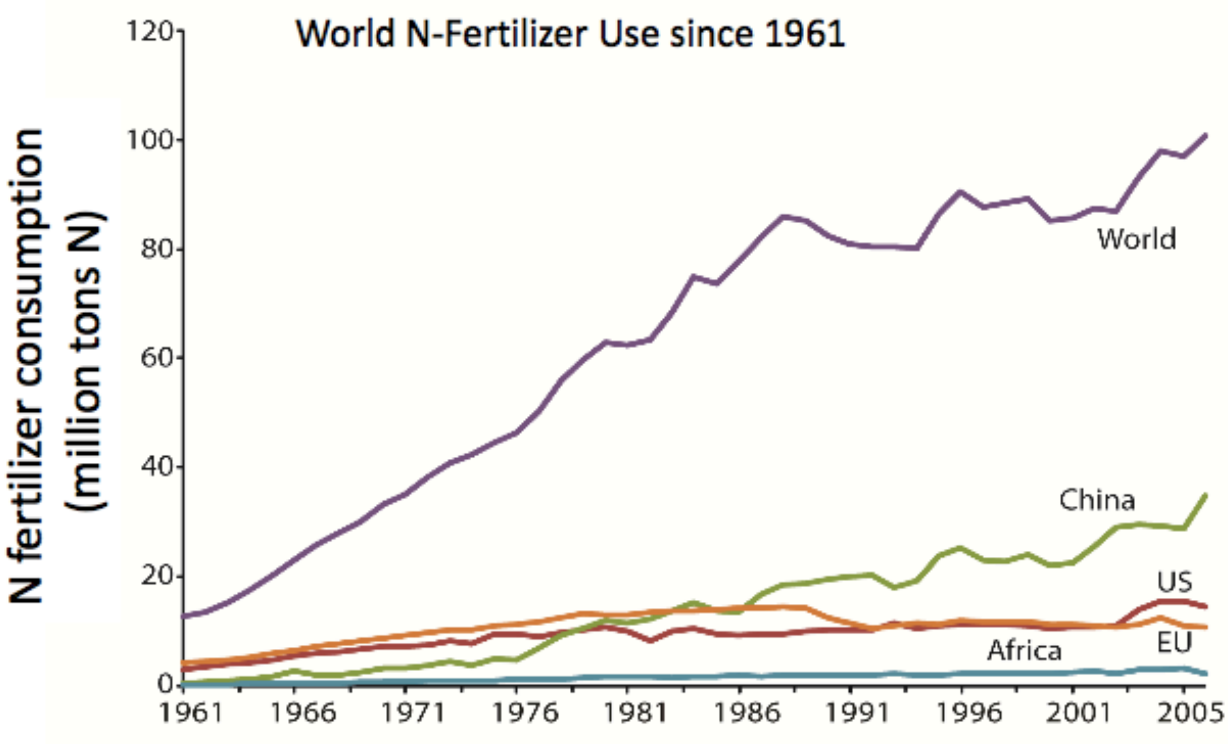
The historical issues of water quality and soil degradation have received considerable research attention (e.g. Nowak, 1987; Napier and Camboni, 1993). The current conservation efforts in agriculture to reduce N fertilizer application rates and correlating N_2O offsets are well situated within previous soil and water conservation research. This literature review addresses three areas of research related to anthropogenic impacts on the nitrogen cycle and farmer decision-making regarding fertilizer inputs. The first section of this review looks specifically at research on the anthropogenic influences of the nitrogen cycle and corresponding environmental implications. The second section addresses studies focused on the association between awareness and conservation adoption, and the third section explores economic and structural factors that influence farmer adoption of agri-ecological practices.

Anthropogenic impacts on the nitrogen cycle

Synthetic nitrogen fertilizers have been instrumental in producing high-yield crops that are characteristic of modern, industrial agriculture. The introduction of synthetic fertilizers in the 19^{th} century, and widespread use during the post-WWII era (Russel and Williams, 1976), have largely transformed agriculture and now contribute 30-50% of grain crop yield (Stewart et al., 2004). This is a significant factor considering that corn yields have increased from an average of 40 bushels/acre in 1940 to 137 bushels per acre in 2000 (Runge, 2002). It is widely argued that synthetic N fertilizers provide a more efficient, and therefore more productive, means of producing food per unit area than biological nitrogen fixers, e.g. legumes, to provide essential nutrients (Vitousek, 1994; Smil, 2001). However, the benefits of agriculture production from nitrogen fertilizer come with significant costs. Increased levels of N_2O in the atmosphere, coastal hypoxia, N deposition onto forests, and reactive N gases in the stratosphere are well-documented side effects of increased nitrogen fertilizer dependence (Robertson and Vitousek, 2009). Overapplication of nitrogen fertilizer compared with plant uptake capabilities is accountable for substantial nitrogen byproduct impacts. N balance research from the 1930s revealed less than 50% of applied N is effectively utilized by corn plants (Allison, 1955), and this fraction has not improved significantly since (Cassman et al., 2002).

Synthetic fertilizers are a dominant component of industrial agriculture, with current estimated global consumption levels of 175 million tons per year (IFA, 2011), of which N fertilizer accounts for 100 million tons (Robertson and Vitousek, 2009; see Figure 2-1). The United States is one of the largest producers and exporters of synthetic fertilizers and consumes an estimated 12 million tons per year (FAO, 2008). Fertilizer inputs are expected to continue increasing with the ever-growing global population and corresponding food needs (ibid). As both population and per capita food consumption rates continue to grow the FAO projects that food production will need to double by 2050 (FAO, 2009).

Figure 2-1: World N-Fertilizer Use since 1961



Robertson and Vitousek, 2009

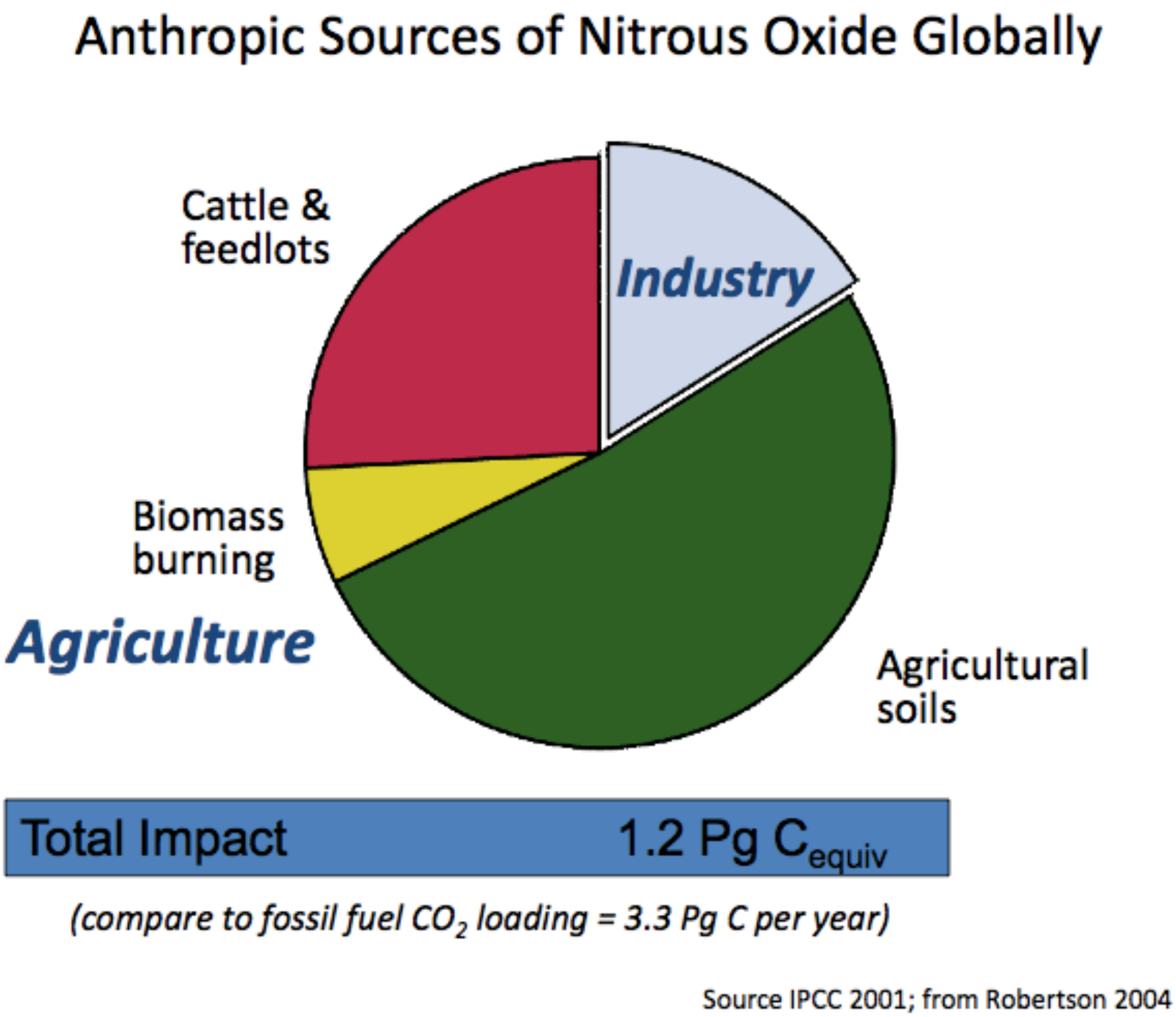
For interpretation of the references to color in this and all other figures, the reader is referred to the electronic version of this thesis.

N_2O emissions

Although they have greatly contributed to increasing crop productivity, synthetic fertilizers have also been identified as contributing to environmental degradation. N_2O has been pinpointed as a harmful byproduct of fertilizer application in agricultural systems, and significantly contributes to the overall emissions produced from soil management practices (USEPA, 2008; IPCC, 2001; Robertson et al., 2000). N_2O is 300 times more effective at trapping atmospheric heat than CO_2 (USEPA, 2010). Additionally, N_2O has been found to effectively deteriorate the UV-blocking layer of atmosphere, the stratosphere (IPCC, 2007). In total, nitrogen fertilizer has been estimated to account for one-third of the greenhouse gas (GHG) emissions produced by agriculture (Stern, 2006). Of the total 1.2 Pg C_{equiv}[1] per year, agriculture is responsible for approximately 60% of nitrous oxide contributions (IPCC, 2001; Prinn, 2004; Robertson, 2004) (See Figure 2-2). N_2O production is the largest source of global warming potential (GWP) in annual, intensive cropping systems, e.g. corn, soy, wheat (Robertson et al., 2000).

[1] 1 Pg (petragram) = 1 billion metric tons; C_{equiv} = is the quantity of CO_2 that would have the same GWP when measured over a specified time.

Figure 2-2: Agriculture Contributions of N_2O Emissions



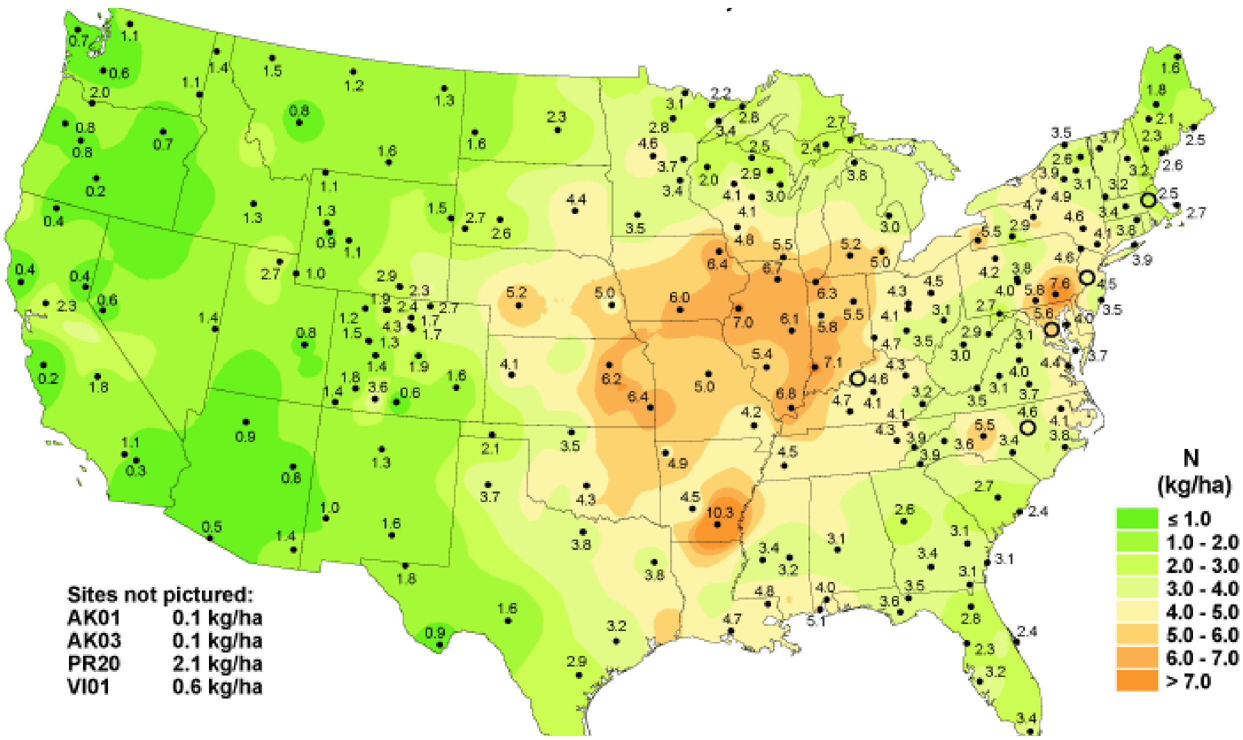
Nitrogen in the hydrologic cycle

Nitrate leaching into groundwater represents an additional sink of excess fertilizer, which can impair drinking water and large watersheds. The most highlighted of these cases is the Gulf of Mexico "dead zone" (Robertson and Vitousek, 2009). Because nitrogen is the limiting nutrient in brackish ecosystems, elevated nitrate levels allow for increased algal growth that results in decreases in dissolved oxygen levels when the algal growth later decays. The diminished oxygen environment, referred to as hypoxic, is insufficient to sustain most marine animal life and, in turn, greatly affects the marine trophic interactions (Rabalais et al., 2002).

The relationship between fertilizer application in upstream intensive corn systems that funnel into the Mississippi River watershed and empty into the Gulf of Mexico has been extensively documented (e.g. Diaz and Rosenberg, 1995). In addition, Diaz and Rosenberg (2008) have identified more than 400 hypoxic areas throughout the world and noted that their frequency has doubled each decade since 1960. In some cases studies have found a direct correlation with increasing nitrogen fertilizer in agricultural systems (Rabalais et al., 2007).

Nitrogen is also measurable in the broader hydrologic cycle. Precipitation studies have identified inorganic nitrogen in the form of nitrate and ammonium, and deposition patterns closely correspond to the spatial locations of intensive agricultural systems (NADP, 2009) (See Figure 2-3). These highly mobile forms of pollution represent large threats to both the quality of life and resource use availability for humans and animals alike.

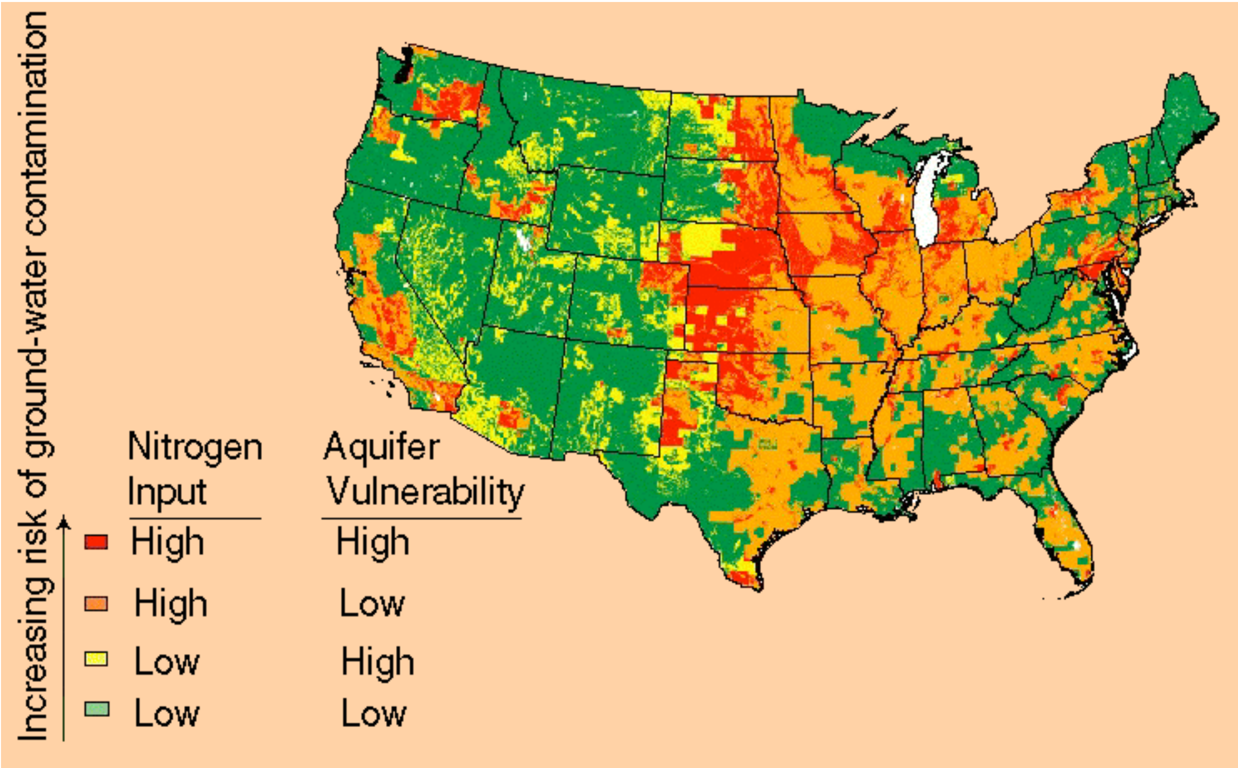
Figure 2-3: Inorganic Nitrogen Wet Deposition, 2009



Source: National Atmospheric Deposition Program/National Trends Network

Fresh water resources are also vulnerable to excess nitrogen application. Although fresh water systems are primarily phosphorous deficient, and therefore limited by this nutrient, nitrogen also serves as a co-limiting nutrient (Lohman et al., 1991). Phosphorous is the primary indicator of eutrophication of lakes, rivers and streams but nitrogen also contributes (Smith, 1998). In addition, nitrate leaching has impacted groundwater resources used for potable drinking water. Ground water contamination from nitrate leaching due to overapplication in hybrid cornfields has been reported in numerous studies (e.g. Ferguson et al., 1991; Jemison and Fox, 1994; Kladivko et al., 1991). Burow et al. (2010) have identified high-risk areas to correlate with high levels of N input; southwest Michigan is indicated as a high-risk zone (see Figure 2-4).

Figure 2-4: Nitrate Contamination in the U.S.

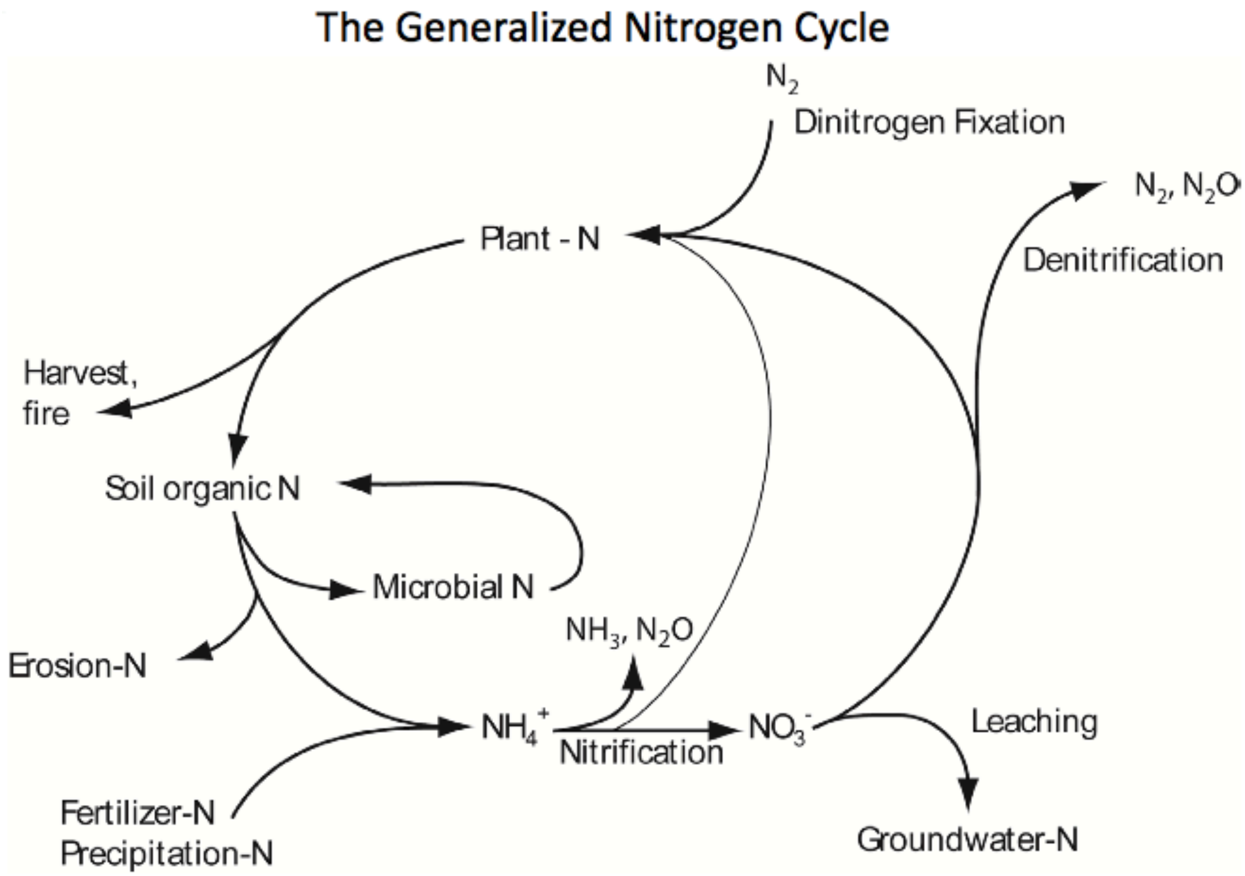


Nolan et al. (1997)

The biological nitrogen cycle

These environmental issues are based on the augmentation of the nitrogen cycle, one of the most fundamental biological processes in the terrestrial world. Nitrification and denitrification are the primary processes of N_2O gas and nitrate to the atmosphere and ground water, respectively. Ammonium (NH_4+) is converted to nitrate (NO_3-) during nitrification and NO_3- is further reduced to N_2O and dinitrogen (N_2) during denitrification (Robertson and Groffman, 2007; see Figure 2-5).

Figure 2-5: The Generalized N Cycle



Robertson and Groffman, 2007.

Nitrogen fertilizer application further enhances this process by contributing to the sum of NH_4+. Without supplemental fertilizer, the cycle is limited to the NH_4+ that is mineralized from the N released by dead organic matter. The augmented surplus of NH_4+ stimulates its oxidation to NO_3- by soil bacteria as well as the enzymatic reduction of NO_3- to N_2O and N_2 (Robertson and Vitousek, 2009). Although this cycle occurs naturally, O_2, carbon (C), and NO_3- have been identified as limiting factors of denitrification (Robertson and Groffman, 2007). Clearly, as fertilizer application increases, the availability of NO_3- increases and contributes to escalating N_2O and N_2.

Initial work on N_2O flux responses were thought to be linear with additional fertilizer inputs, but McSwiney and Robertson (2005) found that fluxes rose exponentially as additional nitrogen inputs were applied to corn systems at levels past maximum grain yield. Additionally, soils demonstrate a similar threshold response to nitrogen fertilizer in the leaching of NO_3^- (Bergstrom and Brink, 1986). As fertilizer inputs surpass plant uptake capabilities, NO_3^- leaching increases dramatically (Andraski et al., 2000; Power et al., 2000). These exponential environmental impacts highlight the need for addressing overapplication of N.

Understanding the N cycle is essential in attempting to match the N supply with crop N requirements. Recalling that N use efficiency is approximately 50% in corn systems (Allison, 1955; Cassman, 2002), a simple answer would be to propose overall application reductions, but studies show that there is substantial regional and farm-level variability. For example, studies in regions such as the North China Plains consistently highlight excess application compared to plant needs (Ju et al., 2009), while post-harvest N results from Western Kenya consistently show deficiencies (Vitousek et al., 2009). Most intensive U.S. systems, as well as other developed nations, demonstrate excessive N loads (Robertson and Vitousek, 2009).

With a fundamental understanding of the N cycle, we can move forward to addressing how anthropogenic impacts can be reduced. Dissemination of these scientific findings to the general farm community is an important link in raising awareness of agriculture's environmental impacts and corresponding solutions. Without an understanding of the socio-economic factors that influence farmer behavior, the impacts of scientific findings may not be fully realized. The review next focuses on the decision-making process of farmers.

Farmer awareness and conservation practices

The negative impacts of intensive agriculture systems have created concern amongst activists, scientists, and policy makers in many regions of the world. Soil depletion and water quality degradation due to industrial agriculture are two primary foci that have prompted farmers and policy makers to explore alternative practices that mitigate their adverse effects (Duriancik et al., 2008; Osmond, 2010). Conservation tillage, the use of cover crops, crop rotation, and integrated pest management strategies are well known practices that are promoted as “conservation agriculture” by the Food and Agriculture Organization (FAO) and the European Conservation Agriculture Federation (ECAF) (ECAF, 2012; FAO, 2001). The USDA National Conservation Service (NRCS) programs also employ conservation measures to reduce soil erosion, improve water supplies and quality, provide wildlife habitat, and minimize damages caused by natural disasters (USDA NRCS, 2012). The overarching goals of these conservation measures are to make better use of agricultural resources through soil management, and reduce external inputs that impact water and biological resources (FAO, 2001).

Awareness of environmental issues

The rapid rise of industrial agriculture resulted in soil management practices that quickly degraded productivity and encouraged erosion at unsustainable rates

(Montgomery, 2007). As new technologies developed to better manage soil erosion, research efforts focused on the factors that influenced farmers' decisions to adopt conservation tillage practices. Awareness of the problem has been identified as a prerequisite to conservation adoption in many studies (e.g. Carlson et al., 1994; Gould et al.,1989; Napier and Camboni, 1993). In their survey of 327 Wisconsin family farms, Gould et al. (1989) found a significant correlation between perceptions of soil problems and adoption of conservation tillage practices. The results suggest that dissemination of information to the farm community regarding environmental impacts of agricultural practices can be effective in encouraging conservation adoption (ibid).

Napier and Camboni (1993) also discovered in their study of 1,300 farmers in the Scotio River watershed of Ohio that awareness of water quality problems increased the likelihood of conservation practices. Similarly, surveys of farmers in the highly erodible region of the Palouse and Camas prairies (eastern Washington to north-central Idaho) revealed increased adoption of conservation tillage as awareness increased (Carlson et al., 1994). However, studies have highlighted that farmers continue to express doubt about individual practices actually impacting water resources or wildlife habitat (Camboni and Napier, 1993). This lack of understanding and skepticism about actual environmental impacts from farm practices is common. Traore et al. (1998) found a similar lack of understanding in their survey of potato farmers in Ontario. Although overall awareness was low in the surveyed respondents, education, participation in government programs, and engagement in producer organizations did correlate to increased environmental awareness (ibid).

Farmer awareness and attitudes are malleable factors that can be molded by information sources and personal beliefs. For example, Walter (1997) points out through his analyses of Illinois commercial farmers that perceptions of a “successful” farm vary across the community and are influential in shaping the awareness of environmental priorities. Industrial agriculture is often typified by a productionist definition of success, despite environmental externalities (Tegtmeier and Duffy, 2004). When farmers perceive their practices as harmonious with nature, it becomes difficult for them to acknowledge polluting byproducts (Silvasti, 2003). Individualized definitions of stewardship and conservation can lead to varying levels of conservation practice adoption (McCann et al., 1997).

In an attempt to develop a baseline understanding of stewardship, it is useful to revisit the philosophy of Aldo Leopold, widely thought of as America’s most influential conservationist (Callicott and Freyfogle, 1999). Leopold argues, “A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it tends otherwise” (1949, p. 262). In regards to farm activities, which often produced great alarm for Leopold, he proposed that resources be kept in working order and over-use be prevented at all costs (Leopold, 1939). Furthermore, Leopold charged farmers with the responsibility to balance personal profitability from the land with land-use decisions that profited the broader community (Leopold, 1939). But individual attitudes about conservation can be developed and maintained in a manner that falls short of traditional stewardship or conservation understanding. In many cases, individual farmer perceptions of stewardship are overestimated in comparison to actual on-farm practices, even though environmental responsibility is placed as a central concern of the operator (Urban, 2005).

Attitudes of environmental issues

More generally, conservation adoption has been related to conservation attitudes. Although ecological awareness and attitude can be overlapping, each has separate connotations. Attitudes can be defined as: "… the more or less permanent feelings, thoughts and predispositions a person has about aspects of his environment. Components are knowledge, feelings and inclinations to act…" (Van den Ban and Hawkins, 1996, p.81). Attitudes are developed after awareness is gained and found to heavily influence ecological-based actions (Kaiser et al., 1999). Attitudes can reach beyond conservation practices to include community interest. For example, Sheeder and Lynne (2011) found that farmers, who indicated on a survey that they had fewer self-interested attitudes and greater shared interest, were more likely to adopt conservation tillage practices in order to improve downstream water quality for the community. This connection to the broader community surpasses basic awareness of environmental issues, suggesting that attitude encompasses social responsibilities (Pretty and Ward, 2001).

Ecological attitudes have been studied from a behavioral perspective and found to be effective indicators for predicting action (Maloney et al., 1973; Azjen, 1988). In their mail survey of farmers in southwestern Ontario, Warriner and Moul (1992) found social networks to be influential in farmer attitudes and corresponding conservation adoption. Rogers (2003) also argues that effective transfer of information happens through strong social networks within a community. This process of communicating innovation through social networks over time was further thought to be effective at increasing conservation adoption as social networks increased (ibid). Farmers who are more open to outreach services, both professional and non-professional, are more likely to adopt conservation practices (Mathijis, 2003).

Even when environmental awareness is low, general attitudes about issues can speed up or slow down the progress of adoption. In their study of Wisconsin farmer attitudes regarding native grasses, Doll and Jackson (2009) note that even when awareness of native species is low, ecological attitudes can encourage conservation adoption. Similar results can be found in an in-depth study of Ohio farmers and their attitude towards the local watershed where awareness was low but positive ecological attitudes correlated to expedited conservation adoption (Napier et al., 2000).

The influence of education

Educational opportunities and experiences can play a significant role in shaping awareness and attitude. In their empirical study of Iowa corn farmers, Rahm and Hoffman (1984) find that education positively impacts the adoption of conservation tillage soil management practices for reduced soil erosion. Iowa water quality impacts have also been a research focus, with similar findings suggesting that agricultural conservation practices relating to water resources were more readily adopted as educational levels increased (Ervin and Ervin, 1982; Shortle and Miranowski, 1986). These efforts offer a foundation for approaching current agriculture-related environmental problems, but often overlook the increased complexity of farmer-decision making amidst industry influence, and continued state and federal budget reductions for such educational outreach and extension programs.

Educational outreach can also be a factor in successfully increasing awareness of environmental issues. In his study of the adoption of nutrient management plans (NMP) by Wisconsin farmers, Genskow (2012) found that workshop attendance and general educational materials were effective approaches for helping farmers develop NMPs. As information about nitrogen fertilizer and global warming factors are communicated through farm community networks, the result could increase conservation measures, including reducing nitrogen rates. Giovanopoulu et al. (2011) support this finding in their empirical study of farmers who adopt the European Union Nitrate Reduction Program (NRP). The extent of adoption measured in this study hinged significantly on existence of available information and current education, as well as opinions of subsidies, land eligibility, and attitudes about risk (ibid). In their recent study of Illinois farmers exposed to two different educational outreach programs, Lemke et al. (2010) noted that environmental awareness was positively associated with the intensity of outreach programs, such as one-on-one landowner interactions and localized workshops. The findings suggest that increased farmer interaction with outreach specialists could be very important in efforts to encourage adopting conservation practices. In addition, the findings articulate how instrumental extension services and other outreach programs are in influencing farm practices.

Still, a variety of studies have found that the correlation between outreach education and conservation is weak. In comparison to potential profitability, awareness of the problem can be a less important influencing factor with regards to conservation practice decision-making (Okoye, 1998; Saltiel et al., 1994; Napier and Bridges, 2002). In their survey of Montana farmers and corresponding adoption of sustainable soil practices, Saltiel et al. (1994) found that profitability was far more important to producers than awareness of the issue when deciding on new practices. Although this study highlights financial drivers as motivation for change, the authors are quick to note that varying individual farm characteristics often produce different priorities and correlating drivers for decision-making (ibid). Despite findings suggesting strong economic influences, they advocate for information dissemination through farm journals and other publications as an effective means to reducing uncertainty associated with new practices (Saltiel et al., 1994).

Decision-making can also fluctuate based on individual farm characteristics. Okoye (1998) explored farmers' willingness to adopt soil conservation practices that were located in a highly erosive region of Nigeria. Various regression models across the 125-farm sample showed that income, risk perceptions and farm size were the most significant factors in adopting reduced erosion practices (ibid). Understandably, economic influences should not be understated, especially in situations that are highly unstable. Supporting studies have found similar priorities in regions that suffer from a combination of economical, political and environmental instability (Berhanu and Swinton, 2003; Shively, 1997; Tenge et al., 2004). Regardless of geographic location, the element of risk is inherent in all decisions that farmers make. Nitrogen input decisions are particularly important because of the risk associated with yield variations.

Efforts to study potential correlations between the level of environmental awareness and adoption of conservation practices across the farm community have produced varying results; some find that awareness of problems is positively associated with conservation adoption (e.g. Gould et al., 1998), others find weak links between these factors (Okoye, 1998), and yet others distinguish between awareness and attitudes of problems (Carlson et al., 1994). Nonetheless, these research efforts serve as valuable information for understanding how farmers may adopt new practices because of new knowledge about emerging environmental impacts. This work may help us to better understand farmer decision-making related to reducing N fertilizer application or other measures farmers can adopt to mitigate global climate change.

Economic and structural influences

Although education, awareness, and attitude are important factors in farmer decision-making, economic considerations (as noted above) and structural influences related to the political economy of agriculture also play an important role. Farmers must evaluate decisions from multiple angles and, at the end of the day, must be able to economically justify their actions in order for their businesses to continue. These economic risks are often prioritized according to individual farm circumstances. Often economic influences can enhance the perceived risk of conservation practices and, in turn, diminish the adoption of such practices. This is an important aspect to understand when considering the promotion of nitrogen reduction rates.

Farmer decision-making is complex, and some have proposed that the process involves a number of steps when considering changes to farm management. Ervin and Ervin (1982) suggested that the first two steps of the decision process are 1) awareness of the issue and 2) economic feasibility of the new technology or practice to be adopted.

The second step in this process suggests that farmers will maximize utility, including farm profit and externalities associated with farm practices (Uri, 1997). It can be expected that a reduction of fertilizer inputs would be perceived as a reduction in the maximization of utility for farm profits. Although environmental externalities may be reduced, this perceived compromise might negatively influence voluntary action.

Economic efficiencies

Many producers make production decisions based on economic principles. A set of simplified assumptions is based on the production function–an attempt to show how the quantity of crop output is achieved in relation to the inputs (Dillon and Anderson, 1990). This is not an infinite relation, as biological and technical capabilities constrain the upper limits of production. Furthermore, price of inputs and price of the product, both fluctuating and contingent on commodity markets, must be considered for calculations. Producers can aim for profit-maximization by incorporating these variables into the production function (Dillon and Anderson, 1990). However, environmental ethics can be compromised in the face of decisions based solely on profit maximization. In particular, knowledge and awareness have limited influence on behavior when strong economic constraints are present (McCann et al., 1997).

In addition to maximum utility, the literature also identifies farmers as risk-averse decision makers. Many farmers are not willing to change current practices because they perceive them as the least risky (Nowak, 1987). Reducing fertilizer inputs, in contrast, is perceived by farmers as a high-risk behavior, often not associated with environmental or personal harm (Napier and Tucker, 2001). Although perceived risks can be a designated challenge to fertilizer reductions, in their study of factors that influence nutrient application, Napier and Tucker (2001) did not find conclusive risk indicators that were consistent across all of the 1,000 farmers surveyed. Again, farm-level decision-making and implementation is highly variable.

In their study of German farmers' acceptance of varying conservation measures, Sattler and Nagel (2010) found that economic rationality is not always the sole driver of adoption. Risk perceptions were the number one consideration of farmers who were evaluating adoption of conservation practices (ibid). In addition, is the importance placed by farmers on "observability," or perceived effectiveness, of the conservation measure. In contrast to very observable conservation measures, e.g. cover crops or permanent grasslands, fertilizer reductions have opaque results if trying to observe nitrous oxide emissions. Baerenklau (2005) points out that farmers are less influenced by off-farm conservation examples than reduced risks related to the conservation practice at their farm-level. A necessary step for increased adoption of fertilizer reduction could be to create small on-farm trials that offer the producer an opportunity to observe results before committing to larger practice changes.

Although farm economics is a central factor in decisions about conservation practice adoption or management changes, developing standardized models that fit all farms is a difficult task. In their study of North Carolina farmers' adoption of Best Management Practices (BMP) that aimed to reduce nitrogen loading in the local watershed, Osmond and Wossink (2002) point out that economic analysis of program participation is essential and at the same time, very different for individual farmers, resulting in highly variable participation. This study suggests that participation in a similar incentive program for nitrogen fertilizer reduction would be variable due to farm-level characteristics that influence economical evaluation.

Farm-level variability

Structural influences within the industry and community also shape decision-making. Featherstone and Goodwin (1993) studied 541 Kansas farmers and found that large, corporate-structured operations were more likely to adopt conservation measures. This is due in large part to the relatively well-capitalized nature of corporate farm businesses and their ability to employ capital towards innovation (ibid). A majority of analyses that explored the impacts of increasing farm income and profitability on the adoption of conservation agriculture have found a positive correlation (Gould et al., 1989; Saltiel et al., 1994; Soul, 2001). However, as farm size grows and emphasizes production efficiencies, important environmental characteristics, such as ecological diversity, can be compromised (Swift et al., 2004). Furthermore, it has been found that large farm holders are more influenced by economic incentives than land ethic concerns (Schneider and Francis, 2006). In other words, these types of farmers are more concerned about how the conservation measure might impact their production model (Cary, 1993). This suggests that unless a lucrative instrumental incentive is in place, changes to nitrogen management for the sake of climate change mitigation will be minimal if the individual does not understand the environmental impacts caused by the farming practices.

Additional studies of the diffusion of technology and conservation techniques have revealed similar economic drivers. In their study of over 1,000 farmers in three different Midwest watersheds, Napier et al. (2000) found that farmers with sufficient economic resources were more likely to adopt precision farming technologies to lessen the impact of local water resources. In these studies, age also plays a role in the economic analysis of the adoption of new practices or technology; findings highlight that younger farmers are both more informed about conservation methods, as well as more interested in making long-term economic investments, due to the realization of benefits within their lifetime (Featherstone and Goodwin, 1993; Roberts et al., 2004). As the average age of famers continues to increase, researchers may find it challenging to implement nitrogen reduction programs due to perceptions that are less vested in long-term outcomes.

Efforts to understand economic policy mechanisms for influencing conservation practices reveal a need for site-specific characteristics. In their modeling assessment of nitrogen limiting policies for regions of the Great Plains, Mapp and Bernardo (1994) found that per-acre restrictions were more effective than total nitrogen restrictions at reducing run-off and percolation. But the authors also noted that anticipated results were variable because of the distribution of soil types in the region (ibid). Ecological variability is also of concern in modeling expected results for N_2O offsets programs.

The findings from Hopkins et al. (1996) in their study of nitrogen reduction policies for two sites in Ohio suggest that targeted taxation of gross polluters is the most effective mechanism. That said, these authors also confirm that individual farm characteristics, and corresponding ecosystems, are variable in effectiveness of reducing inputs (ibid). But as Stonehouse and Bohl (1993) point out, tax mechanisms to encourage conservation practices can be costly to farmers and potentially detrimental to business. These initial findings can help guide emerging policies regarding N_2O reductions.

External structural influences

Financial incentives are important mechanisms to help overcome perceived risks and ultimately drive behavior change (Schneider and McCarl, 2006). In addition, participation and corresponding behavior changes by farmers can be influenced by external factors, including relationships with agriculture companies, government programs, and relationships with input suppliers (Hendrickson and James, 2005; Stuart, 2009). James and Hendrickson (2008) point out that economic pressures from external actors on the individual farm operation can contribute to increased adoption or tolerance of unethical behaviors by farmers. Therefore, a farmer's ability to react to the environmental effects of intensive agricultural practices may be inhibited if structural constraints are not addressed (Bos and Grin, 2008; Lawrence et al., 2004).

Structural influences are distinct when comparing commercial corn operations and seed corn operations. Seed corn farmers yield a product for subsequent years of commercial corn planting. Due to lower inbred vigor and the need for genetic integrity, seed corn production demands more particular growing conditions compared with commercial corn. Irrigation, field isolation, and soil characteristics are of greater importance when producing seed corn (Key Informant #4, personal communication, April 2011).

In general, seed companies contract with farmers for hybrid seed production. These competitive, or tournament, contracts are organized as principal-agent agreements between the seed company (principal) and contracted farmer (agent) (Preckel et al., 2000). These contracts are of notable economic interest due to difficult-to-observe differences in risk aversion, efficiency, and double-moral standards (ibid). The principal designs the contract to best meet his/her needs and the agent aims to satisfy the contract in a fashion that best fits their needs. In particular, the seed company benefits from this arrangement because optimum yields are provided without the company needing to acquire land or machinery (Hamilton, 1994).

Tournament contracts are common in livestock and seed production (Knoeber and Thurman, 1994; Swinton et al., 1997). The primary goal of seed contracts is to encourage competition between agents by offering lucrative incentives for performance that surpasses average yields (Nalebuff and Stiglitz, 1983) and linking performance to contract renewal. Implications of the competition include increasing nitrogen application rates as a measure of offsetting risk (Preckel, 2000). The consolidation of the seed industry (Howard, 2009) limits the options producers have available for both product and contract arrangement. Monsanto and Pioneer control 65% of the global commercial seed market (Howard, 2009) and in southwest Michigan approximately 75% of seed acres are under contract with these two companies (personal communication, May 2011). Nitrogen reduction schemes will need to address the competitive nature of seed corn production contracts in order to attract seed corn producers.

Summary

Economic and structural constraints are influential factors in farmer decision-making regarding N fertilizer. Together with environmental awareness and attitudes, these characteristics can be largely responsible for conservation adoption in intensive agriculture systems. Many farmers adhere to economic efficiency principles when evaluating participation in a conservation program. However, varying farm-level characteristics can produce differing economic analysis of such programs. Furthermore, external structural forces play an important, and sometimes constraining, role in farmer decision-making. An effective approach to reducing N fertilizer inputs and mitigating N_2O emissions is to consider these variables together in the development of offsets programs. This study aims to offer further knowledge about farmer awareness of N_2O associations and the challenges farmers face in adopting new practices.

CHAPTER 3: METHODS

Nitrogen fertilizer application in intensive agricultural systems can have adverse impacts on environmental quality. These impacts compound as fertilizer inputs increase and various factors contribute to overapplication. Intensive corn cropping systems are both a dominant agricultural system and a large source of nitrogen fertilizer use. In order to effectively mitigate the environmental impacts of nitrogen fertilizer application, farmer decision-making regarding this input needs to be better understood.

The research questions for this study explored farmer perceptions of nitrogen fertilizer and the barriers to reducing application rates. The following questions were used as a guide for this study:

1. Do farmers associate nitrogen fertilizer with nitrous oxide emissions and/or global warming?
2. How do farmers perceive nitrogen fertilizer to impact water quality?
3. Are farmers willing to reduce nitrogen fertilizer in their operation?
4. What are the challenges/barriers to reducing nitrogen fertilizer application through an N_2O offsets program?

This study describes the perceptions of corn farmers and industry representatives regarding nitrogen fertilizer use and associations with environmental quality. Interviews were used to collect data about current fertilizer use, factors that influence decision-making, associations with environmental quality, and willingness to reduce rates. The primary goal was to understand the willingness of farmers to participate in an N_2O offsets program. The narrative data were transcribed, coded, and categorized into three themes related to the research questions.

Setting

The geographic focus was on four counties of southwest Michigan: Branch, Calhoun, Kalamazoo, and St. Joseph. These counties are home to 1,353 grain-corn farms that produce close to 38 million bushels on over 317,000 acres (Census of Agriculture, 2007). Table 3-1 provides statistics for each county.

Table 3-1: County Statistics for Grain-Corn (Census of Agriculture, 2007)

County	# Of Farms	Avg. Farm Size	Corn Acres Harvested	Bushels Harvested
Branch	378	248	93,639	10,518,900
Calhoun	379	199	75,444	8,154,455
Kalamazoo	217	259	56,312	6,388,288
St. Joseph	379	242	91,693	12,907,430
Total	**1353**	**234**	**317,088**	**37,969,073**

Southwest Michigan is also host to a large concentration of seed corn farmers. Both Pioneer Hybrid and Monsanto hold regional seed corn production headquarters in St. Joseph County and contract with farmers in the surrounding area. Agricultural census data does not distinguish between commercial corn acres and seed corn acres, but industry representatives estimated that southwest Michigan has over 100,000 acres in seed corn production (Key informant #4, personal communication, 2011). The proximity of industry to farmers was thought to be influential in not only the number of acres that are contracted but also in the farm management practices.

The study setting was also selected because of its proximity to the Kellogg Biological Station (KBS) Long Term Ecological Research (LTER) site. Researchers have extensively studied nitrogen fertilizer in corn systems at the Kellogg LTER farm sites and have developed a protocol for a N_2O emissions reduction program (Millar et al., 2010). The setting of this study complements current research efforts by exploring farmer perceptions of agricultural systems that are similar to those at Kellogg LTER.

When possible, I conducted interviews on-farm or at the place of business. Many farmer interviews were held in designated offices within equipment buildings or repair shops. In some cases farmer interviews were conducted in informal settings, such as at dining room tables or on the tailgates of pickup trucks. Industry representative interviews were held in company conference rooms. All interview sites were selected by the respondent in an effort to insure both convenience and comfort.

Sample/respondents

I used a snowball sampling method to identify respondents. This chain referral method is used to recruit respondents from hard-to-reach populations (Bernard and Ryan, 2010), such as the agricultural community. Michigan State University (MSU) Extension provided initial contacts for farmers in each of the four counties. Each respondent provided the direction for subsequent contacts, often providing 2-3 additional referrals. This approach was effective because it served to identify individuals who were more likely to participate in the study. In addition, the approach was appropriate because farmers looked favorably upon participation knowing that their peers had participated and recommended their involvement.

A total of 40 corn farmers and 6 key informants from the corn industry were interviewed. Of the interviewed farmers, 23 were commercial corn producers, 6 grew both commercial and seed corn and 11 grew only seed corn. An effort was made to evenly represent the four counties by interviewing an equal number of farmers from each. The process resulted in interviews with 8 farmers from Branch County, 11 from Calhoun County, 9 from Kalamazoo County, and 12 from St. Joseph County. Key informant interviews represented companies that produce parent seed stock, independent wholesale companies who grow seed stock from other manufacturers, and crop consultants who provide services for both commercial and seed corn farmers. Table 3-2 and 3-3 list industry representatives and farmer respondents, respectively, as well as the distribution across the four counties. All interviewees were guaranteed confidentiality, and research results use corresponding numbers for identification of respondents.

Table 3-2: Key Informant Roles and Acres under Contract

Key Informant	**Role**	**Acres under Contract**
1	Crop Consultant	10,000
2	Wholesale Contract	10,000
3	Parent Seed Manufacturer	40,000
4	Parent Seed Manufacturer	36,000
5	Wholesale Contract	2,000
6	Wholesale Contract	1,200

Table 3-3: Farmer Location, Crop and Acreage

Farmer #	County	Seed Acres	Commercial Acres			
1	Calhoun					
2	Calhoun					
3	Calhoun					
4	Calhoun			**n=40**		
5	Calhoun			Seed=11		
6	Calhoun		700	Commercial=23		
7	Calhoun		750	Both=6		
8	Calhoun		1700			
9	Calhoun		300			
10	Calhoun		700	**County**		
11	Kalamazoo	1700		Branch=8		
12	Kalamazoo		640	Calhoun=11		
13	Kalamazoo		1000	Kalamazoo=9		
14	Kalamazoo	1500		St. Joe=12		
15	Kalamazoo		1400			
16	Kalamazoo	900	500		**Seed**	**Commercial**
17	St. Joe	1100		**Total Acres**	18,720	17,420
18	St. Joe	70		**Avg. Reported**	1,170	726
19	Kalamazoo	1800				
20	St. Joe	2300				
21	Calhoun		800			
22	St. Joe	900				
23	Branch		250			
24	St. Joe	1600				
25	Branch	800	600			
26	Branch		350			
27	St. Joe	1500				
28	Branch	1200	1200			
29	St. Joe	1500				
30	St. Joe		150			
31	Branch		2000			
32	St. Joe		90			
33	St. Joe					
34	Branch	350	1000			
35	Branch	500	1300			
36	Kalamazoo		100			
37	Kalamazoo		400			
38	Branch		250			
39	St. Joe	1000	1000			
40	St. Joe		240			

Data collection

This study used interviews as part of an elaborated case study approach. The purpose of this approach is to obtain narratives that describe perceptions, understandings, and personal characteristics that can help explain a phenomenon through the understanding of causes and broader processes (Rubin and Rubin, 2005). Through the insight of respondents, this approach provides a social understanding of how nitrogen fertilizer decisions are influenced and, in turn, what factors may effectively promote change.

An interview guide was created to collect the data (see Appendix A & B). Semi-structured interviews were conducted through a question-based approach. The question-based approach, compared to a topic-based, outlines expected content in a series of questions, rather than broad topics (Morgan and Guevara, 2008). In addition, this format is conducive to follow-up questions that further probe the main concepts (Roulston, 2008).

In-depth personal interviews of farmers and industry representatives were conducted between January and May 2011. MSU guidelines for research on human subjects were followed for interview structure (Michigan State University Institutional Review Board – approved 11/4/2010, IRB# x10-1100). Two different interview guides were created for the interview process: farmer and key informant. The main questions in the farmer interview guide focused on sources of information regarding nitrogen (N) application rates, willingness to reduce N application rates, and associations of N fertilizer with environmental quality impacts. The questions for key informants focused on information provided by the company regarding N fertilizer, perceptions of the impacts of N fertilizer, and willingness to support farmers who might reduce N rates. These scaffolding questions encourage the respondents to talk about the research questions that drive the study (Rubin and Rubin, 2005). Open-ended follow-up questions were used to clarify comments or further encourage participation. Interviews were audio recorded and lasted between 30 and 90 minutes.

I used a reflection process to continually assess my involvement and potential biases that inform the study. Absolute objectivity in a qualitative research process is recognized as an ideal that is impossible to achieve in practice. Responsive interviewing models, therefore, insist on acknowledging the dynamic role of the researcher and respondent (Rubin and Rubin, 2005). After initial interviews, I found it necessary to sensitively approach questions related to global warming because respondents had expressed feelings of accusation or criticism. Furthermore, these initial interviews highlighted the need to include additional questions about global warming information sources. This grounded theory process allows for both data gathering and analysis to inform each other (Charmaz and Bryant, 2008). Despite sometimes harsh comments from respondents, I used self-reflection to maintain a stance that was as neutral as possible.

Data analysis

All recorded interviews were transcribed and served as the primary data source. One farmer did not consent to the recording, in which case my detailed notes of the responses were the sole method of data collection. After each interview was conducted, I wrote a summary of the responses that served as a secondary source of data storage.

This process of summarizing also contributed to the iterative nature of the analysis. I entered all transcribed interviews into NVivo 9 for coding and qualitative data analysis. This computer software facilitates the development of thematic content analysis through the simplification of coding and display of data (Bazeley, 2007).

In the first step of analysis I coded for emerging themes. Thematic analysis assists in the search for overarching patterns that unite individual experiences within a qualitative data set (Ayers, 2008). Coding was developed to organize data according to the main questions within each interview guide. I then selected quotations from each main theme to be used as supportive evidence for the broader findings.

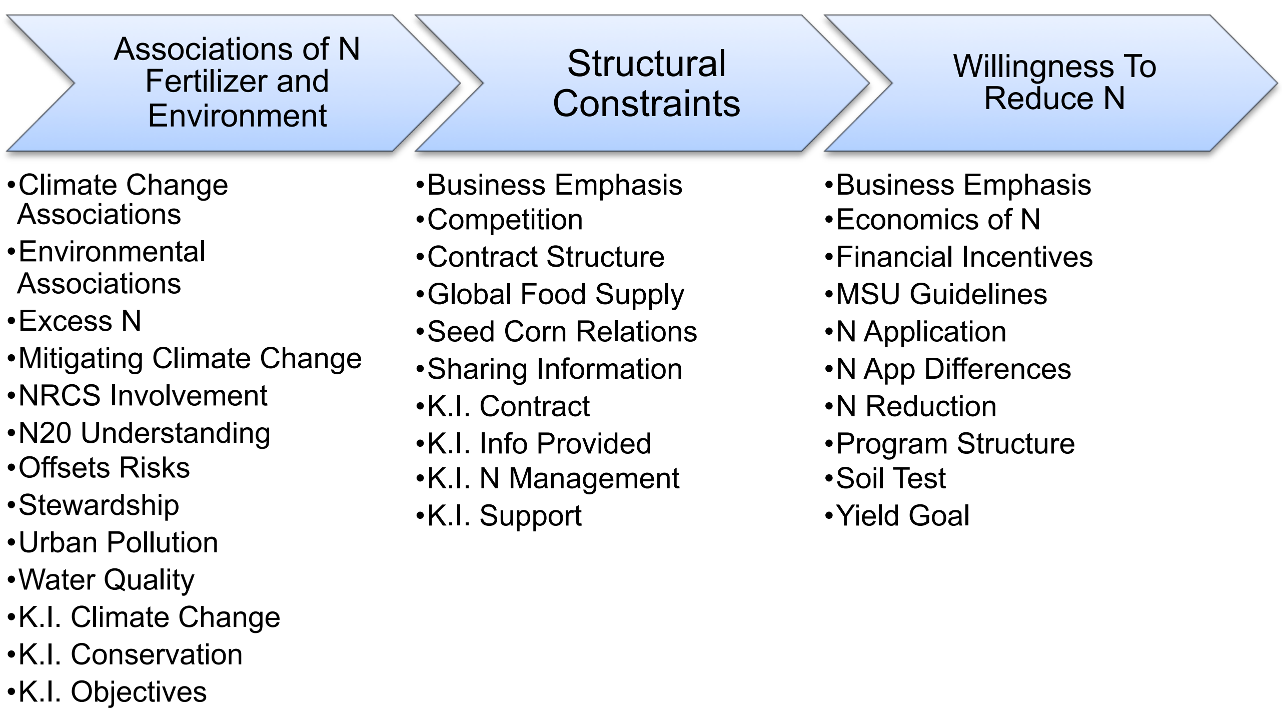
In the second step of analysis, I coded the closed-ended interview question. Some of this data was quantitatively analyzed in order to determine representational percentages of the sample. Responses to global warming and water quality issues were quantitatively expressed according to the central theme that they adhered to. This type of data organization illustrated the representative percentage of responses from respondents as well as more precise demographic information, such as farm size. The two approaches to data analysis served to complement one another, both articulating overall responses while highlighting individual data that could be collectively grouped. An overview of the coded concepts from the thematic analysis is listed in Table 3-4.

Table 3-4: Coded Concepts for Farmer and Key Informant (K.I.) Interviews

Business Emphasis	Environmental Association	K.I. Climate Change	K.I. N Reduction	N Application	Offsets Risks	Stewardship
Climate Change	Excess N	K.I. Conservation	K.I. Objectives	N Application Differences	Program Structure	Climate Change Sources
Competition	Financial Incentives	K.I. Contract	K.I. Support	N Reduction	Seed Corn Relations	Urban Pollution
Contract Structure	Global Food Supply	K.I. Info Provided	Mitigating Climate Change	N20 Association	Sharing Info.	Water Quality Concerns
Economics of N	Information Sources	K.I. N Management	MSU Guidelines	NRCS Involvement	Soil Test	Yield goal

As the concept analysis progressed, main themes were developed for broader representation of significant findings. Figure 3-5 illustrates the organization of concepts based on prominent findings and themes. The data within these concepts and themes served as the groundwork for understanding farmer decision-making regarding nitrogen fertilizer and how practices might change.

Figure 3-5: Organization of Themes



CHAPTER 4: RESULTS & DISCUSSION

Nitrogen (N) fertilizer application has received much attention from scholars due to rising environmental concerns associated with intensive agriculture practices. N fertilizer application and its corresponding byproducts have been linked to nitrous oxide (N_2O) emissions and water quality degradation. Although technology, timing, and other agronomic practices offer partial solutions to the abatement of these harmful side effects, it is imperative to understand the factors that influence farmers' decisions. Collectively, the socio-economic and agri-ecological approaches can help researchers and policy makers determine the most effective approach for mitigation of N_2O emissions and water quality impairment.

This study investigates some of the socio-economic factors that influence farmer decisions regarding N fertilizer application. In-depth interviews of 40 famers and 6 agri-industry employees in southwest Michigan explored how farmers associate N fertilizer with environmental impacts, such as N_2O, global climate change and water quality. In addition, the interviews aimed to understand farmer perceptions about reducing N fertilizer, as well as barriers to N_2O offsets program participation.

This chapter describes the results that were found from the interviews and subsequent data analysis. In concert with the qualitative nature of this study, the results are organized as narrative data that emerged as major themes related to the research questions. The first section reports on the attitudes about, and associations with, N fertilizer and environmental quality. The second section reports on significant factors that commercial corn farmers use to make N fertilizer application decisions, and their interest in proposed N_2O offsets programs. The final section addresses the findings from seed corn farmers, and contrasts these results with those of the commercial producers.

Descriptive statistics of sample

The sample of commercial corn farmers included 23 farmers who grew only commercial corn. An additional 6 farmers grew a combination of commercial and seed corn. Total acreage represented by the commercial corn sample was 17,420 with an average farm size of 726 acres. The four-county region (Branch, Calhoun, Kalamazoo, and St. Joseph) is home to 1,300 corn farms and over 300,000 corn acres (Census of Agriculture, 2007). This sample, therefore, represents approximately 2% of the farmers and 6% of the acreage in corn production.

The sample of seed corn producers included 17 respondents. Of this total, 6 respondents also produced commercial corn. Total acreage represented by the seed corn sample was 18,720 seed corn acres with an average farm size of 1,170 acres. Key informants #3 and #6 suggested that close to 100,000 acres are in seed corn production within the southwest Michigan region (Key Informant #3, #4, personal communication, April, 2011). Given this information, this sample then represents approximately 18% of the contracted acreage.

Seed corn production typically entails a contractual agreement between the seed corn company and producer. Respondents in this study had contracts with Pioneer Hi-Bred, Monsanto, Remington Seeds, and Mendon Seed Farmers. Fifteen respondents contracted with Pioneer Hi-Bred, while 5 contracted with Monsanto, 3 with Remington, and 1 with Mendon Seed Growers.

The sample of key informants included 6 respondents. These respondents had a variety of roles relating to the seed corn industry: 1 crop consultant, 3 presidents of wholesale seed contractors, and 2 plant managers for seed stock companies. Together, the key informants, and corresponding companies, have over 160,000 acres under contract. The crop consultant's business oversees 60,000 seed corn acres, the parent seed companies together contract 81,000 acres, and the wholesale companies contract approximately 19,000 acres.

Acknowledgement of associations between N fertilizer and environmental impact

Following previous studies of water and soil conservation practice adoption, in-depth interview questions explored farmer awareness of N fertilizer and the corresponding environmental impacts. Both interview guides (See Appendices A & B) included the following closed-ended questions to gauge understanding and association of N fertilizer application with N_2O emissions and global climate change.

1. Do you associate N fertilizer with emissions of N_2O gas?
2. Did you know that N_2O is considered an important greenhouse gas (GHG)?
3. Do you associate N fertilizer with climate change?

Overall, farmers and key informants expressed a low awareness of N_2O emissions produced because of N fertilizer application. Only 8% of the 40 farmers associated N fertilizer with N_2O gas and zero key informants made the association.

When asked about their understanding of N_2O as an important GHG, 20% of the farmers were aware, while half of the 6 key informants acknowledged awareness. Five percent of the farmers and zero key informants made the association between N fertilizer and global climate change. In response to the question, farmer #18 explained, “There isn't enough conclusive research on global warming to make the association with fertilizer.”

Perceptions of global climate change

In addition to the “yes” and “no” responses about N_2O emissions, interview questions produced some very strong opinions about the validity of human-induced climate change. Although their beliefs about climate change were not directly polled, many respondents offered thoughts and explanations relating to claims about global climate change issues. Of these responses, a strong theme emerged around the disbelief of global climate change. Of the 30 farmers who chose to elaborate on their feelings about global climate change, 11 (37%) explained that climate change is part of a much larger cycle that surpasses current scientific understanding. For example, Farmer #11 noted, “I’m not concerned about global warming. I’m not saying it’s not a problem, but I think they’re just long cycles.” An additional 9 farmers (30%) expressed their disbelief of global climate change altogether. Explanations from this group ranged from beliefs that the climate is actually cooling to highly politicized views of mistrust and dishonesty. Farmer #9 strongly explained, “I think global warming is bullshit, you can put that down, and it’s just another craze. I don’t think many people this winter would believe in global warming after the winter we had.” The remaining 10 farmers (33%)

who elaborated on global climate change beliefs acknowledged the presence of anthropogenic factors. Statements like the one from farmer #34 represented these farmers, “I think the consensus is that there is a global warming trend.” Additional examples of these responses are listed in Table 4-1.

Table 4-1: Farmers’ Comments Regarding Global Climate Change

Some Farmers Believe Global Climate Change is Related to Large “Natural” Cycles
“I don’t think there has been enough research done on just the long-term nature of weather patterns.” Farmer #29
“I don’t know if global warming is even true. Who is to say this isn’t a cycle. 600 years ago there was no one around to keep track…you watch the lakes and ponds go up and down in cycles and everything else is in cycles.” Farmer #30
“The globe is warming anyways. Michigan was covered in ice and when it melted it made the great lakes; so my theory is just because man came along why would the earth stop warming, how arrogant are we?” Farmer #15
Some Farmers Don’t Believe Climate Change is Occurring
“…Sometimes I think global warming is all made up and they (researchers) have to have something to do…” Farmer #27
“I’m not going to agree with global warming yet. I think Al Gore just came up with that.” Farmer #3
“Global warming doesn’t exist.” Farmer #4
“I think if the good Lord wants it to be 1 degree warmer, I think he’s going to make it warmer.” Farmer #37
“In my opinion, climate change is a crock. I’m a Christian and the only person who can change climate is God himself.” Key Informant #2
Some Farmers Acknowledge Anthropogenic Influences on Climate Change
“I think it goes in cycles and humans probably aren’t helping.” Farmer #5
“…One thing that I feel is the biggest thing causing global warming in the US…is the fact that, and we don’t have control over this, we have tarred/cemented over and eliminated so many trees and all the things that help us digest the problem, its pitiful.” Farmer #1

After initial interviews revealed strong opinions regarding global climate change, I became interested in exploring the information sources that farmers and key informants trusted regarding this issue. I inserted questions into the interview guide regarding which sources of information were trusted regarding global climate change and how science was perceived to contribute to global climate change explanations. It was originally thought that political media source preferences would correlate with the perceptions of global climate change; conservative media contributing to global climate change denial and liberal media supporting anthropogenic global climate change. McCright (2011) argues that U.S. media sources have become increasingly polarized, and deliver climate change information that supports the beliefs of the audience. While some farmers acknowledged allegiance to prominent media sources, most responses revealed that farmers are highly uncertain about which information sources are trustworthy. Farmer #38 explains, “You can read everything you want to read, but for everything you read that points this way you can find something that points the other way.” When asked how science influences their understanding of global climate change, many individuals noted that science should be the fundamental pillar from which conclusions are drawn. Farmer #40 notes, “My degree was in a science-based program so the research scientists and university research is probably the first place I would go (for trusted information).” But some farmers expressed doubt about scientific research, and explained that caution should be used when interpreting findings. Farmer #31 points out, “There is good science and there is bad science.”

The abundance of information related to global climate change has left some farmers in this sample skeptical of trusting scientific information, even though they articulated that science is a trustworthy source. Although scientific findings have clearly associated N fertilizer application with N_2O emissions and global climate change factors, many farmers believe otherwise. Until a more cohesive agreement amongst the farm community can be reached about this issue, skeptical farmer attitudes could inhibit the adoption of N fertilizer application reduction practices.

Perceptions of N fertilizer and water quality

In addition to questions posed about N_2O emissions and global climate change, farmers were asked about their perceptions of regional water quality, and the impacts of agriculture on water quality. Although 85% of the farmers noted that water quality is of importance, only 23% acknowledged that agriculture-related issues were impacting water resources. In recognition of the importance of water quality, Farmer #1 explained, “It (water) should be the number one issue; if we screw up the water, we screw up everything.” But when asked about how agriculture, N fertilizer application in particular, was affecting water resources, many farmers did not believe there was an association. Farmer #23 notes, “I really think the fertilizer application probably doesn’t have a whole lot to do with the water quality.” Some farmers rationalized this disconnect by noting that economics prevents overapplication and resulting impacts, while others explained that historical water issues had been solved because of better application technology. For example Farmer #14 explains, “The economics of fertilizer use prevent that (overapplication) from happening.” Additional narrative examples are provided in Table 4-2.

Table 4-2: Farmers' Comments about N Fertilizer and Water Quality

Many Farmers Believe that Water Quality is an Important Issue
"It is right up at the top of the list for us and that is why we are concerned." Farmer #17
"I don't want to drink it (nitrates) and that's why I was saying earlier that I try to limit the amount of nitrogen we use..." Farmer #5
"I think we really need to watch it. We don't want to ruin our water supply." Farmer #6
Some Farmers Did Not Link Water Quality with Agriculture Practices
"Water quality is not an issue for me. I am not spreading it close to a lake." Farmer #21
"We have some nitrate problems in the water here, but that could be from swamps." Farmer #13
"I know it can happen and I don't think it's really a big issue, I'm not thinking it's a big issue." Farmer #10
"We haven't done tests or anything like that but from what our crops look like and the way we apply our nitrogen…it doesn't seem like it's disappearing so I would say the leaching is not a really a concern." Farmer #16
"I don't believe there is any connection between water quality and fertilizer applications." Farmer #36

As previously mentioned, recent studies have identified regions at high risk of groundwater contamination to correlate with high N input activities (Burow et al., 2010). Southwest Michigan is included in this high-risk zone. Of the 12 farmers located in St. Joseph County, all but one acknowledged the importance of water quality and half indicated that agriculture impacts water quality. Farmer #29 explained the historical context of the situation and articulated his understanding of the relationship, "I guess 20-25 years ago nitrate was an issue in some ground water and I think that probably the vast majority of the wells that you would pull water samples from now will probably show some degree of nitrate. I would say that the vast majority are well below threshold levels so I know that it is there and I know it's going to happen and I know were going have a little." Just as nonpoint source pollution is difficult to directly associate with an individual or operation, awareness and responsibility of N_2O emissions from N fertilizer application may be difficult to realize at the farm level.

Farmers better understood water quality relationships with N fertilizer application than with N_2O emissions. This awareness might be attributed to the historical understanding of these relationships, and previous work that has identified problems related to overapplication in hybrid corn systems (e.g. Ferguson et al., 1991; Jemison and Fox, 1994; Kladivko et al., 1991). In addition to low awareness, attitudes about global climate change across the sample were mixed, with a majority of the farmers perceiving climate shifts as either part of a larger cycle or not at all related to human influences. Of the 9 farmers who did acknowledge human influences in global climate change, only 2 associated N fertilizer with global climate change. If awareness positively correlates to conservation adoption, as suggested by other studies (e.g. Gould et al., 1989; Napier and Camboni, 1993), a first step in the effort to reduce N_2O emissions from N fertilizer application might be to increase the awareness of the environmental impacts. But as farmers' responses about water quality relationships with fertilizer indicate, awareness of the issue is subject to individual interpretation.

Farmers' roles in climate change mitigation

An interesting contrast to the lack of awareness and anti-climate change attitudes appeared in the responses about mitigation contributions. Farmers and key informants were both asked, as follow up questions to the global climate change associations, if they felt they could contribute to future mitigation of global climate change. Although the perception of climate change was weakly linked to anthropogenic actions (33%), 75% of farmers and 67% of key informants indicated they thought they could play a role in future mitigation. Many of these responses highlighted positive, historical influences and pivotal roles those farmers have had regarding the improvement of environmental quality. Farmer #29 explained, "I don't think there is a reason why we wouldn't play a role in most any aspect of human life." For those individuals that didn't believe farmers could play a role in future mitigation, reasons varied from agriculture's insignificant role in comparison with other industries, to non-cooperative behavior characteristics of farmers. Farmer #19 explained, "I think your large industries and things like that are the ones that you really have to go after because to harness a group like this (farmers), that are so independent, is going to be really tough…farmers are very stubborn and independent." This sentiment was echoed by Farmer #23, "I would think we could have a pretty huge impact on it, but we have too many free thinkers in agriculture."

The high percentage of farmers believing they can play a positive role in future mitigation may suggests that the framing of the question is influential in responses. During the course of the interviews, it was observed that questions about N fertilizer regarding the negative associations with the environment tended to create a defensive response from the farmers. Farmer #20 expressed this sentiment, "The implication is that as a farmer, I don't understand what I'm doing. It implies that I use an input without regard to economic return, cost or other repercussions." These questions probed at the foundation of farmer understanding about the environment, suggesting that their practices were contributing to ecological degradation. But the follow-up question regarding the farmer's role in future mitigation of climate change was framed in a positive, opportunistic way. This potentially allowed the farmer to see himself/herself as a positive actor, rather than a defender of personal actions. This framing effect (Druckman, 2001) could be responsible for the contrasting responses. The image of the “good farmer” (Silvasti, 2003) is also suggested by the positive nature of the question and could be a reason for the strong response. As efforts to reduce N fertilizer further develop, it may be found that the framing of the issue and proposed management solutions are influential in how attitudes and actions are adopted.

Factors influencing current N fertilizer application

An important aspect to consider when evaluating individual N fertilizer rates are what kind of information is utilized, and who is providing this information. The interview questions inquired about the information sources used by farmers, and if they perceived additional fertilizer application to offset any risks they take into consideration. The influence of fertilizer dealers and MSU guidelines were specifically explored. Forty five percent of the farmers acknowledged that fertilizer dealers are influential in their decision-making and only 28% of the farmers noted that they adhere to MSU guidelines. Those farmers who did not follow MSU guidelines characterized the recommendations as outdated, excessive, and out of touch with the farm community. Farmer #32 notes, “It’s sad but I have no faith in Michigan State.” Farmer #13 offered his reasoning for no longer adhering to MSU guidelines, “For rates not anymore…we are below probably what you guys (MSU) would recommended on rates.” When asked what were the primary information sources for N fertilizer management strategy, 62% of the commercial farmers explained that they use traditional yield goal analysis as the guiding force for deciding on N fertilizer application rates. However, many farmers noted that their fertilizer dealers derive these yield goals. This dependence is unlikely to support a reduction in N fertilizer application behaviors, as it would be counter productive to fertilizer sales. Those farmers that fell outside of these categories noted other contributors to their decision-making process, such as past experience, farm journals, and other educational institutions, i.e. Purdue and Iowa State.

Traditional yield goal estimations don't often correlate to economically optimum nitrogen rates (EONR) (Vanotti, 1994; Bundy, 2000). The Maximum Return To Nitrogen (MRTN) approach, developed by researchers at Iowa State, has gained attention due to its incorporation of individual farm characteristics, fertilizer and corn prices, and overall reduced N fertilizer recommendations. The farmers (62%) who acknowledged that they currently use traditional yield goal approaches are then presumably overapplying. While MSU has been suggesting N fertilizer application rates based on MRTN since 2009, the lack of adherence to MSU guidelines expressed by farmers could be contributing to their continued use of traditional yield goal strategies. Additionally, this could be attributed to findings that highlight how farmers often continue to use practices because they are perceived as less risky than alternatives (Nowak, 1987). Better dissemination of the latest information and making field trial results available may encourage N fertilizer reductions.

Many farmers also expressed their belief that they, and farmers in general, are good stewards of the land. Farmer #16 expressed this in his statement about the farm community, "I'm as environmentally sensitive as everybody else but I think us, as farmers, try to be more environmentally sensitive than most people; you know it's how we make our living.” This self-acknowledged stewardship (Lawrence et al., 2004) contributes to the lack of responsibility farmers claim regarding agricultural impacts on environmental quality (Beck and Lau, 2005). Responses highlight a discrepancy in how stewardship is defined by farmers compared with other conservationists (Carr and Tait, 1991). In this case, farmers claim that N fertilizer is being applied with stewardship principles while the impacts of application are raising concern amongst the scientific community.

In addition, some farmers and key informants noted that adherence to fundamental economic principles were responsible for overapplication and environmental impacts. Farmer #2 notes, “Our best tool to minimize our effects on the environment is to maximize our productivity. When I say productivity I’m not necessarily saying the most yield, I’m saying the most efficient yield.” Fertilizer application rates for commercial corn farmers are dependent on both corn and fertilizer prices. Increasing fertilizer prices tend to reduce application rates but rising corn prices can overshadow these reductions and encourage some farmers to increase N fertilizer: “you can’t afford to be short on N at $6 a bushel.” These attractive economic possibilities can prevent stewardship from being realized (Millar and Curtis, 1999). Additional supporting remarks of these influences are listed in Table 4-3.

Table 4-3: Factors Influencing Management Decisions

Environmental Stewardship as a Guiding Principle
"I think farmers as a group are good stewards of the land and were not out here to cause pollution and problems…" Farmer #8
"We don't try to do anything to cause pollution or cause problems… we try to limit our nitrogen and no-tilling is a good way to farm." Farmer #9
"I think that farmers ought to be good stewards on their own and as far as I know most of them are." Farmer #37
"Well I try to be a good steward to the land anyways; I haven't tipped over my 55 gallon barrel of used oil in the back yet." Farmer #5
Economics as a Guiding Principle
"I think the US is as efficient as it can possibly be just for the simple fact of the pure economics of the whole thing." Farmer #39
"…Excessive fertilizer application…I don't see how you can economically do that anymore." Farmer #25
"Right now we won't overuse it because its over $350/ton so its extremely expensive." Farmer #19

Yet, a few individuals noted that the environmental externalities of agricultural systems are not realized. With hindsight, it is easy to recall examples of environmental externalities that weren't immediately connected to the farm community. Farmer #31 explains,

> For a long time my dad never thought about cattle manure running down the water well, and getting nitrates or atrazine in the water, and it was some kind of pie in the sky that wouldn't happen, and now it is just common knowledge, and I think we are going to realize the way we look at ground water our kids will be looking at the oxygen and atmosphere... I think it is just the next step of evolutionary thought of how we are contaminating things.

Citing other sources of N pollution contributing to environmental impact

Further responses also identified alternative entities responsible for contributions to environmental impacts or misplaced blame. Some farmers pointed to the urban population as responsible for large impacts on the environment. Additionally, farmers were quick to note the disconnection between urban and rural communities, and how this can contribute to unfair accusations of farm pollution. The media was highlighted as the main source of misinformation that shaped urban understanding. Farmer #21 suggests that urban awareness needs to be addressed, “The public needs to be educated about farmer stewardship in comparison to urban stewardship.” Table 4-4 provides additional citations of environmental impacts.

Table 4-4: Other Sources of Environmental Impact Cited by Farmers

Other Sources of Environmental Impact Cited by Farmers
“I’m wondering how much of it is really coming from the farming community and how much is coming from the residential community…” Farmer #37
“Environmental causes are led by the wealthy and there are some very hypocritical things happening by those leading these efforts.” Farmer #25
“A lot of the public doesn’t realize the strides were making in conserving our nitrogen and fertilizer use.” Farmer #10
“Farmers, as a whole, have done a better job (managing N) than people living in cities… you hear of someone in town putting on 500 or 600lbs of N in a little yard, well that’s more than we put on a whole acre.” Farmer #7
“Overuse is going to cause pollution but I feel that the biggest polluters out there are home owners and golf courses and they don’t realize it. I mean they want their green lawn and want their perfect golf course, and they don’t care about costs, and then they wonder where this water issue comes from.” Farmer #38

The responses suggest that although farmers acknowledge the impact of N fertilizer application on the environment, it is easier to point out other sources of pollution than their own actions. While some have argued that environmental disturbance is obvious to the farmer (Beck, 1992), others claim that some farmers are not able to see the destruction caused by their practices (Jensen and Blok, 2008). Farmers rationalize N fertilizer application in a way that aligns with the production priorities of agri-food systems. In order to address the irresponsibility, systemic changes are needed.

Summary: associations between N fertilizer and environmental impact

Overall, farmer and key informant awareness of environmental impacts due to N fertilizer application was low. Only a small percentage of individuals associated N fertilizer with N_2O emissions or global climate change factors. The issue of global climate change produced strong opinions from respondents who largely believed the phenomenon is nonexistent or part of a larger cycle not affected by human behavior. A small number of farmers acknowledged the anthropogenic factors that have contributed to global climate change.

If traditional yield goal critiques are correct, most commercial farmers in this study could benefit from the alternative MRTN approach. But the lack of faith in MSU recommendations and strong connections to fertilizer dealers suggest that farmers are relying on information sources that may not be conducive to such reductions.

Information sources that contribute to the development of awareness and attitude varied across the respondents. However, farmers were consistently uncertain about what sources to trust. Although science was stated as a trustworthy source, many farmers articulated their current lack of faith in the scientific process. The quantity of information available, as well as the political nature of the global climate change topic, has impacted attitudes, and could contribute to future adoption levels of conservation practices that aim to mitigate an issue that many farmers view as dubious.

Evaluation of commercial farmers' interests in an offsets program

A section of the interview guide was also dedicated to exploring the overall interest in a N_2O emissions offsets program. To best gauge these characteristics, interview questions directly asked about important economic characteristics (e.g. high economic return vs. high yield), information sources used for determining optimal N fertilizer application, and interest in a N_2O emission offsets program and how it might best be structured. Responses indicated that commercial corn farmers are most concerned with the economic returns regarding N fertilizer application and have a strong interest in evaluating a N_2O emissions offsets program based on these principles. Information sources used to evaluate optimal N fertilizer application rates varied but the most prominent determinants were traditional yield goal evaluations and fertilizer dealers. Challenges to participation in such a program were extensive but centered around the perception that reduced N fertilizer rates would negatively impact yield, “bad actors” would be rewarded instead of the individuals who already sought reductions, and the offsets program would require more time and resources that farmers don’t have.

Economic analysis

Commercial corn farmers demonstrated a high interest in N_2O offsets program participation. When asked how they felt about a program that paid farmers to reduce N fertilizer application, approximately 86% of the commercial farmers indicated they would be interested in reviewing the program. To many of the farmers, all programs are at least worth exploring from an economic standpoint. The response from Farmer #40 is representative of many commercial farmers first reaction, “Any program that is out there I will certainly look at and evaluate and see how it fits here.” Ninety percent of the commercial farmers noted that high economic return is more important than high yields in their operation. When asked what was most important in his farm operation, Farmer #23 explains how high yield can be detrimental to a farmer, “Certainly economic return. You know when I was a kid there was a man over here in Schoolcraft that set a new state record in corn yield and that was his last year farming.” Table 4-5 provides additional comments illustrating the importance of economic return.

Table 4-5: The Importance of High Economic Return

Most Commercial Farmers are Concerned with Optimizing Economic Return
“$300 bushel corn doesn’t pay the bills if it cost $320 to produce it… We’re not farming for yield, we’re all farming for the black number on the bottom of the page, and it better not be red…” Farmer #4
“Definitely go by economics; we are not a high yield farm; again a lot of that has to do with the soil type.” Farmer #40
“…Maximum yield doesn’t really help you if you have to spend a lot to get there.” Farmer #35

Many farmers expressed concern that a reduction in N fertilizer application will translate into decreased revenue. Farmers explained that financial incentives would need to offset any income reductions in order for participation to be attractive. When asked how much he might need to be compensated in order to reduce his N fertilizer, Farmer #8 explains, “We’re trying to make a living and that dollar amount would have to be worth the farmers while to do these things.” Many of these responses support the findings from other studies (Sheriff, 2005; SriRamaratnam et al., 1987) where additional N fertilizer application is considered a risk reducing activity; therefore reductions in fertilizer application is perceived as risky. Table 4-6 provides additional comments from farmers about the compensation structure and program participation.

Table 4-6: Farmer Thoughts about Incentives

Incentives Need to Address Risks
"…Put a pencil to it and see if it is worth the risk basically…you are asking him (farmer) to take a risk that he doesn't have right now. For every risk there should be an award." Farmer #39
"Well I think it would have to reflect yield loss and…if we have proven yield data and we reduced our nitrogen by 35% to participate in the program and we lost that much yield, I would expect to be compensated for it." Farmer #13
"It should be commensurate to what you're going to lose in yield, and right now its $7 a bushel for corn, so if you're going to lose 15 bushel that's $100…" Farmer #36
"If there was yield reduction I think we would need to be compensated for it, and I guess if they were able to maintain our yields with less fertilizer, I don't know if we really need to be paid unless there was extra time involved." Farmer #6

Program structure

Program structure was also an important component according to respondents. Farmers responded decisively when asked which program structure was more attractive: a market-based approach or a government-based program. To provide clarification for the farmers throughout the interviews, the proposed N_2O offsets program was compared to carbon trading through the Chicago Climate Exchange. Although trading has ceased, most farmers were aware of the mechanism and found the context helpful when discussing the N_2O offsets program. The government-based approach was explained parallel to current subsidy incentives that offer payments or cost shares to implement conservation practices, such as buffer strips, fertilizer containment facilities, and Conservation Reserve Programs (CRP).

Eighty-two percent of commercial farmers preferred a market-based approach instead of a government run program. Farmers were frank in their dislike of government programs, and perceived additional government efforts as ineffective, and potentially harmful. Farmer #3 explains, “The government goofs up anything they get into. Like our subsidies…once you’re hooked on that you can’t just yank it away without a great amount of pain being felt.” Farmer #29 supported these sentiments with his comment, “I would say that a market-based sounds more appealing; I don’t think there are very many people that are high on the government right now.” Table 4-7 illustrates additional comments from farmers about how they believe the program should be structured.

Table 4-7: Farmer Preference for Offsets Program Structure

Most Farmers Believed That a Market-Based Mechanism is Best
“I think that most people would view it (market-based) as more palatable…rather than some number that the government determines they want to give you.” Farmer #29
“In the end I swear the free market is the best system going and especially today because we’re not in this market by ourselves anymore.” Farmer #3
“It’s got to be a market-based program it can’t be a subsidy program because they can’t afford that.” Farmer #4
“I’ll say market-based just simply because everything the government gets a hold of somehow gets messed up.” Farmer #8
“I’m a conservative so everything should be market-based.” Farmer #15
“The government program, I think all it does is allow the smaller farmer that is hanging out to hang on a little longer, and that probably sounds really bad, but I just don’t like it. Let us farm and if you can make it, you can make it.” Farmer #19

Although most farmers were very vocal about their anti-government preferences, some farmers did recognize the historical importance and familiarity of government programs, suggesting they would be well received. Farmer #34 notes, “I don’t think people care if it is government-driven when all is said and done. We are used to that with incentive programs with NRCS.” Farmer #13 also explains that adding another program payment would be easily streamlined into the existing process, “Making it part of the farm program does a good thing… you go into NRCS and…sign up for this while you’re here signing up for the payment program.” Despite anti-government comments, almost all of the farmers acknowledged working with NRCS and/or receiving government subsidies. Yet others expressed doubt about a market mechanism because of the defunct carbon trading effort. Farmer #31 explains his experience, “look at carbon credits right now… they were supposed to be able to trade them…what ended up happening is that 4-5 companies control it and called me and told me, well you’re going to go no-till and we will give you $2 an acre for 7 years…that’s nothing, it’s ridiculous.”

Barriers to participation

Although there was a strong positive interest in a N_2O offsets program, commercial farmers articulated common barriers to participation. A main theme that developed through the interviews was the perception that N fertilizer application can’t be further reduced in commercial corn systems without adverse yield and economic impacts. Additionally, farmers expressed concern about a program that rewarded the “bad actor” without acknowledging the proactive individuals.

Many farmers noted that they would like to reduce N fertilizer in their systems but were unsure how the resulting yields would impact their business. “Any of us would give up nitrogen if it was proved to us there is a cost effective way to do it,” Farmer #7 explains. Less than half (41%) of the farmers believed they could effectively reduce N fertilizer application without incurring economic consequences. Many of the farmers explained that N fertilizer application reductions had already been made in their systems and they were operating at high efficiency levels. Farmer #36 explains, “I’m not sure I could reduce it much more than I am really because I really don’t think I’m wasting any.” Still others believed that application should be dictated by economics; as prices rise, reductions and innovation will naturally occur. Farmer #3 explains, “We are not in this world anymore by ourselves. China, Russia, and everybody else…if they all of sudden have a demand for potash or nitrogen when there is no more…someone is going to have to go without.” Table 4-8 shares additional comments illustrating farmers’ beliefs that reducing N fertilizer application will impact yields.

Table 4-8: N Fertilizer Reductions Not Possible

Many Farmers Believe N Reductions Will Reduce Yields
“I would say right now that if we reduced it you’re going to end up cutting back on your yield. For the amount of money your saving you would be losing more than that. It wouldn’t be economically feasible to reduce it.” Farmer #4
“I’m putting the least amount that I think I can and still getting the max yield for economics.” Farmer #5
“No, I would like to stay where I am at because I know it works.” Farmer #27
“No because we have reduced them (N rates)… and we are trying to soil test and only put stuff on that needs to be there.” Farmer #6
“I think we have already done that (reduced N rate) to be honest.” Farmer #7
“We are thinking we need to be putting a little more on.” Farmer #26

Many farmers also felt that reduced yields will negatively impact the global food supply. Farmer #2 explained his perception of the tradeoff between N fertilizer reduction and world hunger, “Whether I use fertilizer or not, and whether a larger percentage of the population of the earth has access to reasonable priced nutrition, is huge.” Farmer #39 offers additional support of this perception,

> In agriculture we are seeing a very formidable task ahead of us in the next 20 years; we need to feed the people on this earth. I’m not just talking from my perspective, I’m talking about from the world’s perspective, and if you reduce the production in any way, shape, or form that just means more millions of people are going to starve.

While reduced yields do have an impact on commodity markets, the majority of the commercial corn farmers revealed they are selling crops to ethanol plants. Furthermore, approximately 55% of U.S. corn and 65% of total global corn production is used to feed livestock (FAO, 2006).

Farmers also expressed concern about “bad actors” being rewarded through a N_2O offsets program. The offsets program proposed would provide payments based on fertilizer reduction this year compared to the average of three previous years. Some farmers felt that such a program would unfairly reward farmers who had not been proactive with nutrient management and overlook those that had already reduced N fertilizer application in their operation. Farmer #31 explains, “I hate to see the guys not doing the good job getting the benefit, and that’s one of the worries I have about the program.” This articulates the challenges of developing policies that offer incentives for conservation practices while not excluding farmers (Dobbs and Pretty, 2004). While many farmers expressed concern about the reward system, it is unclear whether equity issues would significantly deter participation.

Additionally, barriers to participation were thought of in the form of increased time demands due to program administrative work. Farmer #39 makes the representative comment, “The farmer in general has a lot on his plate as it is, and to keep it as simple as possible would probably be the best approach if you want to appeal to more farmers.” Farmer #28 adds to this idea with his perceptions about programs being too complicated, “There would be too much red tape involved and too many hoops to jump through, which would discourage us from participating, especially when commodity prices are good.”

Summary: commercial farmers' interests in an offsets program

When posed as a theoretical and non-intrusive idea, an N_2O offsets program is attractive for farmers. Commercial farmers responded positively with interest to further examine opportunities through such a program. Economic analysis of the program was at the center of concern for most farmers who expressed interest. In addition, most commercial farmers believed that a market-based program would be more attractive than a government-led effort.

Commercial farmers in this study were not confident that N fertilizer application reductions are possible without adverse yield impacts. This further supports the idea that overall awareness of innovative N fertilizer application reducing strategies is low. Attitudes about global food supply depending on maintained N fertilizer application rates for adequate crop yields also indicate that there are obstacles to farmer adoption of conservation practices. Some farmers also expressed frustration with a program that rewards "bad actors." Program development will benefit from the consideration of these perceptions.

Seed corn results

Results from seed corn farmers have been dealt with separately in this study. Seed corn producers are a unique set of farmers that operate under different growing and contractual conditions. Previous seed corn studies (e.g. Preckel, 2000) have highlighted these particular circumstances that are deserving of individual attention compared to commercial corn farmers. The results from this study support the need to evaluate seed corn scenarios separately.

Responses from the interviews congregated around three main themes that are relevant to the ideas of N fertilizer application reduction and a N_2O offset programs. It was found that although the competitive contract, under which seed corn farmers operate, does not have limiting language regarding N fertilizer management, the nature of the competition limits a farmer’s ability to explore alternatives, i.e. N fertilizer application reductions. In addition, seed corn farmers made fewer associations between N fertilizer use and environmental impacts. The differing results highlight unique farm characteristics for seed corn farmers and corresponding challenges to participation in a N_2O offsets program.

Contract structure

Contract criteria for selecting farmers were generally the same when explained by each key informant. Characteristics noted by all key informants included soil type, irrigation, experience, and farmer history. Some key informants also noted geographic isolation capabilities for genetic purity, and farmer personality compatibility as significant criteria.

Contract structure varied between parent seed company contracts and wholesale company contracts. Parent seed companies use research and development to create new hybrids, which are then grown by farmers who engage in a contract with the parent seed company. Wholesale seed companies are contracted by parent seed companies to grow hybrid seeds; farmers enter into contracts with the wholesaler for the production. Pioneer Hi-Bred and Monsanto control approximately 65% of the global commercial seed market share (Howard, 2009). Both Pioneer and Monsanto use highly competitive contracts when engaging farmers to grow seed stock. These contracts are based on an average yield for the particular hybrid. Averages are calculated across the yields of numerous farmers growing the same hybrid. Baseline seed corn bushels are equated to the average commercial corn yield for the region. This conversion occurs because the vigor of seed corn produces much less than commercial corn. With a commercial corn equivalency as the starting point, contract multipliers are factored into the final payment. Additional incentives are offered for farmers whose yield is above average. Conversely, penalties are incurred if yields are below average. Table 4-9 provides key informant explanations of the competitive contract structure.

Table 4-9: Competitive Contracts as Expressed by Key Informants

Parent Seed Companies Offer Competitive Contracts
"It's strictly a competition contract…they're structured in a way that like fields of like hybrids are competing against one another…that way it takes any ambiguity out of what we do…you would harvest all the hybrids and get total bushels. Divide that by total acreage to get an average and then you would track individual grower's yields and they would compete against that average for the hybrid." Key Informant #3
"The more you were above average, the more you would be compensated. The commercial corn equivalent in St. Joe County was determined to be around 205-208 bushels per acre, if you're producing decent irrigated commercial corn. It's always fixed. Good growers, on good ground, you'll probably get between 205-208 bushels per acre. So that's their equivalency. If they hit average, that's what they're going to get. If they're below average then bushels are taken away. If they're above, a certain premium is given, whether it was 5%, 7%, or 10% more on top of the average. And likewise, it was for the reverse on the negative side as well. So you didn't want to be below average." Key Informant #3
"It's a very competitive contract. It's all based on growers being above hybrid average. It's worth at least 15 bushels to them to be above average versus 99% of average. So there's a lot of competition for growers to get there." Key informant #4

The wholesale seed contracts are not structured with the same degree of competitiveness. In general, wholesale companies are growing seed for seed stock companies that do not or cannot grow the seed themselves. Names of seed stock companies are held in confidentiality by wholesale farmers and were not released during interviews. Two key informants from wholesale companies explained that contracts with farmers are based on a fixed-price per bushel. Table 4-10 highlights the differences in contract structure for wholesale seed corn farmers.

Table 4-10: Wholesale Contracts as Expressed by Key Informants

Wholesale Contracts are Less Competitive
"Seed contracts are all different. Mine is a fixed price with an average bushels. We set a dollar an acre goal based on the average yield of that hybrid. If it's $1200/acre and it's a 50 bushel yielder, then they'd get paid around $24, in that range." Key Informant #5
"I figure it out on my own every year. I want to be $200 per acre better before seed stocking, trucking, bases, drying, all those things they don't have to do with seed corn. So it ends up being $400 an acre better usually and that's a good incentive for them to come with me. That way I can pick the good growers, the ones I want." Key Informant #5
"We have a minimum guarantee in our contract, minimum bushels per acre. A lot of the companies don't have that and that's fine but then we have a cap on the topside where the other companies don't have a cap." Key informant #2

All seed corn farmers were asked if their contract allowed for the flexibility to explore alternative N fertilizer application management strategies. No responses were given from seed corn farmers that indicated specific language in the contract prevents the farmer from exploring alternatives. Farmer #35 explains, "They (seed company) are fairly hands-off as long as the yield is what they think it ought to be; they don't really care how you get there. They give you guidelines to try and help with what the inbred might be, but they don't really tell you how you have to do anything." Notably, seed corn farmers acknowledged that seed companies don't specifically dictate their nutrient management, but an overwhelming number of respondents articulated that the competitive nature of the contract creates a constrained environment to exploring alternatives. This perception contributed to fewer seed corn farmers believing they had room to reduce N fertilizer application in their operation compared with commercial farmers. Table 4-11 provides additional data for this finding.

Table 4-11: Seed Corn Farmer Perceptions of Contract Restrictions

Perceived Restrictions of Contract
"…They really didn't dictate that per se but you're a fool if you don't fertilizer it, too. And if you don't, you won't be growing very long…" Farmer #11
"They don't expect a certain amount but they expect results. If I was to cut my nitrogen and my yields will go down I wouldn't have a contract." Farmer #20
"We have some room but you have to make for sure that it is okayed by the company agronomist and by the plant manager before you make at least any radical changes. They had us up in our nitrogen rates in the last 2 years over what we were doing because they felt we weren't competing as favorably…" Farmer #17

Competitive contract structures

Competitive seed corn contracts are structured such that financial incentives reward individuals whose yield is above average, and penalize individuals with yields below the average for a particular hybrid. In addition, the competitive reward (and penalty) system makes it difficult to calculate what an additional unit of input (e.g. nitrogen fertilizer) costs or benefits a farmer. On the other hand, commercial corn producers are largely dependent on prices being established through futures trading on the Chicago Board of Trade.

When seed corn farmers were asked about the importance of high yield versus high economic return, respondents from the seed corn sample indicated that high yields were of significant importance in their operation. Sixty-three percent of the respondents noted that high yields were either most important in their business or directly tied to high economic return. Farmer #17 explains this stark difference, "…high yields have to be where your emphasis is put as a seed grower or you will get killed (within yield rankings).” This is a notable difference from the responses given by commercial corn producers. High economic return was indicated as the most important factor for 90% of commercial corn farmers. These differences can be related to the financial incentives offered in each system. Seed corn farmers were very articulate in describing the competitive pressures that influence their decisions (See Table 4-12).

Table 4-12: Competition in Seed Production Encourages Yield Objectives

Competition Heavily Influences Choices
“If you don’t meet your goal you run the risk of losing your contract so it’s very competitive to a point no matter how you grow…whether you are competing against yourself or everybody else.” Farmer #39
“You wouldn’t think that 2 bushel/acre would make a difference but it could because you compete with everybody that’s growing that same variety in an average and 2 bushels could make it or break it.” Farmer #11
“It’s exceptionally competitive a lot of people won’t even tell you who they use for book keeping…the seed companies also highly discourage any interaction amongst growers; they do not want growers talking back and forth.” Farmer #17
“…It’s competition based with the seed corn so you want to grow the most bushels of that hybrid because you are competing with other growers so it is up to us but yet it isn’t.” Farmer #19
“I have to have yield and my end goal is I would like to stand in the top third…I’d be satisfied as long as I’m over the average but my real goal is to be in the top 3rd because I want to be that party. If I have acres to go to and when they need a few more acres they will come and say, ‘hey do you have somewhere you can put these for us’…” Farmer #33

Largely due to the competition, interest in participating in a N_2O offsets program was much lower amongst seed corn farmers. Only 25% of the seed corn farmers indicated that they would be interested in participating in an offsets program, compared to 86% of commercial farmers. While commercial farmers suggested that appropriate financial incentives could motivate their participation, seed corn farmers perceived potential contract rewards as much more appealing than program incentives. Farmer #27 explains,

> Anything above average has a lot of incentives and premiums so you want to stay in that super spot above average…a lot of times there are some fellow farmers that tend to play the economic thing and cut back a little bit, and they tend to be on the lower end…we really don't look at the economics of it and we tend to produce a little more, and that puts us above average which in turn makes more money.

Perspectives about associations between N fertilizer and environmental impact

Recognition of linkages between N fertilizer and environmental impacts were low across both seed corn farmers and commercial farmers. Seed corn farmers demonstrated a lower awareness of the associations between N fertilizer application, N_2O emissions, and global climate change. Only one seed corn farmer acknowledged the association between N fertilizer application and N_2O emissions, compared with 3 in the commercial corn sample. Two seed corn farmers claimed they were aware that N_2O is considered a harmful GHG, while 6 commercial farmers claimed an understanding. No seed farmers associated N fertilizer application with global climate change while 2 commercial farmers made the connection. An equal number (6) of farmers in each group denied the reality of global climate change. Farmer #11 expressed similar sentiment to that of many commercial farmers, "I'm not concerned about global warming. I'm not saying it's not a problem but I think there are just long cycles."

Seed corn farmers did express more awareness of water-related issues. Agriculture-related water issues were recognized by 42% of seed corn farmers while only 10% of commercial farmers were aware of local water quality problems regarding agriculture practices. The increased awareness amongst seed corn farmers could be attributed to the attention rendered by previous studies that have identified overapplication of N fertilizer in regions at high risk of groundwater pollution (Preckel et al., 2000). In addition, overall public awareness of water quality issues has increased as municipal sources have been compromised. Seed corn farmers also expressed concern about something that was absent in commercial farmer responses; water quantity issues were noted as an emerging issue due to the irrigation requirements of seed corn systems. Three farmers expressed concern about water quantity issues in the region. Michigan Department of Environmental Quality (DEQ) introduced two regulatory measures regarding well drilling and water extraction. Beginning in February of 2006, DEQ introduced a measure that stipulated, "All new withdrawals are prohibited from causing an adverse impact to the waters of the state" and starting in July of 2009, the Water Withdrawal Assessment Tool was mandatory for all new proposed wells (DEQ, 2009). Due to the heavy concentration of irrigated corn systems in southwestern Michigan, these farmers believed the larger concern should be water distribution amongst the agricultural community. In defense of what they perceived as increased regulations that could negatively impact irrigated systems, these farmers noted their preemptive legal groundwork for future face-offs. Farmer #24 explains,

> We figure they are going to tax us on gallons…. we are paying them (consultants) $2/acre for all the acres and we are hiring our own people… We have a longer term deal that when we start litigating…we are going to have our ducks in a row with our lawyers…

Although the water quantity concern was limited to a few farmers, it offers insight regarding what farmers perceive as important future issues. More directly, it highlights factors of importance that are immediately related to farm operations, e.g. water availability for crop irrigation. One of the difficult aspects of mediating global climate change behaviors is the inability to directly associate actions with immediate impacts.

Lack of collaboration among seed corn farmers

Contract systems have fostered an environment where seed corn farmers are resistant to collaborate or cooperate with each other, likely impacting their willingness to participate in regional climate change mitigation efforts. Distrust is prevalent amongst seed corn farmers and further constrains willingness to change nutrient management strategies. Farmer #22 explains his distrust, “There are those guys out there that would say ‘yea’ but if everyone would decrease nitrogen they would increase theirs just to try to take advantage of it…at least that’s the feeling that a grower has.” Additional data are provided in Table 4-13.

Table 4-13: Seed Corn Farmer Perception of Community Collaboration

Seed Corn Farmers Expressed Little Faith in Community Collaboration
“I don’t want anybody to govern how I raise my crop, that’s kind of the way I feel because then you’re telling me I can’t do that and I’m competing against somebody else, and that puts me at a disadvantage.” Farmer #19
“…It is just hard to do that when you are competing because I don’t know how that would work on a competitive contract. I really see a problem there, and how could you trust guys, so that would be my question.” Farmer #24
“It’s kind of a dynamic thing because if one grower agrees to live by this it allows another grower to opt out and use more, and if he is successful at increasing his yield significantly above yours then it drives your income lower.” Farmer #22
“One of the things that is difficult about growing seed corn is that if the field across the road is planted the same as mine and I’m competing against it then it’s hard for me to ever feel good about seed on my neighbors ground…I’m thinking jeez when’s the hail going to get here…it’s that kind of thing that you can’t be happy for the neighbor because it means so much to you. We’re all friendly to each other but we all know the stakes of competition.” Farmer #29

These responses suggest that the competitive nature of the contract discourages cooperation amongst the farm community. The benefits of community influence, or civic structure, on farmer behavior (Morton, 2009) might be lost as competition further divides communities. Resulting insular and anti-social actions can further inhibit conservation adoption (Corral-Verdugo and Frias-Armenta, 2006). This is unfortunate because collaborative frameworks that bring together stakeholders can be more effective in policymaking (Koontz, 2006) and may be beneficial at engaging farmers and seed corn companies for N_2O emissions mitigation efforts.

Summary: seed corn results

Seed corn farmer responses suggest that N fertilizer application reductions will be particularly challenging for this group. Competitive contracts further constrain farmer ability to explore alternative N fertilizer management schemes. Responses suggest that risks of N fertilizer application reductions are perceived to be greater than those had by commercial farmers. This can be attributed to both the financial incentives of current-year crops as well as the ability to secure subsequent-year contracts.

Summary

Interviews of farmers and key informants revealed a low awareness of the association between N fertilizer application and N_2O emissions or global climate change. Bringing up climate change elicited strong responses that indicated many respondents do not believe current scientific findings that point to anthropogenic influences. Large climate cycles or total denial were common arguments from farmers and key informants. Contrary to their denial, most farmers believed they could play a positive role in future mitigation efforts. There was higher water quality awareness compared to climate change, but farmers largely believed that water quality is not being adversely impacted by intensive agriculture practices. Lack of public education and a disconnection between urban and rural communities were pointed to as alternative culprits for misconceptions of farming impacts on the environment.

Commercial corn farmers responded positively to the idea of a N_2O emission offsets program. High economic returns were of first importance to commercial farmers and their responses suggest they will use this as a guide for any program evaluation. Almost all farmers preferred a market-based compared to a government-based approach regarding program structure. A majority of commercial farmers noted they use traditional yield goal estimates for N fertilizer application rates and are influenced by fertilizer dealers.

Seed corn farmers were less aware of the associations between N fertilizer and N_2O emissions. Although explicit language is not present, the competitive nature of the contract structure inhibits many farmers from seeking ways to be more efficient with N fertilizer application. Furthermore, the lucrative incentives offered through the contract are in many cases more attractive than N_2O offsets program incentives would be. The competition has also bred a sense of distrust amongst the community, and farmers expressed doubt that collaboration would be successful.

CONCLUSION

Environmental impacts due to intensive agriculture practices are widespread. Water quality, soil productivity, habitat availability, and global climate change all represent concerns related to modern intensive agriculture systems that provide food, fiber, and fuel for the growing population. Nitrogen (N) fertilizer application is a focal point in this relationship, both as a key component to production agriculture as well as a significant contributor to environmental degradation. Understanding farm-level perceptions of this relationship and the decision-making factors regarding application is critical for developing successful efforts to mitigate environmental problems.

Reflections on research results

This study has been an exploration of the perceptions of corn farmers and industry representatives in southwest Michigan regarding the environmental impacts of N fertilizer. The study focused on perceptions of the impacts of N fertilizer application on nitrous oxide (N_2O) emissions, global climate change, and water quality. It was not the intent of the study to gauge the adoption of conservation practices related to these environmental issues rather to develop an understanding of how farmers might react to a N_2O offsets program that provides rewards based on N fertilizer application reductions. In addition, respondent input regarding program and incentive structure was sought to help identify qualities that might increase or inhibit participation.

Through 40 farmer and 6 key informant in-depth interviews, this study explored perceptions about the association between N fertilizer application and environmental impacts. Research questions aimed to understand if respondents associated N fertilizer application with N_2O emissions or global climate change, how N fertilizer application was perceived to impact water quality, how willing farmers were to reduce N fertilizer application, and what barriers might prevent participation in an N_2O emissions offsets program.

Results indicated that farmer awareness of associations between N fertilizer and environmental impacts are low. Very few farmers were aware that N_2O is considered a harmful greenhouse gas (GHG) and fewer associated N fertilizer application with N_2O emissions or global climate change factors. Furthermore, questions about global climate change revealed that most farmers are skeptical about current scientific findings that attribute anthropogenic influences to global climate change. Although water quality associations were greater than climate change, most farmers believed that historical nitrate leaching and surface runoff issues had been abated. The implication of these findings suggests that the voluntary adoption of N fertilizer reduction schemes will be low without acknowledgement of the environmental issue.

Information sources were found to both shape individual farmer perceptions of environmental issues as well as guide the decision-making for farm practices. In this study almost twice as many farmers noted they are more influenced by fertilizer dealers than by Michigan State University (MSU) fertilizer recommendations. Some farmers also noted allegiance to conservative or agri-business positions of climate change denial, like that of the Farm Bureau. This suggests individual perceptions are shaped by, and respond to, the structural and social context.

Farmers often pointed to other contributors of GHG emissions and environmental deterioration. Urban residents were frequently identified as gross polluters and also as unaware of current farm stewardship efforts. This community disconnection was highlighted as a reason for farm pollution misconceptions. While some farmers acknowledged the need to better harmonize farm practices with environmental concerns, global food production demands was a common defense to continue current practices. This reasoning aligns with agri-business sentiment for continued intensive production agriculture. These relationships, and lack thereof, suggest that awareness and attitude of environmental issues regarding N fertilizer will be slow to evolve.

Financial incentives to reduce N fertilizer application rates could be an effective mechanism for encouraging commercial corn farmers to change practices. Most commercial farmers indicated that if economic analysis of participation in a N_2O emission offsets program continued high economic return, their willingness to participate would be high. This response highlights the importance of short-term economic return and the inability to reflexively act on environmental conservation needs without appropriate incentives. Although most farmers are familiar with government programs that encourage conservation, almost all the interviewed farmers explained that a market-based program would be more attractive. Considering the lack of U.S. political will to mandate climate change legislation, bottom-up programs that engage farmers in conservation practices may be effective at mitigating N_2O emissions. However, farm policies that continue to prioritize production over conservation could serve to limit participation.

Seed corn farmers engaged in competitive production contracts represent a unique group that deserves special attention when considering N fertilizer application reductions. The findings suggest that due to the competitive nature of the contract, a famer's ability to explore N fertilizer application reductions through a N_2O emissions offsets program is greatly constrained. Furthermore, farmers noted that competition encourages excess application of N fertilizer. Seed companies dismiss responsibility for shaping farmer behaviors regarding N fertilizer application, but they are clearly instrumental in influencing production decisions. Without addressing these structural influences, the promotion of N fertilizer application reduction will likely be ineffective in changing seed corn farmer practices within the broader context of GHG emissions mitigation. In addition to potential environmental impacts, competitive contracts also inhibit collaboration. Farmers expressed concern about diminished community engagement due to the contracts. As social networks break down, the diffusion of information regarding environmental impacts and correlating solutions becomes further fragmented. Although some farmers and seed companies might financially benefit from the contract arrangement, socially optimum outcomes regarding environmental quality are diminished.

As scientific and political undertakings aim to mitigate climate change, it's imperative to understand factors that shape participation in mitigation efforts. Understanding farmer decision-making is an essential component to implementing effective mitigation programs; however, specific socioeconomic barriers have thus far been neglected in the climate change literature. This study begins to address the gap by identifying barriers to participation in agricultural practices that are motivated because of needed climate change mitigation. More broadly, the findings from this study contribute to the already substantial literature about farmer decision-making, stewardship, and farmer values. While contribution to these areas is beneficial, this study offers new and much needed insight into the limited understanding of factors that inhibit responses to climate change.

Future research

This research exposes some important findings related to the political nature of addressing global climate change. Growing concern amongst the scientific community about the anthropogenic influences are not perceived in the same manner across the farm community. Future research could further explore how political affiliations shape farmer perceptions of global climate change and how these orientations might impact adoption of conservation and mitigation practices. In addition, it was clear in this study that although research institutions are generally respected in the farm community, many farmers are out of touch with current scientific findings. As our information sources continue to evolve, it might be beneficial for future research to explore the most effective avenues of scientific communication with the farm community.

This study also highlights the need for future research to continue to address the environmental implications of structural constraints. In the case of competitive seed corn contracts, farmers are largely responsible for environmental impacts even though contract structure encourages environmentally harmful behavior. The short-term financial benefits of such an arrangement are jeopardizing important ecosystem services for society. As research continues to identify the real costs and benefits of intensive agriculture systems, understanding these factors might better support efforts to alter farm-level decisions.

APPENDICES

APPENDIX A: FARMER INTERVIEW GUIDE

General

1. What kind of corn do you grow? (Commercial, Seed, Sweet)
2. Who do you sell your corn to?
3. What type of N fertilizer do you use and when and how do you apply it?
4. Where do you get information regarding how much fertilizer to apply?
5. How do you determine how much fertilizer to apply?
6. Who do you share your fertilizer application information with?
7. What factors change how much you would apply in a given year? Costs of fertilizer?
8. How have your application practices changed since you've been farming?
9. Who might influence how much you apply? (buyers, fertilizer dealers, other farmers)
10. *Commercial Farmers Only*: Do you follow the MSU guidelines for application?
11. *Seed Corn Farmers Only*: Do you feel you have room to change application rates or do the companies you grow for expect a certain rate of application or yield?
12. Where do you purchase your seed and what kind is it?
13. Do you think that additional fertilizer application offsets certain risks? Which ones?
14. What is most important to you in your business - having high yields or having a high economic return (take-home income)?
15. Do you think it would be reasonable to reduce fertilizer application in your operation?
16. Do you participate in any NRCS programs? Which ones? Why?

Potential N Fertilizer Reduction Program

17. What would you think of an incentive program that paid farmers to use fertilizer more efficiently – paying for reduced application? Would you be interested in participating?

18. How much do you think you would need to be compensated to reduce application?
19. Does a program through the government or a market-based program that offered payments for fertilizer reduction sound more attractive to you?
20. Would a commodity-based incentive structure discourage your participation?
21. Would you be interested in payments through such a program whether or not you are concerned about global warming?
22. Do you associate nitrogen fertilizer with the emissions of nitrous oxide gas?
23. Did you know nitrous oxide gas is considered an important greenhouse gas?
24. Do you associate fertilizer use with global warming?
25. What sources do you trust regarding global warming?
26. How does science influence your feelings about global warming?
27. Do you think farmers can play a role in the future regarding mitigating global warming?

Water quality questions

24. What watershed is your farm located in?
28. Do you hear much information about water pollution in the area? From where?
29. What do you know/hear about Nitrate leaching into groundwater? Do you think this is an important issue?
30. Are you a part of a NRCS EQIP program? If so, what do you do? A Nutrient Man Plan?
31. What do you see as the relationship between fertilizer application and water quality?
32. Are your fertilizer application practices influenced by water quality considerations?
33. Do you consider water quality impacts to be a collective or regional issue?
34. Do you consider water flow off of your property to impact collective or regional water sources?
35. What other agriculture-related issues do you think are important?

APPENDIX B: KEY INFORMANT INTERVIEW GUIDE

1. How many farmers and acres are under contract?
2. What are the criteria for a new farmer to enter into contract?
3. How are the contracts structured?
4. What are the factors that determine contracts for subsequent years?
5. What information do you provide the farmer? Seed? Yield Potential? Nutrient Requirements?
6. Does the contract provide guidelines for N application?
7. What agronomic consulting services does the company provide the farmer?
8. Does the contract allow the farmer flexibility to explore alternative nutrient management strategies?
9. Do you think it would be reasonable for farmers to reduce N fertilizer application?
10. Does the company collaborate with conservation programs or conduct any of its own? Which ones?
11. Is there flexibility within the contract for farmers to participate in conservation programs?
12. What would you think of an incentive program that paid farmers to use fertilizer more efficiently – paying for reduced application?
13. Do you associate N fertilizer with emissions of nitrous oxide gas?
14. Did you know that nitrous oxide is considered an important GHG?
15. Do you associate N fertilizer with global warming?
16. Do you think (your company) can play a role in the future regarding the mitigation of global warming?
17. Does the company have a plan or vision for future/sustainable agriculture that it promotes? What is it?

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