ADOPTION AND PERCEIVED USEFULNESS OF PRECISION SOIL SAMPLING INFORMATION IN COTTON PRODUCTION

D.C. Harper, D.M. Lambert, R.K. Roberts, B.C. English, M. Velandia, J.A. Larson, D.F. Mooney

Department of Agricultural and Resource Economics
University of Tennessee
Knoxville, Tennessee

S.L. Larkin

Department of Food and Resource Economics
University of Florida
Gainesville, Florida

J.M. Reeves

Cotton Incorporated
Cary, North Carolina

ABSTRACT

Precision soil sampling helps farmers identify nutrient variability within fields and optimize input application. Anecdotal evidence suggests that soil test information has a useful life of 3–4 years before field information needs to be updated. However, perceptions about the usefulness of soil test information over time may depend on a variety of factors, including field variability, farmer experience and education, farm size, Extension recommendations, and other factors indirectly related to farming. In 2009, a survey of cotton farmers in 12 Southern states collected information about the use of precision soil sampling technologies. A regression model incorporating farm operator and business characteristics, use of precision agriculture technologies, and information sources analyzed (1) the adoption of soil testing technologies and (2) the number of years adopters perceived the soil test information to be useful. We find that a number of farm operator and business characteristics are associated with the length of time producers perceived the information they obtained from soil tests to be useful, including farmer experience, land tenure, and the use of other information gathering technologies such as Greenseeker® and electro conductivity.

Keywords: Adoption, cotton, frequency of soil testing, precision agriculture

INTRODUCTION

Input management decisions for cotton producers involve trade-offs between plant genetics, soil variability, soil nutrient carrying capacity, prices, and other deterministic and stochastic factors. The spatial and temporal variability of soils over a field also makes efficient allocation of inputs difficult. Yet, identifying an optimal nutrient management program over a planning horizon is important for maintaining soil fertility, increasing profit margins, and reducing variable input costs. Producers often look for new information to help solve this complex problem, as they can expect higher returns once they invest resources to obtain more information about their fields. Precision soil sampling technologies supplement a broader array of information gathering technologies which may be useful for making complex input management decisions.

Producers invest in precision agricultural (PA) technologies when the expected returns outweigh the costs. Several studies have considered the factors related to the adoption of PA technologies and their continued use (e.g. Batte and Arnholt, 2003; Daberkow and McBride, 2003; Roberts et al., 2004; Walton et al., 2008; Walton et al., 2010). Ease-of-use, usefulness, and increased returns are often reasons why farmers adopt precision agriculture technologies (Roberts et al., 1999). Other reasons for adoption include more reliable results newer technologies promise compared to older methods. While the perception of profitability and usefulness of PA technologies may encourage producers to adopt soil testing, few studies have identified the factors influencing how long producers perceive soil test information to be useful after collecting grid or zone soil tests.

The length of time a producer chooses between soil testing may be driven by a number of factors, including the duration a producer has worked with other PA technologies (e.g. yield monitoring, remote sensing, and variable rate application), the public or private information sources an operator uses to gain knowledge about new technologies, and the inherent soil variability of fields. Direct experience with other precision technologies may decrease unfamiliarity with processing and applying soil sampling information, which may correspond with a better understanding of soil sampling information usefulness. For example, Irani (2000) examined the perceived usefulness of internet communication technologies and found that perceptions of information usefulness were higher for individuals more familiar with the software applications than for those with less experience. But over time, producer perceptions about the length of time soil test information is useful may change as increased familiarity with soil sampling technology and new information about within-field soil variability is gathered or updated.

This research identifies the farm business, operator, off-farm attributes, and information sources influencing the period of time soil test information is perceived useful by cotton farmers. As producers realize economic benefits from precision agriculture technologies, they may also demand more accurate, real-time, site specific information. Understanding the factors contributing to the perceived usefulness of soil test information (as measured by the time between which producers conduct soil tests) may provide guidance to industry with respect to product and service marketing. Findings may also help Extension tailor outreach efforts for individual producers about the benefits and costs of soil sampling and the optimal timing between soil tests. To the extent that soil tests are required by some conservation programs, information about the factors related to producer willingness to test soil to complement nutrient management plans may be helpful as well.

DATA

The 2009 Cotton Incorporated Precision Agriculture survey was mailed to 13,783 producers in Alabama, Arkansas, Georgia, Florida, Louisiana, Mississippi, Missouri, North Carolina, South Carolina, Tennessee, Texas, and Virginia. Using Dillman's (1978) general mail survey procedures, the initial questionnaire was mailed February 20, 2009 with a reminder post card sent two weeks later and a follow-up mailing to producers who had not responded on March 27, 2009. The mailing list was comprised of cotton producers and provided by the Cotton Board (Memphis, Tennessee). The survey included questions about producer adoption of specific precision agriculture technologies, farm and operator characteristics, and the number of seasons between soil tests. The response rate was 12.5%. Mooney et al. (2010) provide details of the survey. Of the cotton farmers responding, 14% (242) had adopted soil testing. The average time between tests was about 3 years.

Post-stratified survey weights were estimated to expand the sample to match the number of cotton famers enumerated by the USDA's 2007 AgCensus. The post-stratified weights contain information about characteristics of the population that would otherwise not be included. The weight is a 'raking' weight suggested by Brackstone and Rao (1976) which iteratively normalizes cell weights by the Cartesian product of the marginal row (cotton acres farmed size class) and column (state cotton farm numbers) totals from the AgCensus cotton farm population (Lohr, 1999). By construction, the sum-product of the weight with the survey counts in each size class-by-state category match the AgCensus 2007 farm numbers in the states surveyed. Thus, each respondent in a given farm size class (1-99, 100-249, 250-499, 500-1000, 1000-1999, 2000+ acres) and state received the same weight. By incorporating information about the population into the weighting design, the leverage attributed to respondents in different size classes may be moderated or increased, depending on the characteristics of the entire population.

MODEL

The decisions to adopt soil testing and to retest following some period are examined using a hurdle count model (Cameron and Trivedi, 1998 p. 124). Hurdle models are typically applied to attend to problems arising from sample selection bias, and the discrete, non-negative nature of the outcome period (e.g. years soil test information is useful). Producers must have adopted grid or zone soil sampling to answer how long they perceived soil test information to be useful before retesting. The first stage therefore models the decision to adopt soil testing with logit regression. Given adoption of soil testing, the number of years between tests is modeled using a Poisson regression.

Farmers are hypothesized to maximize expected (discounted) profit over a time horizon, subject to input and commodity prices and technology constraints.

A producer must weigh the benefits and cost of incorporating precision agriculture technologies into their operations. Let the expected utility of profit (π) from adopting precision soil sampling (PSS) technology in time period t_0 to be E[$U(\pi_{t_0}^{PSS}$)]. There are often additional variable and fixed costs to consider in the initial period, such as the implementation of an input management plan based on soil sampling results and the collection and storage of information, and these differences in cost also affect profits. Define the latent utility a producer receives from adoption (AD) of precision soil sampling as $U_i^{AD*} = \mathrm{E}\left[U\left(\pi_{t_0}^{PSS}\right)\right] - \mathrm{E}[U(\pi_{t_0})]$. A producer adopts soil sampling when $U_i^{AD*} > 0$ (Walton et al., 2008).

Given adoption of soil testing, producers choose the amount of time until they restest. It is hypothesized that this time period is also consistent with profit maximization. Let $\mathrm{E}[U\left(\pi_{t_0+k} \middle| U_i^{AD*} > 0\right)]$ represent the expected utility from profits *k* seasons after the initial soil test and $U\left(\pi_{t_0+k-1} \middle| U_i^{AD*} > 0\right)$ represent the utility from realized profits in *k*-1 seasons after the initial soil test. Defining $U_i^{RT*} = \mathrm{E}\left[U\left(\pi_{t_{0+k}} \middle| U_i^{AD*} > 0\right)\right] - U\left(\pi_{t_0+k-1} \middle| U_i^{AD*} > 0\right)$ as the utility gained from retesting (RT) *k* periods after the previous soil test, a profit maximizing producer will retest soil when the utility from retesting soil is greater than the expected utility from waiting another period between soil tests; $U_i^{RT*} < 0$.

Once soil testing has been adopted, produce must decide how long to wait between periods before retesting. The unobservable latent variables U_i^{AD*} and U_i^{RT*} are hypothesized to be functions of observable exogenous variables, x_i, (including farm household and business attributes, operator characteristics, and possibly off-farm factors), and unknown parameters, β_{AD} and β_{RT}. The decision to adopt soil testing is modeled as a linear random utility function;

$$U_i^{AD*} = \beta_{AD}^{'} x_i + \varepsilon_i^{AD} \tag{1}$$

with ε_i^{AD} a random disturbance term.

The adoption decision is $I_i^{AD} = 1$ if $U_i^{AD*} > 0$ and the decision of how long to wait between soil tests is measured as a discrete, count variable; thus $I_i^{RT} = k$ if $U_i^{RT*} < 0$. The probability of adopting precision soil sampling technology is therefore:

$$\begin{aligned} \Pr[I_i^{AD} = 1] &= \Pr\,[U_i^{AD*} > 0] \\ &= \Pr\,[\varepsilon_i^{AD} > \beta_{AD}' x_i] \\ &= F_1(\beta_{AD}' x_i) = \Phi\,(\beta_{AD}' x_i) \end{aligned} \tag{2}$$

where Φ is the normal cumulative probability distribution.

After adoption (the "hurdle") the producer decides how long to wait between tests before updating soil test the information. Because the choice set is observed as years (a discrete, countable decision), the decision must be modeled using a count regression model such as the Poisson (Cameron and Trivedi, 1998). Typically, the log link function is used to model expected counts, which implies $k_i^* = exp(\beta'_{RT} x_i)$. The probability of waiting k years after adopting precision soil sampling is therefore:

$$\Pr[\, k_i{}^* = k_i \,|\, I_i^{AD} = 1, k_i > 0] = F_2(\beta'_{RT} x_i) = \frac{exp(\beta'_{RT} x_i)^{k_i} . exp\,(-exp(\beta'_{RT} x_i))}{k_i!} \quad (3)$$

$$\Pr[\, k_i{}^* = k_i \,|\, I_i^{AD} = 1, k_i > 0] = \frac{F_1(I_i^{AD} = 1)}{1 - F_2(k_i = 0)} \cdot F_2(k_i > 0).$$

EMPIRICAL MODEL

The variables hypothesized to be associated with the soil test adoption decision and the length of time between soil tests are summarized in four categories: 1) farm operator characteristics, 2) information sources, 3) information gathering/processing technologies, and 4) off-farm and regional attributes. Definitions of the variables, the hypothesized signs, and the sample and weighted means are summarized in table 1.

Farm Operator Characteristics

The natural logarithm of the average of cotton acres grown in 2007 and 2008 (ACRES) was hypothesized to be positively associated with the decision to adopt soil testing, but negatively related to the years between testing. The more acres a producer manages, the more likely soil fertility may vary. Thus producers may be more likely to invest in precision soil sampling technologies. Soil information may also need to be updated more frequently when more acres are managed. The percentage of owned land to total farmland operated (LANDTEN) was expected to be positively associated with adoption and the period between sampling, because operators who owned relatively more land may be concerned about decisions affecting the future quality of their cropland. Operators reporting higher shares of income from farming (INCFARM) were expected to be more likely to adopt precision soil sampling technologies and test more frequently. Producers with more farming experience (EXPERIENCE) (as measured by years farming/operator age) were hypothesized to be less likely to adopt precision soil sampling technologies but more likely to extend the time between soil tests. Experienced farmers content with current management plans may also perceive it too costly to change production practices and, therefore, may resist adoption of new technologies (Batte et al., 1990). Following adoption, producers may more easily understand how information relates to particular fields, which would correspond with longer lapses between soil testing. Operators with a bachelor’s degree (BS) were expected to be more likely to adopt soil test technologies and more likely to wait longer periods between soil tests because higher levels of education may aid in the synthesis of complex information obtained from precision soil sampling (Batte et al., 1990). The percentage of non-cotton acres to total cropland acres (OCROPS) and soil fertility variability (YVAR) of fields were hypothesized to be positively related with adoption of soil testing but negatively correlated with the period between tests. Greater yield variability may encourage the adoption of information gathering technologies like soil sampling but also encourage more frequent testing.

Information Sources

The availability and use of information sources may influence the likelihood of adopting soil sampling and the time period between soil testing. Information from crop consultants (INFOCONS), trade shows (INFOSHOWS), and the use of consultants or dealers to apply inputs (APPCONS) were hypothesized to positively correlate with the adoption of soil testing but negatively associated with the time period between soil tests. Private consultants or those working for companies may have financial reasons for promoting or marketing soil tests and encourage producers to decrease the period of time between tests. The expected signs associated with information gathered from other farmers (INFOOTH) and university Extension services (INFOEXTEN) are ambiguous. Producers using media outlets (such as the internet or other news sources) (INFOMEDIA) may be more likely to adopt soil testing and increase the time period between soil tests. News is most often acquired by television, newspapers, or the internet, and operators who use the internet may already have a familiarity and comfort of using computer technologies that come along with soil testing. The number of farm suppliers (FARMSUPPLY) in a region may also be positively correlated with the adoption decision but negatively associated with the time period between testing. The accessibility to technologies and support may increase the likelihood operators will purchase soil test information technologies and decrease the time period between tests.

On-Site Information Gathering Technologies

The use of aerial imagery (IMAGE), cotton yield monitors to generate a yield maps (YMXMAP), variable rate fertilizer management plans using GPS-referenced soil sample information (VRTPLAN), GPA/PDA handheld devices (HANDHELD), soil electro conductivity technology (ELECTRIC), Greenseeker® technology (GREENSEEK), and the use of a computer for farm management decisions (COM) were hypothesized to be positively associated with the likelihood of soil test adoption and the time period between testing. Producers already using some combination of precision agriculture technologies may be more likely to use soil sampling technologies. In addition, these technologies together may provide complementary information with respect to soil quality, which may decrease the frequency between soil tests.

Off Farm Regional Attributes

Six regional variables from the USDA Economic Research Service (table 1, U. S. Department of Agriculture-Farm Resource Regions 2007) were included in the adoption/use model. Using Southern Seaboard as the reference region, the five other regions of Heartland (HEARTLAND), Prairiegate (PRAIRIE), Eastern Uplands (EASTUP), Fruitful Rim (FRUITFUL), and Mississippi Portal

(MISSPORT) were included to control for regional differences such as growing seasons, weather conditions, and input costs (Khanna, 2001).

Multicollinearity

Multicollinearity arises when two or more regressors are highly, but not perfectly, correlated. Problems include coefficients with unexpected signs and inflated standard errors (Greene, 2000). Variance inflation factors were used to detect whether multicollinearity might be an issue. In general, variance inflation factors greater than ten suggest there may a problems arising from multicollinearity (Chatterjee and Price, 1991).

RESULTS

Estimation

The null hypothesis that all the coefficients (β_{AD}, β_{RT}) were different from zero was rejected at the 1% level of significance (Wald = 182.28, d.f. = 27). The first-stage logit model and second stage Poisson model appear to explain adoption and the period between soil tests as a function of farm operator, business, and regional attributes. The variance inflation factors associated with the explanatory variables suggested collinearity was not an issue. The variance inflation factors for the unweighted model averaged 2.2 (maximum of 8.2). The average of the variance inflation factors for the Poisson model was 1.9 (maximum of 7.1).

Precision Soil Sampling Adoption

The characteristics associated with the likelihood of soil sampling adoption and the time period between soil tests are summarized in table 2. Operators with a bachelor's degree, the use of a consultant or chemical dealer to apply inputs, and the use of a variable rate technology plan were positively associated with soil sampling adoption. Farmers who had a bachelor's degree may more easily understand the systems and specialized applications that typically accompany precision soil sampling. The use of a variable rate technology plan was positively associated with the adoption decision, suggesting that producers planning to make custom input applications using a variable rate input management plan recognize the managerial benefits soil sampling can provide.

Alternatively, the use of electro conductivity devices was negatively correlated with the adoption of soil tests. These results suggest farmers who used other precision agriculture technologies were less likely to use soil sampling technologies.

Years Between Soil Testing

The number of years between soil testing increased with land tenure (acres owned/acres operated), farmer experience, and the use of electrical-conductivity devices and Greenseeker® technology. Producers with more farming experience may have more familiarity with the soil conditions and nutrient variability of their fields. The positive correlation with the time between tests and these personal attributes suggest that operators may understand soil and field variability to an extent that requires less soil testing with respect to fertility management. Farm size and the use of a variable rate fertilizer management plan based on GPS-referenced soil sample information were associated with more frequent soil testing. Farmers using relatively new precision soil profiling technologies (e.g. electro-conductivity devices and Greenseeker®) may be more inclined towards using sensor technology applications to manage their operations. The interest in newer technologies appears to be positively correlated with longer periods between or zone soil testing. Therefore, there appears to be some degree of substitution between the information acquired from soil testing (often considered an "entrance" technology), and the information generated from newer sensor-based technologies like Greenseeker® or electro conductivity.

SUMMARY

This research provided a preliminary analysis of the factors influencing the adoption of soil testing by cotton farmers in the southern U.S., as well as the perceived usefulness of soil test information over time. Farm operator and business attributes, information sources, and technology characteristics correlate with the decision to adopt soil testing, and the length of time between soil tests. Operators with a bachelor's degree, the use of a consultant or chemical dealer to apply inputs, and the production of a variable rate technology plan increased the likelihood that precision soil sampling technology may be adopted. Land ownership, farmer experience, and the use of electro conductivity devices and Greenseeker® technologies increased the time period between soil tests. Understanding the factors contributing to the perceived usefulness of soil test information may provide guidance to industry with respect to product and service marketing, and help Extension tailor information efforts regarding the benefits and costs of soil sampling.

ACKOWLEDGEMENTS

This research was funded by Cotton Incorporated. The authors would like to thank Cotton Incorporated for their continued support. The views expressed herein do not necessarily represent those of Cotton Incorporated or the institutional affiliations of the authors.

REFERENCES

Batte, M.T. and M.W. Arnholt. 2003. Precision Farming Adoption and Use in Ohio: Case Studies of Six-Leading Edge Adopters. Comput. Electron. Agric.. 38:p. 125-139.

Batte, M. T., E. Jones, and G. D. Schnitkey. 1990. Computer Use by Ohio Commercial Farmers. Am. J. Agric. Econ. 72(4):p. 935-945.

Binder, D.A. and A. Theberge. 1988. Estimating the Variance of Raking Ratio Estimators. The Canadian Journal of Statistics. 16:p. 47-55.

Brackstone, G.J. and J.N.K Rao. 1976. Survey Methodology: Raking Ratio Estimators. A Journal Produced by Statistical Services Field, Statistics Canada. 2(1):p. 63-69.

Cameron, A.C. and P.K. Trivedi. 1998. Regression Analysis of Count Data. New York: Cambridge University Press.

Chatterjee, S., and P. Price. 1991. Regression Analysis by Example. Wiley-Interscience Pub. New York. 1991.

Daberkow, S. G., and W. D. McBride. 2003. Farm and Operator Characteristics Affecting the Awareness and Adoption of Precision Agriculture Technologies in the US. Precision Agriculture 4(2):p. 163-177.

Davis, F. 1989. Perceived usefulness, perceived ease of use, and user acceptance of information technology. MIS Quarterly 13(3):p. 319-340.

Deville, J-C, C-E Sarndal, and O. Sautory. 1993. Generalized Raking Procedures in Survey Sampling. J. Am. Stat. Assoc. 88(423):p. 1013-1020.

Fagan, J.T. and B.V. Greenberg. 1990. Minimizing λ-Measures for Table Additivity in Three Dimensions. Bureau of the Census. Census/SRD/RR-90/14.

Feather, P.M., and G.S. Amacher. 1994. Role of Information in the Adoption of Best Management Practices for Water Quality Improvement. Agricultural Economics 11:p. 159-170.

Greene, W. H. 2000. Econometric Analysis. Prentice Hall. Upper Saddle River, NJ, USA.

Irani, T. 2000. Prior experience, perceived usefulness, and the web: Factors influencing adoption of internet communication tools. Paper presented at the Southern Association of Agricultural Scientists Conference. Lexington, KY. Retrieved May 20, 2003 from http://agnews.tamu.edu/ saas/paperti.htm

Khanna, M. 2001. Sequential Adoption of Site-Specific Technologies and Its Implications for Nitrogen Productivity: A Double Selectivity Model. Am. J. Agric. Econ. 83:p. 35-51

Little, R.J.A. 1993. Post-Stratification: A Modeler's Perspective. J. Am. Stat. Assoc. 88(423):p. 1001-1012.

Liu, Y., S.M. Swinton, and N.R. Miller. 2006. Is Site-Specific Yield Response Consistent Over Time? Does it Pay? Am. J. Agric. Econ. 88(2):p. 471-483.

Lohr, Sharon L. 1999. Sampling: Design and Analysis. Brooks/Cole Publishing Co. Pacific Grove, California.

Mooney, Daniel F., Roland K. Roberts, Burton C. English, James A. Larson, Dayton M. Lambert, Margarita Velandia, Sherry L. Larkin, Michele C. Marra, Roderick Rejesus, Steven W. Martin, Kenneth W. Paxton, Ashok Mishra, Eduardo Segarra, Chenggang Wang, and Jeanne M. Reeves. 2010. Status of Cotton Precision Farming in Twelve Southern States. Proceedings of the 2010 Beltwide Conference, New Orleans, LA, January 5 – 8.

Roberts, R.K., B.C. English, J.A. Larson, R.L. Cochran, W.R. Goodman, S.L. Larkin, M.C. Marra, S.W. Martin, W.D. Shurley, J.M. Reeves. 2004. Adoption of Site-Specific Information and Variable-Rate Technologies in Cotton Precision Farming. J. Agric. Applied Econ. 36:p. 143-158.

Roberts, R.K., B.C. English, and S. Mahajanashetti. 1999. Spatial Break-Even Variability for Custom Hired Variable Rate Technology Adoption. Paper presented at the Am. Agric. Econ. Assoc. Annual Meeting, Nashville, TN, 8-11 Aug.

Rogers, E. M. 1983. Diffusion of Innovations. New York: Free Press.

Swinton, S. M., and J. Lowenberg-Deboer. 1998. Evaluating the Profitability of Site Specific Farming. J. Prod. Agric. 11:p. 439-446.

U. S. Department of Agriculture, Economic Research Service (USDA-ERS). Farm Resource Regions. Online. Available at http://www.ers.usda.gov /publications/aib760/aib-760.pdf. Accessed October 2010.

Walton, J.C., D.M. Lambert, R.K. Roberts, J.A. Larson, B.C. English, S.L Larkin, et al. 2008. Adoption and Abandonment of Precision Soil Sampling in Cotton Production. J. Agric. Res. Econ. 33: p. 428-448.

Walton, J.C., D.M. Lambert, R.K. Roberts, J.A. Larson, B.C. English, S.L Larkin, S.W. Martin, M.C. Marra, K.W. Paxton. J.M Reeves. 2010. Grid Soil Sampling Adoption and Abandonment in Cotton Production. Precision Agric. 33: p. 428-448.

Wooldridge, J. 2004. Introductory Econometrics. Ohio: Thomson South-Western.

Table 1. Variable Definitions, Hypothesized Signs, and Means in the Precision Soil Sample Adoption and Perceived Years Useful Equations

Variable	Definition	Hypothesized Sign		Mean	
		adopt	yrs. useful	no weight	raking weight
Farmer Characteristics:					
ACRES	Average cotton acreage grown in 2007 and 2008	+	–	562.220 (1.032)[1]	381.487 (1.044)
LANDTEN	Percentage of owned land to total land farmed	+	+	0.3430 (0.011)	0.366 (0.013)
INCFARM	Percentage of 2007 taxable household income from farming	+	–	0.743 (0.008)	0.695 (0.011)
EXPERIENCE	Years farming divided by farmer age	–	+	0.540 (0.004)	0.535 (0.006)
BS	1 if farmer holds a B.S. degree	+	+	0.908 (0.009)	0.899 (0.011)
OCROPS	Percentage of non-cotton acres to total farmed acres	+	–	0.209 (0.010)	0.218 (0.011)
YVAR	Difference in average yields between the most productive 1/3 and the least productive 1/3 of a typical field	+	–	5.457 (0.089)	5.387 (0.104)
Information Sources:					
INFOCONS	1 if used information from a crop consultant	+	–	0.316 (0.014)	0.304 (.016)
INFOEXTEN	1 if used information from Extension	NA	NA	0.397 (0.015)	0.389 (0.017)
INFOOTH	1 if used information from other farmers	NA	NA	0.605 (0.015)	0.600 (0.017)
INFOSHOWS	1 if used information from trade shows	+	–	0.343 (0.015)	0.335 (0.016)
INFOMEDIA	1 if used information from the media	+	+	0.479 (0.015)	0.482 (0.017)

FARMSUPPLY	Number of farm input suppliers in the region	+	–	7.663 (0.293)	7.959 (0.320)
APPCONS	1 if farmer used a consultant or dealer to apply inputs	+	–	0.153 (0.011)	0.140 (0.011)
Information Technologies:					
IMAGE	1 if used aerial imagery	+	+	0.066 (0.007)	0.056 (0.007)
YMXMAP	1 if used a yield monitor and then generated a yield map	+	+	0.051 (0.006)	0.038 (0.005)
COM	1 if used a computer for farm management	+	+	0.600 (0.015)	0.551 (0.017)
VRTPLAN	1 if made a Variable Rate Fertilizer Management Plan using the GPS-Referenced soil sample information	+	+	0.214 (0.013)	0.193 (0.013)
HANDHELD	1 if used a handheld GPS/PDA	+	+	0.034 (0.005)	0.034 (0.006)
ELECTRIC	1 if used electro conductivity	NA	NA	0.033 (0.005)	0.032 (0.006)
GREENSEEK	1 if used Greenseeker®	NA	NA	0.006 (0.002)	0.005 (0.002)
Regional Characteristics:					
FARMDENS	Number of farms in county divided by the total land in farms (2007)	+	+	-5.904 (0.032)	-5.920 (0.032)
HEARTLAND	1 if farm located in the Heartland USDA Farm Resource Region	+	+	0.269 (0.015)	0.267 (0.018)
PRAIRIE	1 if farm located in the Prairegate USDA Farm Resource Region	+	+	-0.103 (0.026)	-0.077 (0.029)
EASTUP	1 if farm located in the Eastern Uplands USDA Farm Resource Region	+	+	0.256 (0.016)	0.263 (0.018)

FRUITFUL	1 if farm located in the Fruitful Rim USDA Farm Resource Region	+	+	0.218 (0.017)	0.218 (0.021)
MISSPORT	1 if farm located in the Mississippi Portal USDA Farm Resource Region	+	+	0.102 (0.021)	0.110 (0.025)

[1] Numbers in Parentheses are standard errors.
Variables defined as having a value of “1” have a value of zero if the condition does not hold.

Table 2. Logit and Hurdle Poisson Estimates for the Factors Influencing Adoption and Perceived Years of Usefulness of Precision Soil Sampling Technology

	Logit[1]			Poisson[2]		
Independent Variable	Coeff	P-value Wtd[3]	P-value Unwtd	Coeff	P-value Wtd	P-value Unwtd
ACRES	0.165	.446	.289	-0.144	.022	.072
LANDTEN	0.215	.755	.298	0.305	.094	.217
INCFARM	0.207	.779	.504	-0.255	.255	.865
EXPERIENCE	-1.794	.193	.132	0.748	.063	.487
BS	1.365	.053	.039	0.115	.628	.955
OCROPS	0.965	.136	.222	-0.139	.400	.392
YVAR	0.053	.497	.478	-0.001	.958	.967
Information Sources:						
INFOCONS	-0.159	.747	.436	-0.006	.961	.810
INFOEXTEN	-0.178	.718	.749	0.189	.121	.172
INFOOTH	0.623	.221	.361	0.066	.521	.379
INFOSHOWS	-0.308	.496	.710	-0.112	.358	.107
INFOMEDIA	0.201	.656	.738	0.126	.344	.166
FARMSUPPLY	0.036	.403	.352	-0.005	.717	.398
APPCONS	1.888	.000	.000	-0.143	.250	.912
Information Technologies:						
IMAGE	0.926	.172	.160	-0.153	.334	.585
YMXMAP	0.926	.379	.446	-0.039	.794	.909
COM	0.764	.218	.123	-0.171	.221	.241
VRTPLAN	6.428	.000	.000	-0.407	.052	.134
HANDHELD	.266	.720	.438	0.032	.818	.795
ELECTRIC	-1.346	.056	.360	0.295	.095	.089
GREENSEEK	-0.667	.496	.744	0.692	.030	.192
Regional Characteristics:						
FARMDENS	-0.219	.359	.316	-0.020	.713	.591
HEARTLAND	0.970	.394	.331	0.180	.369	.620
PRAIRIE	-1.260	.060	.009	0.413	.166	.223
EASTUP	0.023	.969	.955	-0.031	.911	.557
FRUITFUL	-1.176	.214	.314	-0.305	.052	.627
MISSPORT	1.307	.003	.006	0.290	.009	.055
R^2 = .693						
AIC (Akaike Information Criterion) = 6.695						
N = 9951						

[1]Logit regression models the probability that a producer adopts grid or zone soil test technology.
[2]The Poisson regression models the years between soil tests.
[3]The post-stratification sampling weights are based on raking weights.