Soil Management and the Farm Typology: Do Small Family Farms Manage Soil and Nutrient Resources Differently than Large Family Farms?

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There is increasing recognition that farmers face constraints on their farming decisions depending on the their resources, stage in life, and lifestyle choices. These factors are captured in a new farm typology developed by the Economic Research Service. The farm typology's definition of small and large farms is used to test the commonly stated hypothesis that small farmers practice better land husbandry than do large farmers. The adoption of eleven different soil and nutrient management practices used by U.S. corn producers is analyzed with a bivariate logit model for each practice. The farm typology is found to be significantly associated with two of the practices—rotation with legumes and conservation tillage.

In the 20th Annual Family Farm Report to Congress (Sommer et al. 1998) on the characteristics of U.S. farms, the Economic Research Service (ERS) reported on a new farm typology that delineates five types of small family farms, large family farms, and nonfamily farms. This typology grew out of the recognition that farmers are not a monolithic group; they face different constraints on their farming decisions depending on the resources available to them, their stage in life and their lifestyle choices (e.g. full-time or part-time farmers). In addition, some policies may be more appropriate or beneficial for some types of farmers than for others. The typology will be increasingly used to understand in what ways production decisions vary across farmers and how policy instruments might affect different groups of farmers, especially small family farmers.

This paper takes as a starting point the hypothesis that farmers' soil and nutrient management practices differ by farm type, as defined by the ERS typology. This hypothesis is derived from a commonly stated, but untested, idea that small family farmers are more likely to practice better land husbandry, including the use of conservation and other soil management practices, than are larger farmers. For example, Wendell Berry (1995, p. 59) writes, "If conservationists are serious about conservation, they will have to realize that the best conserver of land in use will always be the small owner or operator, farmer or forester or both, who lives within a securely placed family and community, who knows how to use the land in the best way, and who can afford to do so." In a similar vein, a report put out by the Dakota Resource Council Education Project (Lamb and Keaveny 1987, p. 31) hypothesizes that the loss of family farms may "lead to environmental degradation." Finally, in the American Farmland Trust report, "Small is Bountiful: The Importance of Small Farms in America" (1986, p. 26), Edward Thompson writes, "There are many reasons that suggest the conclusion that small farmers must be better land stewards than their larger counterparts. Small operators are less economically dependent than large farmers on row crops that tend to promote erosion. They farm fewer acres and can devote more attention to caring for it, and so forth."

Due to the public's concern over agriculture's contribution to nonpoint-source water pollution

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from soil erosion and chemical runoff and leaching, government programs have been put in place to encourage and assist farmers in adopting improved soil and nutrient management practices. Some practices, such as conservation tillage and strip cropping, are designed to decrease soil erosion. Nutrient management practices, such as conducting nitrogen (N) tests or applying nitrogen only at or after planting, seek to lower the amount of nitrogen that might possibly leach or run-off.

In this paper, the hypothesis that small farmers are better stewards of the land than larger farmers is tested by examining the adoption rates, by farm type, of 11 different soil and nutrient management practices used by U.S. corn producers. Individual practices are an imperfect measure of conservation effort or effect in terms of reduced soil erosion or improved water quality. However, given the available data, examining the adoption of individual soil and nutrient management practices by farm type gives at least an initial indication of whether there is support for the small farm conservation hypothesis.

The analysis of nutrient management focuses on N management because nitrate contamination of streams and groundwater in agricultural areas is of growing national concern. The soil and nitrogen management practices of corn producers have important implications for nitrate contamination of streams and groundwater. The areas of the U.S. that are at the highest risk of groundwater contamination from N are concentrated in the corn belt (Nolan et al. 1998).

A large number of studies have been devoted to studying the factors that affect the adoption of soil and nutrient management practices (e.g. Featherstone and Goodwin 1993; Fuglie and Bosch 1995; Norris and Batie 1987). Farm and farmer characteristics such as farm size, operator education and years farming have often been found to be positively associated with adoption of conservation and nutrient management practices. The farm typology is a new factor with potential policy importance since it highlights the situation of small family farms and allows policy analysis to isolate effects by farm type.

The next section of this paper describes the farm typology used in this study. This is followed by a description of the stratified sampling method used to collect the data and the statistical implications of the sampling method. Next, the percentage of adopters within each farm type are presented and compared to determine if differences in adoption rates across farm types are statistically significant. Because differences in adoption rates across farm types may be associated with factors other than farm type, multiple regression analysis is then conducted for each practice. This study does not explain what causes a farmer to adopt certain practices, nor does it explain why a farmer has chosen to be a small operation. Further research is required to understand farmers' motivations for being a certain type of farmer. However, the empirical analysis does show if different farm types indeed use different soil and nutrient management practices and what other factors are associated with those choices. Finally, issues for further consideration are explored.

The Farm Typology

The farm typology defined by ERS includes five small family farm categories (sales of less than $250,000), two large family farms (sales greater than $250,000) and nonfamily farms (USDA, ERS 1999). The farm typology broadens the definition of a small farm beyond acres operated or gross sales alone, and includes monetary resources as measured by farm assets and the major occupation of the farmer. The farm typology was developed in recognition of the diversity among farms in terms of resources and lifestyle. Although every farmer is unique, the farmers within each type are more like each other than like farmers in the other categories. The typology is a summary measure, which encompasses the results of many economic decisions made by the farmer, and this study does not attempt to explain how farmers decide whether to be a small or large operator.

Due to data limitations, this analysis collapses the eight farm types down to five. We define four small family farm categories and one large family farm category (see table 1). The nonfamily farm category was dropped since there are only five such farms in our sample—too few to make meaningful comparisons. The first category of small family farms, limited-resource farms, have gross sales of less than $100,000 and farm assets of less than $150,000. The second, third, and fourth categories of small family farms, retirement, residential/lifestyle, and low sales farms, include farms with less than $100,000 of gross sales but assets greater than $150,000, or farms with gross sales between $100,000 and $250,000. The retirement farmers also report retirement as their primary occupation, while the residential/lifestyle farmers report a nonfarm occupation as being primary, and low sales farmers consider farming their main occupation. The fifth category, high sales farms, are all family farms with gross sales over $250,000.

Table 1. The Farm Typology—Corn Producers in the 1996 ARMS Survey

Farm Type	Gross Sales	Operator's Primary Occupation	Other Characteristics
Small family farms			
Limited-resource farms	<\$100,000	Farming, retirement or a nonfarm occupation	Farm assets <\$150,000
Retirement farms	<\$100,000 ≥\$100,000 and <\$250,000	Retirement Retirement	Farm assets >\$150,000 or none
Residential/lifestyle farms	<\$100,000 ≥\$100,000 and <\$250,000	Nonfarm occupation Nonfarm occupation	Farm assets >\$150,000 or none
Low sales farms	<\$100,000 ≥\$100,000 and <\$250,000	Farming Farming	Farm assets >\$150,000 or none
Large family farms			
High sales farms	≥\$250,000	Farming, retirement or a nonfarm occupation	None

Source: USDA, ERS 1999.

Data and Methods

The data used in this paper to determine farm types and production practices comes from ERS's Agricultural Resources Management Study (ARMS) survey administered by the National Agricultural Statistical Service (NASS) of the U.S. Department of Agriculture (USDA). The ARMS is a multiframe, probability-based survey in which farms are randomly selected from groups of farms stratified by attributes such as economic size, type of production, and land use. Each selected farm represents a known number of farms with similar attributes. Weighting the data for each surveyed farm by the number of farms it represents is the basis for calculating estimates. The survey method included three phases: screening, obtaining production practices and cost data, and obtaining financial information. The definition of a farm, and thus the target population of the ARMS, is any business that produces at least \$1,000 worth of agricultural production during the calendar year. This study focuses on the population of farms that grew corn during 1996 in the 16 main corn producing states (IA, IL, IN, KS, KY, MI, MN, MO, NC, NE, OH, PA, SC, SD, TX, WI).

For the 1996 crop year, data on corn production practices and costs were collected in the fall for a randomly selected field on each sampled farm. The following spring, enumerators returned to those same farms to collect farm costs and returns and farm operator demographic data. A total of 1379 surveys were completed in the fall, while 950 operators responded to the spring follow-on survey. This study uses the sample of operators who responded to both surveys. Operators who irrigate corn and those operators who use no commercial nitrogen are excluded from the analysis because irrigated production practices are significantly different from rainfed corn production practices and because we cannot analyze the nitrogen application practices of those who do not use nitrogen. The resulting sample size is 842 corn producers. Data on precipitation were obtained from the NRCS-Oregon State PRISM project.

When generalizing results from a sample to the population of interest, the main econometric results developed in most textbooks rely on the assumption that the data is generated by simple random sampling with replacement. Many studies based on data collected with complex survey designs have relied on these basic econometric methods, although the theoretical statistical literature shows that conventional regression methods applied to data generated by complex survey designs yield parameter estimates for which the standard errors are biased (Kott 1998). For example, in the literature on the adoption of conservation practices, Norris and Batie describe a sampling system in which a random sample of 50 farm operators is drawn from each of two counties, but the sample is also stratified by race to ensure a sufficient number of black farmers would be included in the study. However, they use standard econometric methods designed for analyzing random samples. As Ullah and Breunig (1998) point out, household and farm survey data is rarely based on simple random sampling with replacement, although the theoretical statistical literature shows that this can lead to large bias in the standard errors of the parameter estimates.

The complexity of the ARMS survey design (multiple phases of sampling and stratification, including post stratification to adjust for nonresponse) requires a replication method for variance estimation to compute unbiased standard errors. We, therefore, use a "delete-a-group jackknife" procedure (Kott 1998). The delete-a-group

Table 2. Soil and Nutrient Management Practices

Nutrient (N) management	**Benefits**
	Reduces nitrate leaching and denitrification by changing the quantity, timing, or the source of the N
Practice	*Description*
N-inhibitor	Chemical compounds that can be added to the ammonia fertilizers to slow the conversion to nitrate N, which is susceptible to leaching
N test	A soil or plant tissue test used to determine N needs
N at or after planting	A practice in which all N is applied at planting or after planting, synchronizing soil N availability and crop N requirements
No N broadcast	N that is banded or injected, rather than broadcast
Precision agriculture	Nutrient application rates are varied according to the yield potential of the soil in various parts of the field
Rotation w/legumes	Corn is rotated with a N-fixing crop
Soil management	**Benefits**
	Reduces soil erosion and runoff and increases infiltration
Practice	*Description*
Conservation tillage	Any tillage and planting system that leaves 30 percent or more of the soil surface covered with crop residue to reduce soil erosion by water, or, for control of wind erosion, maintains at least 1,000 pound per acre of flat, small-grain-residue equivalent on the surface throughout the critical wind erosion period
Grassed waterways	Natural or constructed channels covered in suitable vegetation that control erosion and spread the flow of water from the field
Terraces	An earth embankment, channel, or a combination ridge and channel constructed across the slope to intercept runoff water
Contour farming	Preparing land, planting, and cultivating a crop along the contours of a field
Strip cropping	Growing different crops in a systematic arrangement of strips across or along the contour of a field to retain runoff

Sources: Huang 1997; Sandretto 1997.

jackknife method consists of partitioning the sample data into r groups of observations ($r = 15$ in our case) and resampling, thus forming 15 replicates and deleting one group of observations in each replicate. A set of sampling weights was calculated by NASS for each replicate. The model is then run 15 additional times (using each of the 15 replicate weights) and the vector of parameters obtained in each case $\boldsymbol{b}(\boldsymbol{k})$ is compared to the full-sample parameter vector $\boldsymbol{b}$ in order to calculate the standard errors $se(\boldsymbol{b})$: $se(\boldsymbol{b}) = \{c \cdot \Sigma_k [\boldsymbol{b}(k) - \boldsymbol{b})]^2\}$, where $k = 1, 2, \ldots 15$ and $c = 14/15$. Note that this results in 14 degrees of freedom for the model. In the section reporting on the regression results, an example with our data will be constructed to illustrate the potential bias of ignoring the complex survey design in the analysis.

Soil and Nutrient Management Practices by Farm Type

This study analyzes 11 nutrient and soil management practices. Six of the practices are classified as nitrogen management practices while the other five are classified as soil management practices. The nitrogen management practices include use of an N-inhibitor, a soil or plant tissue test for N, applying N only at or after planting, not broadcasting any N (meaning that the N was either banded or injected), rotating corn with a legume, and using precision agriculture technologies. The soil management practices include conservation tillage, grassed waterways, terraces, contour plowing, and strip cropping. Table 2 describes each of the practices. In general, the nutrient management practices are expected to lower fertilizer costs and to provide positive environmental benefits by reducing nitrate leaching and denitrification. The soil management practices are expected to reduce soil erosion and runoff and to increase infiltration, which has both on-site and off-site benefits.

The percentage of farms in each farm type as well as the adoption rate for each of the 11 practices is reported in table 3. The majority of farms, 55%, fall into the category of low sales family farms. Only 5% of corn farms fall into the retirement category. Limited resource farms make up 8% of the total while residential/lifestyle farms make up 14% and the remaining 17% of farms are high sales family farms.

The overall adoption of practices varies widely as does the adoption of each practice between groups. Less than 5% of all corn producers use N-inhibitors while 57% rotate corn with legumes. High sales family farms have the highest adoption rate for four of the 11 practices (N test, precision

Table 3. Adoption Rates of 11 Soil and Nutrient Management Practices by U.S. Corn Producers in 1996 by Farm Type

		Family Farm Types				
Practice	All	Limited Resource	Retirement	Residential Lifestyle	Low Sales	High Sales
% of farmers adopting		(1)	(2)	(3)	(4)	(5)
Nitrogen management						
N-inhibitor	5.0	1.6	0.0	2.2	6.2	6.4
N test	12.4	15.7	7.5	10.3	11.7	16.2
N at or after planting	44.6	53.3	64.0	44.8	45.5	31.0
No N broadcast	45.9	60.2	54.2	37.0	47.1	40.1
Precision agriculture	9.7	3.6	11.9	2.1	6.6	28.7
Rotation w/legumes	56.6	59.7	35.1	70.5	49.2	74.2
Soil management						
Conservation tillage	28.6	18.6	11.6	18.4	31.9	36.5
Grassed waterways	32.5	26.7	9.5	34.1	35.9	30.2
Terraces	9.0	12.4	2.2	4.5	11.0	7.0
Contour plowing	16.7	8.8	7.8	12.5	19.9	16.2
Strip cropping	8.3	4.3	2.8	11.0	10.1	4.2
% of all farms in each farm type	100.0	8.4	5.3	14.1	55.1	17.1

t-statistics for comparisons of means	1–2	1–3	1–4	1–5	2–3	2–4	2–5	3–4	3–5	4–5
Nitrogen management										
N-inhibitor		0.36	**2.00**	**2.38**				1.54	**1.77**	0.05
N test	0.84	0.66	0.51	0.07	0.36	0.55	0.16	0.25	0.12	0.95
N at or after planting	0.32	0.57	0.62	1.74	0.59	0.58	1.04	0.07	1.28	**2.01**
No N broadcast	0.14	1.55	0.97	1.47	0.41	0.17	0.34	1.15	0.36	1.14
Precision agriculture	0.57	0.41	0.76	**4.40**	0.70	0.38	1.15	**2.43**	**5.50**	**4.80**
Rotation w/legumes	0.78	1.01	1.03	1.50	1.15	0.46	1.28	**2.51**	0.46	**3.52**
Soil management										
Conservation tillage	0.46	0.03	**2.03**	**2.54**	0.45	1.39	1.68	**2.21**	**2.73**	0.85
Grassed waterways	**2.00**	0.81	1.36	0.52	**2.54**	**3.50**	**2.75**	0.23	0.48	1.06
Terraces	1.20	0.95	0.17	0.64	0.78	**2.44**	1.39	**2.14**	0.88	1.13
Contour plowing	0.10	0.98	**2.87**	1.65	0.47	1.19	0.81	**2.00**	0.85	0.84
Strip cropping	0.40	1.12	**1.79**	0.05	1.38	**2.30**	0.44	0.17	1.24	**2.57**

Notes: The means are significantly different from each other at the 5% (10%) level when the t-statistic is greater than 2.145 (1.761). Bold indicates significance at the 10% level.

agriculture, conservation tillage and rotation with legumes). Limited resource farms have the highest rate of adoption for terraces and for applying N without broadcasting. Retirement farms have the highest rate for applying all N at or after planting, and strip cropping is most often practiced by the residential/lifestyle farms. Low sales family farms use grassed waterways and contour plowing more than any other group.

T-tests are used to determine if the differences in adoption rates are statistically significant. At the bottom of table 3, t-statistics for comparison of means between each two-way set of farm types are presented. For example, the t-statistic for 1–2 compares the mean rate of adoption among limited-resource farms to the mean rate of adoption among retirement farms. The delete-a-group jackknife method with 15 groups is used to calculate the standard errors for the comparison of means, so the means are significantly different from each other at the 5% (10%) level when the t-statistic is greater than 2.145 (1.761). Comparing adoption rates across farm types, we see that the only distinguishing practice that is statistically significant among the limited-resource, retirement, and residential/lifestyle farms is the use of grassed waterways. Both limited-resource and residential/lifestyle farms use grassed waterways at a much higher rate than the retirement farms.

When comparing the limited-resource farms to the low sales family farms, we see that the limited-resource farms are less likely to use N-inhibitors, conservation tillage, contour plowing and strip cropping. Compared to the high sales family farms, limited-resource farms are less likely to use N-inhibitors, conservation tillage and precision agri-

Table 4. Definition of Variables Used in the Analysis of Adoption of Soil and Nutrient Management Practices by U.S. Corn Producers, 1996

Variable	*Definition*
College education	Farm operator has some college education (1 = yes; 0 = no)
Farming experience	Number of years the operator has been farming
Corn acres planted	Hundreds of acres on the operation planted to corn
Corn/soybean percentage	Fraction of the farm operation planted to corn or soybeans
Cash grain farm	Operation is a cash grain farm vs. a livestock farm (1 = cash grain; 0 = livestock)
Program participation	The farm operator participated in government programs if he/she received any government payments (1 = yes; 0 = no)
Owns land	The field is operated by the owner (1 = yes; 0 = no)
Cash-rents land	The field is operated by a renter under a cash lease (1 = yes; 0 = no)
Share-rents land	The field is operated by a renter under a share lease (1 = yes; 0 = no)
Limited-resource/retired/residential (LRRR farmer)	The operator is classified as a limited-resource, retired or residential/lifestyle farmer (1 = yes; 0 = no)
Low sales family farmer	The operator is classified as a low sales family farmer (1 = yes; 0 = no)
High sales family farmer	The operator is classified as a high sales family farmer (1 = yes; 0 = no)
Precipitation	30 year average annual precipitation in meters
Temperature	30 year average temperature in °F
Highly-erodible land (HEL)	The field is classified as "Highly Erodible" by the NRCS (1 = yes; 0 = no)
Normal corn yield	The corn yield that the operator normally expects to achieve (bu/acre)
Used manure	Manure was applied in the field (1 = yes; 0 = no)

culture. Retirement farms are less likely to use grassed waterways, terraces and strip cropping than low sales family farms and are less likely to use grassed waterways than high sales family farms.

Residential/lifestyle farms are lower adopters of precision agriculture, conservation tillage, terraces and contour plowing than the low sales family farms, but they rotate corn with legumes more frequently. High sales family farms are significantly more likely to use N-inhibitors, soil and plant tissue tests, precision agriculture and conservation tillage than are retirement farms. Finally, when comparing the low sales and high sales family farms, we see that the high sales farms are higher adopters of precision agriculture, rotations, and applying N at or after planting, but they are less likely to do strip cropping.

In these simple two-way t-test comparisons, we do not see evidence that small farmers are using many nutrient and soil management practices at a significantly higher rate than larger farmers. In fact, high sales farmers are using practices such as conservation tillage and precision agriculture at a significantly higher rate than any other type of farmer.

The Model

Differences in adoption rates across farm types may be associated with factors other than farm type. For example, livestock farms may be more likely to use certain practices and at the same time may be concentrated among the high sales family farms. Thus, high sales farms may use a certain practice because it is commonly used by livestock farmers. To control for these types of confounding factors, a logit regression model is used to identify the factors that are correlated with the adoption of each practice. The farm typology will appear in the equations as part of the independent variables. Since the analysis above identified only one difference between the limited-resource, retirement and residential/lifestyle farms, they are grouped together in the logit analysis. Thus, the farm typology takes the form of a three part dummy variable made up of (1) limited-resource, retirement and residential-lifestyle (LRRR) farms, (2) low sales family farms, and (3) high sales family farms.

The logit model (Judge et al. 1988) is used to analyze the factors associated with adopting a technology, which is a binary variable. In this case, the binary variable takes on the value of 1 when the farmer has adopted a certain practice and 0 when the farmer has not adopted the practice. Ten of the 11 practices are examined with the logit model. N-inhibitor adoption is not examined since only 5% of all farmers used it. The probability of adoption is correlated with a number of variables that are drawn from past studies and are listed in table 4.

Previous studies have found that farmers with more education are more likely to adopt new soil management practices (Ervin and Ervin 1982; Fuglie and Bosch 1995). Farming experience may also increase the likelihood of adoption. Farms with large areas in field crops, such as corn, and the percentage of the total farm area devoted to corn or soybeans have been linked to an increased likelihood to adopt conservation tillage and precision agriculture because farmers may be able to spread the cost of equipment over a larger area (Daberkow and McBride 1998; Rahm and Huffman 1984). Cash grain farms are more likely to use some conservation practices, such as conservation tillage, than livestock farms (Saliba and Bromely 1986). Farmers are classified as program participants if they received any government payments. Operators farming highly erodible land (HEL) must have an approved conservation plan in order to receive certain government payments, thus increasing the likelihood that farmers who receive such payments, and operators farming HEL, will adopt a conservation practice. Cash and share-renters may be less likely to adopt soil management practices than owner-operators (Belknap and Saupe 1988; Lynne, Shonkwiler and Rola 1988; Soule, Tegene and Wiebe 2000). Average annual temperature and average annual precipitation variables are used to capture the effect of regional differences in farming practices. Normal corn yield, used as a proxy for land productivity, was found to be positively associated with the adoption of precision agriculture by Daberkow and McBride (1998). The use of manure may affect the other management practices that the farmer chooses (Wu and Babcock 1998). Finally, the perception of an erosion problem has been found to be strongly associated with the use of conservation practices in a number of studies (e.g., Ervin and Ervin 1982; Belknap and Saupe 1988); however, our data set does not include a measure of this variable, and thus we are not able to include it in our analysis.

Results

By using the multiple regression analysis to control for other explanatory factors, we see fewer differences by farm type than we saw by comparing mean adoption rates alone (table 5). In the logit adoption models, only two practices showed significant differences by farm type. Low sales family farmers are less likely to rotate corn with legumes than high sales family farmers, and LRRR farmers are less likely to use conservation tillage than are high sales family farmers. It may be that LRRR farmers farm with older equipment and are less likely to have the resources to invest in newer equipment required for conservation tillage. However, in general, we cannot reject the null hypotheses implicit in the statistical tests that all types of farmers are equally likely to adopt most of the soil and nutrient management practices.

The usefulness of the models for understanding the factors that are correlated with adoption decisions by U.S. corn producers varies by the practice under consideration. In general, the models perform less well when only a small percentage of all producers have adopted the practices. For example, no factors were found to be statistically significant for the N test model (actual adoption rate of 12.4%). Although the N test model shows 87.6% correct predictions, it predicts that all farmers are non-adopters. However, precision agriculture was used by only 9% of the farmers, but two factors are found significant, corn acres planted and the percentage of the farm in corn or soybeans. This suggests that a large area in corn and soybeans is an important determinant of the use of precision agriculture.

Applying N only at or after planting is a practice followed by 45% of the farm operators. Farmers who apply manure and those who live in areas with high levels of annual precipitation are more likely to follow this N application practice. Banding or injecting N, rather than broadcasting N, is more common on farms with large corn acreage, farms that apply manure, and on livestock farms. Farmers who rotate corn with legumes have a small corn acreage, are more likely to be share-renters, and are more likely to participate in government programs. As noted above, high sales farmers are more likely to rotate corn with legumes than are low sales farmers. Corn acres planted can be negatively associated with rotation while high sales farmers are positively associated with rotation because corn acres planted and the high sales type are not strongly correlated since the high sales may be due to crops other than corn.

College education, cash grain farming, and HEL are positively associated with the adoption of conservation tillage, while program participation, cash-renting and LRRR farmers are negatively associated with conservation tillage adoption. Farmers who adopt grassed waterways farm in areas with higher precipitation and lower temperatures, are more likely to be owner-operators than renters and have fewer years of farming experience. HEL is also positively associated with the adoption of grassed waterways. Farmers are much more likely to have terraces on HEL land than non-HEL land and in areas with higher average temperatures, but they are less likely to have terraces if they are program participants or if they farm in high precipitation areas. The adoption of contour farming is also highly correlated with HEL, and contour farming is used less frequently by share-renters than owner-operators and is used less by more experienced farmers. Finally, strip cropping is adopted most often on HEL land, but adopters of strip crop-

Table 5. Parameter Estimates for the Logit Models of Adoption of 10 Nutrient and Soil Management Practices by U.S. Corn Producers, 1996

Explanatory Variables	N-test	N at or after	No N Broadcast	Precision Agriculture	Rotation w/Legume	Conserv. Tillage	Grassed Waterway	Terraces	Contour Farming	Strip Cropping
Constant	−0.307	2.639	1.434	−4.933	−4.106**	−1.236	4.747**	−4.823*	−1.355	6.868**
	(1.97)	(2.06)	(1.82)	(13.25)	(1.23)	(1.45)	(2.08)	(2.35)	(1.85)	(1.56)
College education	0.208	−0.084	0.037	0.665	0.374	0.745**	0.088	0.385	0.319	−0.888*
	(0.39)	(0.267)	(0.22)	(0.39)	(0.38)	(0.34)	(0.23)	(0.46)	(0.39)	(0.44)
Experience	−0.008	0.004	0.009	0.003	−0.002	−0.002	−0.023**	−0.042	−0.027*	0.005
	(0.01)	(0.01)	(0.01)	(0.02)	(0.01)	(0.01)	(0.01)	(0.02)	(0.01)	(0.01)
Corn acres	−0.082	−0.075	0.082*	0.124*	−0.130**	0.070	−0.004	−0.054	−0.026	−0.403*
	(0.12)	(0.07)	(0.05)	(0.06)	(0.06)	(0.05)	(0.07)	(0.11)	(0.05)	(0.20)
Cash grain farm	0.033	−0.653	−0.639**	0.098	0.220	0.669*	0.428	−0.743	−0.366	−0.559
	(0.31)	(0.44)	(0.29)	(0.69)	(0.25)	(0.36)	(0.35)	(0.50)	(0.28)	(0.41)
Program participant	0.854	−0.823	−0.757	2.960	0.737**	−0.849*	−0.253	−1.053*	−0.022	−0.346
	(0.61)	(0.47)	(0.44)	(12.40)	(0.32)	(0.44)	(0.55)	(0.58)	(0.44)	(0.37)
Cash-renter	0.467	0.059	−0.127	0.274	−0.303	−0.298*	−0.514**	0.020	−0.489	−0.052
	(0.43)	(0.33)	(0.28)	(0.46)	(0.27)	(0.17)	(0.15)	(0.58)	(0.40)	(0.47)
Share-renter	0.367	−0.331	−0.517	0.681	0.672*	−0.079	−0.737**	0.062	−1.103**	−0.685
	(0.45)	(0.26)	(0.32)	(0.47)	(0.37)	(0.26)	(0.35)	(0.57)	(0.27)	(0.83)
LRRR farmer	−0.245	0.370	0.400	−0.753	0.087	−1.191**	−0.250	−0.235	0.674	−0.334
	(0.50)	(0.50)	(0.33)	(0.67)	(0.56)	(0.36)	(0.35)	(0.87)	(0.58)	(0.92)
Low sales farmer	−0.427	0.101	0.198	−0.790	−0.621*	−0.069	0.097	0.596	0.201	−0.394
	(0.57)	(0.42)	(0.31)	(0.54)	(0.29)	(0.31)	(0.32)	(0.68)	(0.29)	(0.62)
Precipitation	−1.184	2.691*	−0.620	−2.130	1.444	−0.662	2.185**	−4.925**	−0.979	5.321
	(1.20)	(1.50)	(0.94)	(2.03)	(1.03)	(0.93)	(0.90)	(1.41)	(1.09)	(3.69)
Temperature	−0.020	−0.091	−0.016	−0.020	0.019	0.024	−1.147**	0.158**	0.015	−0.269**
	(0.05)	(0.06)	(0.05)	(0.04)	(0.04)	(0.03)	(0.04)	(0.04)	(0.05)	(0.10)
HEL	0.158	—	—	—	−0.296	1.113**	1.946**	2.172**	2.747**	1.580**
	(0.35)				(0.26)	(0.25)	(0.22)	(0.45)	(0.36)	(0.31)
Used manure	−0.006	0.548*	0.761**	—	—	—	—	—	—	—
	(0.41)	(0.31)	(0.22)							
Normal corn yield	—	—	—	0.007	—	—	—	—	—	—
				(0.01)						
Corn/soybean percent	—	—	—	2.025*	3.911**	−0.624	—	—	—	—
				(1.02)	(0.42)	(0.54)				
Correct predictions	86.6%	64.5%	61.1%	89.2%	75.2%	67.2%	74.4%	92.1%	84.4%	90.7%

Notes: Standard errors are in parentheses. Critical t-values are 2.145 at the 95% level and 1.761 at the 90% level. * and ** indicate significance at the 10% and 5% level, respectively. The symbol — denotes that the variable was not included in that model.

ping have less education and fewer corn acres and farm in areas with lower temperatures than do non-adopters.

HEL was the most consistently significant variable across soil conservation practices (it was not expected to affect nutrient management practices). Operators farming HEL must have an approved conservation plan to receive certain government payments under the conservation compliance provision of the 1985 Farm Act. This result suggests that the conservation compliance provision has been effective in encouraging adoption of conservation practices by all farm types.

Corn acres planted was correlated with adoption of four of the practices, but it was positive in two models where economies of scale in equipment are important (banding or injecting N and precision agriculture) and negative in the models of rotation and strip cropping. The temperature and precipitation variables capture the effect of regional differences in weather on farm practices. Farmers were more likely to adopt application of N at or after planting and grassed waterways in high rainfall areas. Grassed waterways and strip cropping were adopted more frequently in colder regions.

To briefly show the bias in the standard error estimates that can arise from using standard methods with data collected using a complex sampling design, table 6 presents the parameter estimates and standard errors calculated with standard methods and with the jackknife method for the model of adoption of grassed waterways. The parameter estimates are the same in both cases, but the standard errors without the jackknife are smaller for all variables but one. Smaller standard errors lead to larger t-statistics and thus higher levels of significance in general. However, in this example only one additional variable, cash grain farm, is significant with-

Table 6. Comparison of the Standard Error of the Estimates, with and without the Jackknife, for the Model of Grassed Waterways Adoption

Explanatory Variables	Parameter Estimate	S.E. with Jackknife	S.E. without Jackknife
Constant	4.747	2.0751**	1.081**
College education	0.088	0.233	0.177
Experience	−0.023	0.009**	0.007**
Corn acres	−0.004	0.067	0.055
Cash grain farm	0.428	0.350	0.190**
Program participant	−0.253	0.548	0.219
Cash-renter	−0.514	0.153**	0.224**
Share-renter	−0.737	0.348*	0.266**
LRRR farmer	−0.250	0.346	0.340
Low sales farmer	0.097	0.316	0.284
Precipitation	2.185	0.897**	0.841**
Temperature	−0.147	0.038**	0.030**
HEL	1.946	0.220**	0.200**

* and ** indicate significance at the 10% and 5% level, respectively.

out the jackknife while it was not significant when using the jackknife method.

Further Considerations

This study represents an initial attempt at understanding the correlation of farm size and type with conservation and nutrient management practices. The results do not support the view that either small or large farmers practice more conservation than the other group. Rather, factors other than farm type are more important in explaining differences in adoption for most of the soil and nutrient management practices considered. There are several important limitations to this study. First, we were not able to address the question of why some farmers are small in the first place, and how this choice interacts with conservation decisions. Secondly, we looked at several management practices individually, but farmers use a suite of practices to achieve conservation and other goals. It would be useful to develop a method for categorizing whole farm management plans and their impact on conservation and water quality goals. Alternatively, the number of soil and nutrient management practices used could be analyzed as a dependent variable.

On the technical side, the decision to adopt each of the 10 practices was modeled separately in this paper. However, we might expect the disturbances of each equation to be correlated since the disturbances may reflect some common omitted factors. If this is the case, the parameter estimates may be consistent but not efficient, and a seemingly unrelated regression model may be more appropriate. However, if the use of one practice is influenced by the use of another, a recursive or simultaneous equation model may be more appropriate. These issues are left for future research.

Summary and Conclusion

In summary, the farm typology was not found to be significantly correlated with the adoption of eight different soil and nutrient management practices. However, high sales family farmers were more likely to adopt rotation with legumes and conservation tillage than were low sales family farmers and LRRR farmers, respectively. This study does not support the hypothesis that small farmers practice better land husbandry than large farmers, at least when better land husbandry is measured by the soil and nutrient management practices included in this study. For certain practices, other factors were much more likely to be correlated with adoption than was farm type. For example, HEL designation was correlated with adoption of all five of the conservation practices under study, reflecting both the need for conservation on HEL and the importance of the conservation compliance provision of the 1985 Farm Act in encouraging adoption. Corn acres planted was associated with the adoption of precision agriculture and the practice of banding or injecting N. Cash renting was negatively associated with the adoption of conservation tillage and grassed waterways, while share-renters were less likely to adopt grassed waterways or contour farming than owner-operators. Regional differences captured by the temperature and precipitation variables were found to be correlated with the adoption of practices such as applying N only at or after planting, grassed waterways, terraces, and strip cropping.

Many factors other than farm type were associated with adoption of soil and nutrient management practices. However, for each practice, it is important to understand who is and who is not adopting the practice in order to design effective outreach programs for farmers with different needs. For example, if society wishes an increase, say, in conservation tillage acres, as suggested by the national goal of conservation tillage on 50% of all cropped acres by 2002, then efforts to increase the adoption of conservation tillage by large operators may need to be different than those aimed at small producers. At the same time, we need a better understanding of how tenure arrangements affect the incentives of operators to use various soil management practices if we wish to increase the adoption of many types of soil management practices by renters.

Finally, although the type of adoption research presented in this paper sheds some light on the factors associated with adoption of soil and nutrient management practices, it does not explain what motivates farmers to fall within a certain farm type. We need an improved understanding of why some farmers are small or large in the first place, and how that decision interacts with their conservation decisions.

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