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VOLUNTARY VERSUS MANDATORY AGRICULTURAL POLICIES TO PROTECT WATER QUALITY: ADOPTION OF NITROGEN TESTING IN NEBRASKA

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Agriculture is among the principal contributors of nonpoint source pollution, a major cause of impaired water quality (Puckett). The amount of agricultural pollution depends in part on agricultural practices or technologies that farmers employ. In the United States, policies for changing farmers' practices related to soil conservation and water quality protection have usually relied on voluntary adoption of new practices. Policy tools to promote voluntary adoption include extension education, technical assistance, and cost sharing. In recent years, both state and federal water quality projects have been initiated targeting these different approaches to different areas. Increasingly, however, regulation is being used by the Federal Government and by states to mandate the adoption of practices by farmers (United States Environmental Protection Agency 1993; Ribaudo and Woo). To date, little research has been undertaken on the relative effectiveness of regulatory and incentive approaches. While the immediate goal of adoption may be more easily achieved by regulation, that regulation will not necessarily lead to the proper or desired use of the practice. This article investigates the relative effectiveness of incentive projects and regulation to promote both adoption of nitrogen (N) testing and the use of information from the tests to adjust N fertilizer use.

The study is conducted in Nebraska where the effects of agriculture on groundwater are of special concern. Groundwater provides irrigation for one-third of Nebraska's cropland and drinking water for almost all of the domestic water users. In some areas, nitrate concentrations in well-water samples have exceeded 10 mg/L, the maximum limit considered safe for human consumption (United States Environmental Protection Agency 1990). In an effort to control nonpoint source contamination of groundwater resources, Nebraska has pursued a combination of voluntary and regulatory approaches to change farm management practices (see Figure 1).

One of the principal means for reducing nitrate contamination of groundwater from agriculture is to improve the efficiency of N fertilizer management. Soil and/or tissue N testing are important recommended practices in many project areas and are required in some regulated areas. N testing is an information technology that is designed to increase N fertilizer efficiency by more closely matching crop N needs with N fertilizer application, thereby leaving less N residual that could contaminate the environment. Studies by Bosch, Fuglie, and Keim; Shortle et al.; Morris and Blackmer; Blackmer, Morris, and Binford; and Bundy, Schmitt, and Randall have suggested that for many farms, N testing is likely to be profitable in the long run.

In the next section, policies for promoting adoption using voluntary and regulatory approaches are described. This section is followed

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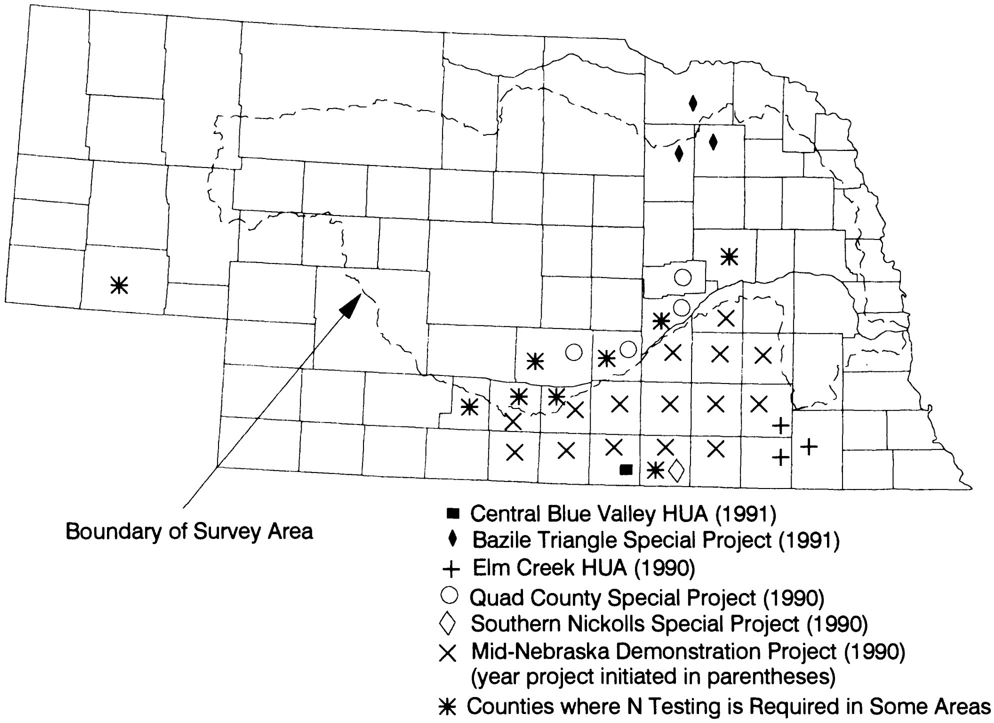

Figure 1. Projects and Regulations to Protect Groundwater Quality in Nebraska

by a discussion of the model and empirical results. The final section concludes with some implications for technology transfer policy.

Promoting Adoption of Farming Practices to Protect Water Quality

There are a number of policy approaches for reducing the environmental impacts of agricultural production. Abler and Shortle identified four general strategies to protect water quality from agricultural chemicals: (1) moral suasion and education; (2) direct regulation; (3) economic incentives; and (4) research and development. Moral suasion and education are based on the premise that farmers will voluntarily adopt pollution control practices if they are fully informed about the economic and environmental consequences of their current practices. Direct regulation can be implemented through either design standards (regulating the way farmers produce and manage their resources) or performance standards (regulating the quantity of observable pollution resulting from production). Economic incentives may include taxes on inputs that contribute to pollution, fees on observable pollutants released, or subsidies to defray the costs of using pollution control practices. A long-term strategy for reducing environmental impacts of agricultural production is to encourage research and development of alternative production practices that result in less pollution. In Nebraska, public policies to protect water quality have relied principally on the first two types of instruments: (1) moral suasion and education; and (2) direct regulation through design standards. The implementation of these policies is described in some detail below.

Education and Information Dissemination

Federally-funded water quality projects that are part of the President's Water Quality Initiative (United States Department of

Agriculture 1991) include Water Quality Demonstration Projects, Hydrologic Unit Area Projects (HUA's), and Water Quality Special Projects. These projects use three basic approaches to information dissemination and education about a common set of practices to protect water quality: (1) providing technical information; (2) cost sharing the adoption of practices to reduce pesticide, nutrient, and/or irrigation water use; and (3) "persuasion" methods.

Providing free technical information is an educational approach that may improve the efficiency of farmers' decisions and result in better water quality. For example, information may be provided in the form of a handout about a management practice such as a soil test to reduce nutrient applications. The information may increase farmer profits, and therefore be effective even if a farmer is a non-altruistic profit maximizer.

A second approach is to provide cost sharing for practices that reduce potential water quality damage. For example, cost sharing may be used to hire outside consultants who provide technical information that increases the effectiveness of chemical inputs and reduces pesticide, nutrient, and/or irrigation water use. This approach represents a combination of educational and economic incentives. The education comes from enabling the farmer to learn about new technology by trying it while economic incentives are provided by the temporary cost share. Because the cost share is temporary, the program is likely to be effective in the long run only if the recommended practices are perceived to be economically viable. Like the public provision of technical information, cost sharing may be effective when the farmer is assumed to be a non-altruistic profit maximizer.

A third approach, which is an example of moral suasion, is to "persuade" farmers to adopt better practices. The case for adoption may be that the practices are needed for the "public good" because of the risks associated with water quality degradation. This approach implies that farmers' objectives may be changed by education so that they derive more satisfaction from reducing pollution, and hence they may be prepared to sacrifice profits for environmental improvement. Persuasion may also be attempted by asserting that if farmers do not act voluntarily to protect water quality, they are likely to be regulated in the future. Rather than attempt to change farmers' objectives, this type of persuasion appeals to farmers' self interests by raising the possibility of high adjustment costs caused by future regulation if farmers do not voluntarily adopt such practices now.

Both the federally-funded special projects and HUA's provide technical and cost-share assistance for practices that reduce nonpoint source problems. The underlying philosophy in the special projects and the HUA's may be characterized as "learning by doing." Seventy-four HUA's and 110 Water Quality Special Projects have been started (United States Department of Agriculture 1993a). In contrast, demonstration projects adopt a more widespread educational approach to technology adoption which includes making technical information widely available, using persuasion, and placing less emphasis on one-on-one technical and financial assistance to individual farmers. The emphasis is on the dissemination of information over a large area using radio, television, and newspaper reports, newsletters, field demonstrations, farm tours, and other methods. The underlying philosophy may be described as "learning by example." Sixteen federally-funded demonstration projects were initiated in 1990 and 1991 (United States Department of Agriculture 1993a).

In Nebraska, federally-funded special projects were initiated in 1990 in the Quad County Special Project which included Buffalo, Hall, Merrick, and Nance Counties located in the Central Platte Basin; and in 1991 in the Bazile Triangle, which includes Knox, Antelope, and Pierce Counties (Figure 1). These projects provide cost-sharing and technical assistance for fertilizer, pesticide, and irrigation management. Assistance is available for up to three years for pest management activities such as field scouting, crop rotations, biological pest control services, ridge till, and the planting of host crops; and for nutrient management activities such as soil testing, legumes in rotation, leaf tissue analysis, and manure analysis (Bazile Triangle Water Quality Group). The Mid-

Nebraska Demonstration Project, which relies primarily on education programs, was established in 1990 in 15 counties south of the Platte River (Figure 1). Two Water Quality HUA Projects were also established in southern Nebraska, the Central Blue Valley HUA in 1991 and the Elm Creek HUA in 1990. State and local support for education and extension programs complement federal resources in all of these projects.

Regulations to Protect Water Quality

Several states have enacted regulations requiring farmers to follow specific guidelines (design standards). Currently, at least 17 states have enacted regulations governing fertilizer and nutrient use by farmers. Regulations may: (1) require farmers to obtain permits to apply nutrients; (2) require the use of "best management practices"; (3) ban certain management practices; or (4) restrict chemical use. Regulations may include land use controls, which can ban crop production from sensitive areas or require vegetative filters. However, no state has a comprehensive legal framework for protecting both surface and ground waters from all agricultural nonpoint source pollution (Ribaudo and Woo).

Although the Federal Government has generally relied on voluntary measures to promote resource conservation, recent legislation has moved toward more regulations. The 1990 Coastal Zone Act Reauthorization Amendments require states in coastal areas to develop a set of "best management practices" and land-use controls to reduce nonpoint source pollution. These states are also obliged to enforce the use of these practices by farmers in sensitive coastal areas (United States Environmental Protection Agency 1993).

In Nebraska, the state legislature enacted the Groundwater Management and Protection Act in 1975 to control fertilizer use to reduce nitrate concentrations in groundwater. This act established broad local control for solving water problems by giving extensive management responsibilities to the 23 Natural Resource Districts (NRD's) covering the State. The NRD's may act alone or in cooperation with the Nebraska Department of Environmental Quality to develop management plans that may require farmers to adopt certain management practices. Since passage of the act, three of the State's NRD's have established groundwater control areas. The most important and extensive of these is the Central Platte NRD, where fall and winter applications of N fertilizer on sandy soils are restricted, and in the most severely affected areas, farmers are required to conduct N tests and keep records of N fertilizer applications. The regulations do not, however, require farmers to actually use N test results or to restrict the amount of fertilizer applied (Williamson). The counties in which N testing is required for at least some cropland are indicated in Figure 1.

Evaluating Effects of Policies on Adoption of N Testing

If the decision to adopt N testing is voluntary, then the adoption decision is assumed to reflect a profit-maximizing decision by farmers. Farmers adopt new technology if and when they determine it is profitable for them to do so, given their knowledge base and available resources.

Let the profitability of adoption be given by I^*. A farmer adopts the new technology if $I^*>0$ and doesn't adopt if $I^*\leq 0$. However, I^* is often a latent variable and is not observed directly. Instead, what is observed is the technology choice decision whether or not to conduct N tests. Regarding the farmer's decision to conduct an N test, the technology adoption decision is NTESTADOPT=1 if $I^*>0$ and NTESTADOPT=0 if $I^*\leq 0$. The profitability of adoption is determined by a set Z of exogenous variables. The adoption of new agricultural technology may be influenced by farm size, tenure status, human capital (including management time and skill), risk aversion, land quality, and other physical or socioeconomic characteristics of the farm or farming environment (Rogers; Feder, Just, and Zilberman; Feder and Umali). Technology adoption can be modeled as:

$$\text{NTESTADOPT} = \gamma Z + \varepsilon, \qquad \textbf{(1)}$$

where Z contains a set of variables that determine the profitability of adoption, γ is a vector of parameters, and ε is a normallydistributed error term with mean 0 and variance σ^2. Since NTESTADOPT is restricted to values of 0 or 1, equation (1) can be consistently estimated by a limited dependent variable model, such as the probit model (Maddala).

Policies affect the profitability of adoption by either influencing a farmer's perception of the value of using the new technology, or by requiring its use and imposing a penalty for noncompliance. Designating the presence of the voluntary assistance program by a variable PROJECT and laws requiring adoption by a variable REGULATE, the adoption decision becomes:

$$\text{NTESTADOPT} = \alpha\text{PROJECT} + \beta\text{REGULATE} + \gamma Z + \varepsilon. \tag{2}$$

In equation (2), α and β measure the effect of the policy variables on the probability that a farmer with characteristics Z will adopt the new technology.

The second level of the policy's effectiveness is to determine how adoption of the N test affects actual N management decisions. Voluntary adoption of N testing would probably influence a farmer's fertilizer application decision more than mandatory adoption because a farmer might ignore information provided by the N test if the test was not considered useful. As previously indicated, the Nebraska regulations require N testing in some cases, but they do not require that results of the tests be used or that farmers reduce N applications. The N test's value to the farmer will depend upon farm and field characteristics as well as the farmer's prior level of knowledge and experience – both about the N test and about nutrient management in general. To assess these factors, define a decision variable, NTESTUSE, as the actual source of information used in fertilizer management. Using only the subsample of adopters, the impact of the policy variables can be assessed by estimating the following model:

$$\text{NTESTUSE} = \theta\text{PROJECT} + \psi\,\text{REGULATE} + \delta X + \nu, \tag{3}$$

where X is a vector of variables measuring a farmer's prior level of knowledge and experience as well as other farm and field characteristics, and ν is an error term.[1] In our specification, X and Z contain the same variables.

Data Description and Definition of Variables

Data for the empirical analysis comes from the United States Department of Agriculture's Area Studies Survey (1993b). In 1991, 3,006 points were randomly sampled from the Central Nebraska Basin using an area-frame sampling procedure. Information corresponding to 1,433 sample points was obtained from personal interview surveys.[2] The interviews were conducted with farm operators to determine farming practices on the fields during the previous three years as well as general information about the farm operation.

The sample points corresponded to the National Resource Inventory (conducted quinquennially by the Soil Conservation Service) so information on soil characteristics of the field was also available. Because the unit of observation was the field containing a sample point, a weighting scheme was devised to make the sampled observations representative of the areas surveyed. Each observation was assigned a weight equal to the inverse of the probability of the field being selected times the acres of the field containing the point. Observations were weighted by this factor for all the statistical analyses conducted in this study.

Fields that were planted to corn in either 1990 or 1991 were selected for the analysis of the adoption and use of N testing for N fertilizer management. Corn is the major user of N fertilizer in the United States (Vroomen and Taylor). A field was included in the data only once in order to avoid serial correlation. If a field was planted to corn in both 1990 and 1991,

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[1]Equation (3) is estimated separately from equation (2). Although in equation (3) we are considering a subset of the population considered in equation (2), there is no sample selection bias because the population being evaluated in equation (3) is the population of N test adopters.

[2]The rest of the sample points either fell in non-agricultural areas or inaccessible areas (12 percent), were screened out because multiple points fell on the same farm (19 percent), or farm operators declined to be interviewed (21 percent).

only the 1991 observation was selected. The selected sample consists of 449 observations.

The two dependent variables are NTESTADOPT, indicating whether a farmer conducted a soil or tissue N test on the sampled field, and NTESTUSE, indicating whether the N test was the principal factor used in determining fertilizer applications. The survey asked farmers to indicate the most important factor in their decisions on when and how much N to apply to crops. The possible responses to the survey are given in Table 1. "Soil and/or Tissue Test" received the highest percentage response among all users as well as among N test adopters. NTESTUSE takes on a value of 1 if the judgement was based on the soil and/or tissue test and 0 otherwise.

Table 2 defines the variables used in the model. The policy variable PROJECT equals 1 if a farm is located in a county in the Quad County Special Project Area and 0 otherwise. While this special project was initiated in 1990, it was preceded by a demonstration project sponsored jointly by the Central Platte NRD and the University of Nebraska that was begun in the mid-1980's (Ferguson). These counties have received a concerted educational effort to promote farming practices, such as N testing, that are designed to reduce chemical loadings and improve groundwater quality. Cost sharing is also available to promote integrated crop management as described earlier. Other projects were too recently established to be evaluated. The second policy variable, REGULATE, takes on a value between 0 and 1, depending upon the proportion of cropland in the county on which N testing is required. Data on the extent of regulation was collected from county offices of the Soil Conservation Service. Information about whether an individual farm was required to conduct N tests was not available.

The separate effects of regulation and the project can be evaluated because the degree of regulation varies across counties both inside and outside of the project. Two counties with 33 sample observations had regulated cropland, but were not in the special projects. Three of the four project counties (82 sample observations) had regulated cropland varying from 0.21 to 0.77 as a proportion of total cropland.[3] The fourth project county (four observations) had no regulated cropland.

Table 1. Most Important Factor in Determining N Application

Response	All Respondents (percent)[a]	Among Adopters (percent)[a]
No N Applied	2.69	0.00
Fertilizer Company Recommendation	12.11	13.00
Consultant Recommendation	13.23	16.59
Crop Appearance	7.17	1.35
Soil and/or Tissue Test	35.43	57.40
Extension Service Recommendation	2.91	4.04
Standard Amount Applied	25.34	6.28
Other	1.12	1.35

[a]Percentages do not sum to 100 due to rounding.

Farm characteristics that affect the adoption decision (vector Z in equations (1) and (2)) include farm sales as a measure of farm size, tenure status, education, farming experience, whether the farmer had crop insurance (a proxy for risk aversion), previous cropping history, previous manuring, whether the field was irrigated in the past three years, and land quality characteristics. Previous cropping history and manuring may affect the level of soil N available for the current crop. N testing may be one way to reduce this uncertainty. LEGUME is a dummy variable indicating whether the previous crop was a legume (e.g., soybeans or alfalfa). MANURE measures whether the field received an application of manure during the previous three years.

Five variables are used in this study to measure various aspects of soil quality. Soil texture (the size of mineral particles) has a critical influence on water and nutrient retention, and is measured by a dummy variable for sandy soils. Sandy soils have large particle size, and therefore a low water and nutrient retention ability. Soil reaction (pH) can influence cation exchange capacity. Cation exchange capacity is

[3]Two other counties in the study area had regulated cropland, but no sample observations in the subset of farms considered here.

Table 2. Description of Variables Used in Statistical Analysis

Dependent Variables	
NTESTADOPT	Whether an N test was performed (1=yes; 0=no).
NTESTUSE	Whether an N test was the main source of information for N fertilizer management decision (1=yes; 0=no).
Exogenous Factors	
REGULATE	Proportion of cropland in county required to conduct N tests.
PROJECT	Sample field located in county with United States Department of Agriculture Water Quality Special Project in 1990 (1=yes; 0=no).
Farm Characteristics	
LHSCHOOL	Farm operator did not complete high school (1=yes; 0=no).
HSCHOOL	Farm operator just completed high school (1=yes; 0=no).
COLLEGE	Farm operator has some college education (1=yes; 0=no).
EXPER	Years the farmer has been operating a farm.
SALE1	Gross annual farm sales < $100,000 (1=yes; 0=no).
SALE2	Gross annual sales between $100,000 and $250,000 (1=yes; 0=no).
SALE3	Gross annual sales > $250,000 (1=yes; 0=no).
OWNER	Sample field owned by farm operator (1=owned; 0=rented).
CROPINS	Farmer had insurance for crops grown in field (1=yes; 0=no).
IRRIG	Field irrigated in past three years (1=yes; 0=no).
MANURE	Manure applied to field or field pastured with livestock in past three years (1=yes; 0=no).
LEGUME	Legume grown in field the previous season (1=yes; 0=no).
Soil Characteristics	
SANDY	Soil has sandy texture (1=yes; 0=no).
ORGMAT	Organic matter of soil in top layer (percent of weight).
pH	Soil reaction (pH).
SLOPE	Slope of field (%).
T-FACTOR[a]	Soil loss tolerance factor (acceptable level of annual soil loss – one to five tons per acre).

[a]For a formal definition of this variable, see Wischmeier and Smith.

related to the soil's ability to hold positively-charged pesticide and nutrient molecules. The organic matter content of the soil influences plant growth by increasing water-holding capacity, improving soil tilth, and releasing mineral nutrients (National Research Council). The other two soil quality variables are the slope and the soil loss tolerances (T-factor) of the field. The T-factor reflects soil depth and other factors (Wischmeier and Smith). Although these five variables measure different aspects of soil quality, they are not entirely independent of one another. Sandy soils, for example, tend to have lower organic matter content, lower pH values, and less soil depth. Organic matter can also affect the pH level (National Research Council).

Empirical Results

Adoption of N Testing

Estimates of the model of N test adoption, standard deviations of variables, and several "goodness of fit" measures are given in Table 3. The χ^2 statistic tests the overall explanatory power of the exogenous variables and indicates that the model as a whole is statistically significant at the 0.01 level. McFadden's Pseudo-R^2 is 0.274.[4] The effect of a change in an exogenous variable on the probability of adoption is quantified by multiplying the estimated coefficients by $\Phi(\hat{\gamma}Y)$, where $\hat{\gamma}$ is a vector of the estimated values of the coefficients, Y is a vector of all the right-hand-side variables, and Φ is the cumulative distribution function of the standard normal distribution (Maddala). At the mean values of the variables in the N test adoption equation, $\Phi(\hat{\gamma}Y)$ equals 0.506. Another "goodness of fit" measure for a probit model is the percentage of correct predictions obtained

[4]McFadden's Pseudo-R^2 is equal to $1\text{-}\ln L_u/\ln L_r$ where $\ln L_u$ is the log likelihood of the unconstrained model and $\ln L_r$ is the log likelihood of the model with all coefficients (other than the constant term) set to zero.

Table 3. Probit Model of N Test Adoption and Use[a]

	N Test Adoption		N Test Use (Among Adopters)	
Variable	Coefficient (t-ratio)	Mean (std. dev.)	Coefficient (t-ratio)	Mean (std. dev.)
CONSTANT	-5.3487***		1.0905	
	(-4.0960)		(0.6470)	
REGULATE	1.3098**	0.0705	-0.8092*	0.1364
	(2.2190)	(0.1847)	(-1.7340)	(0.4902)
PROJECT	0.2854	0.1513	0.6140**	0.2634
	(1.0530)	(0.3587)	(2.2700)	(0.4415)
HSCHOOL	0.5551**	0.4853	0.2646	0.3959
	(2.0190)	(0.5003)	(0.5610)	(0.4902)
COLLEGE	1.0648***	0.4211	0.1527	0.5624
	(3.7020)	(0.4943)	(0.3250)	(0.4972)
EXPER	0.0069	22.3000	0.0106	20.8770
	(1.0970)	(12.5410)	(1.2620)	(11.8810)
OWNER	-0.4295***	0.3435	0.1334	0.2944
	(-2.685)	(0.4754)	(0.5920)	(0.4568)
CROPINS	0.3266**	0.5686	0.0661	0.6779
	(2.3050)	(0.4958)	(0.3370)	(0.4683)
SALE2	-0.3512**	0.3489	0.0689	0.2962
	(-1.9380)	(0.4772)	(0.2630)	(0.4576)
SALE3	0.2917*	0.3375	-0.4753**	0.4616
	(1.6160)	0.4734)	(-1.9350)	(0.5000)
IRRIG	0.8400***	0.5153	0.0524	0.7462
	(4.8880)	(0.5003)	(0.2000)	(0.4362)
MANURE	0.2826*	0.6681	0.1565	0.7872
	(1.773)	(0.4714)	(0.6510)	(0.4102)
LEGUME	-0.0576	0.4176	0.3637	0.2743
	(-0.340)	(0.4937)	(1.4170)	(0.4472)
SANDY	0.4899**	0.1793	-0.6060**	0.2333
	(2.2930)	(0.3840)	(-2.2220)	(0.4239)
ORGMAT	0.2123***	2.6244	-0.2416**	2.4990
	(2.7380)	(1.1249)	(-2.4270)	(1.1168)
pH	0.3748***	6.9427	0.0063	7.0454
	(2.4800)	(0.5303)	(0.0320)	(0.5446)
SLOPE	0.0213	3.7151	-0.3425*	3.4927
	(1.2400)	(4.4648)	(-1.7940)	(5.2165)
T-FACTOR	0.0415	4.8311	-0.1469	4.8075
	(0.4450)	(0.7588)	(-0.9970)	(0.6901)
Sample Size	449		223	
Chi-Squared	170.4***		27.76**	
McFadden's Psuedo-R^2	0.274		0.091	
$\Phi(K\gamma/\sigma)$	0.506		0.574	
Correct Predictions[b]				
Adopters/Users	72%		56%	
Nonadopters/Nonusers	75%		75%	

[a]*, **, and *** indicate statistical significance at the 10 percent, 5 percent, and 1 percent level, respectively.

[b]Adopters/nonadopters refers to adoption of the N test; users/nonusers refers to use of N test information as the most important factor in N application decisions.

from the estimates. From the probit model, the probability of adoption for a farm is given by $\Phi(\hat{\gamma}Y)$. If the predicted probability of adoption is greater than 0.5, then the model is said to predict adoption for this farm. If the predicted probability is less than or equal to 0.5, then the model predicts nonadoption. The bottom of Table 3 shows the percentage of correct predictions for adopters and nonadopters for each model. Seventy-two percent of the predictions for adoption and 75 percent of the predictions for nonadoption are correct.

Results for the policy variables in the N test equation indicated that counties with a higher acreage under regulation have a higher rate of adoption of N testing; whereas, counties in the Quad County Special Project do not. Farms in counties requiring some N testing were 66 percent more likely to N test compared to farms in unregulated counties. Regulation appears effective in inducing adoption, more than the combination of education, technical assistance, and cost sharing embodied in the incentive approach of the special project.

Several characteristics of the field and farm are closely related to N test adoption. Irrigated fields were 42 percent more likely to have N tests conducted compared to unirrigated fields. Irrigated farms tend to use substantially more N fertilizer than non-irrigated farms, and N testing may have greater potential to reduce costs on these farms (Bosch, Fuglie, and Keim). Fields that received a manure application were also significantly more likely to be N tested. One difficulty farmers face in properly crediting the N content of manure applications is uncertainty about the quality of manure being applied (Legg). N testing in these cases may help reduce this uncertainty by providing information concerning how much mineralized N is available in the soil.

More highly educated farmers, renters, and farmers with crop insurance were more likely to use N testing. Note that the coefficients on the education variables (HSCHOOL and COLLEGE) compare the probability of adoption to that of an individual with less than a high school education. While formal education is significantly correlated with N test adoption, farming experience is not. This finding supports the notion that education and experience are not close human capital substitutes where adaptation to new technology is concerned (Schultz). One reason why renters may be more likely to adopt N testing is that this may be a tool for owners and renters to decide upon fertilizer application rates when these costs are shared. To the extent that purchasing crop insurance is a measure of risk aversion, the results support the hypothesis that more risk-averse farmers are more likely to adopt a risk-reducing input such as N testing (Feder; Robison and Barry).

The results indicate a nonlinear relationship between farm size and technology adoption. The coefficients of SALE2 and SALE3 compare the adoption of N testing by moderate and large farms, respectively, to that of small farms. Moderately-sized farms were least likely to adopt N testing. The coefficient for large farms was positive but the level of significance was only 0.1.

Soil texture (SANDY), organic matter content (ORGMAT), and soil pH were all statistically significant in explaining the pattern of N test adoption in Nebraska. In Nebraska, farmers are more likely to employ N tests on soils with higher organic matter and sandy texture, even though a sandy texture is negatively correlated with organic matter content. Various forces may be interacting here. On the one hand, N is less mobile (and more stable over time) in heavier soils with less leaching. At the same time, fields with sandy soils are more prone to leaching and concerns over ground water quality may be inducing or requiring farmers in sandy areas to adopt N testing as a way to reduce potential N losses.

Use of N Test Information in N Management Decisions

Although regulations were effective in inducing adoption of N testing, the results from the second part of the analysis suggest that the regulatory approach is less efficient in promoting effective use of N testing technology. Model estimates of the use of N test information are presented in Table 3 along with means and standard deviations of variables among adopters.

The estimates are based on those farms that planted corn on the sampled field in 1990 or 1991 and conducted an N test. The presence of the special project was positively related to the use of information from the soil N test. For this model, $\Phi(\hat{\gamma}Y)$ equals 0.574. Among farmers who had adopted N testing, farmers in a project area were 35 percent more likely to use the N test information as their principal tool for deciding how much N to apply than farmers outside of the project areas. On the other hand, there is evidence that many farmers in the regulated areas may have ignored the test (the coefficient is negative and significant at the 0.10 level). In some cases, farmers may have indicated consultants or extension recommendations as the most important source of information, when in fact, these recommendations were at least partially based on the farmer's N test results. However, it is doubtful that this type of situation occurred more often in regulated areas than in other areas.

Prior knowledge and information, measured by education and experience, had no significant effect on the use of N test information as the most important factor in N management decisions. SALE3 is significant indicating that large farmers make less use of N test information. Large farms may find it more convenient to apply the same amount to all fields rather than adjust applications to specific fields due to limited management time. Three soil variables (SANDY, ORGMAT, and SLOPE) are significantly and negatively correlated with N test use. Perhaps N test information is perceived as less valuable on sandy soils because of potential changes in available N due to leaching between the time of the test and the time of maximum crop uptake of N. Steeper slopes may be negatively related to use of N tests because of farmer concerns about N loss due to erosion and soluble runoff between the time of testing and crop uptake.

Conclusions

Increasing concerns about the effect of agricultural chemicals on water quality have led to public efforts promoting farming practices to reduce chemical loadings. The United States Department of Agriculture relies primarily on education, technical assistance, and short-term financial assistance to promote adoption of management practices that may benefit water quality. Special projects, demonstration projects, and HUA projects are three federal initiatives that have been implemented for these purposes. State and local incentive programs and regulations are also designed to accomplish these objectives.

Two policies to promote practices beneficial to water quality were evaluated for a study area in Central Nebraska: (1) regulation (design standard); and (2) a combination of incentives including education, technical assistance, and cost sharing. Policy effectiveness was measured in two parts: (1) whether farmers subject to regulation or voluntary incentives were more likely to test for soil N; and (2) whether they were more likely to use the information as the most important factor in N management decisions. The results show that while regulation leads to higher levels of adoption, it does not have an "educational" effect on adopters in that adopters are less likely to use test results as their most important tool for N application decisions. Incentive policies do not appear to have a strong influence on adoption. However, adopters in the project areas made significantly higher use of the information from N tests in making N application decisions compared to adopters outside project areas.

These results suggest that regulation to enforce adoption of practices such as N testing may not induce the desired behavioral changes needed to improve water quality. Farmers may comply with the regulation without changing their fertilizer decisions. This behavior may occur if farmers lack information on the benefits of the practices. Regulatory programs may have to be accompanied with education to insure that farmers are adequately informed about the impacts of the practices on their farm operations as well as on water quality.

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