Factors Influencing Selection of Information Sources by Cotton Producers Considering Adoption of Precision Agriculture Technologies

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Precision farming potentially offers farmers the ability to decrease costs, increase profits, and decrease environmental risks by not applying more inputs than needed (Bullock, Lowenberg-DeBoer, and Swinton, 2002; Roberts, English, and Larson 2002; Watson et al. 2005; Torbett et al. 2007; Bongiovanni and Lowenberg-DeBoer 2004). Given the potential economic and environmental benefits from some precision agriculture practices, dissemination of information about this technology as an alternative production management strategy is important. The needs of farmers for precision farming information have been met by various suppliers, including private and public sources such as crop consultants, farm dealers, trade shows, Extension, and media (Just et al. 2002, Schnitkey et al. 1992).

The demand for information about the technologies used to manage agricultural production systems has increased with the increased complexity of production technologies (Schnitkey et al. 1992). This situation along with declining resources for information sources such as Extension (Aguilar and Thornsbury 2005; Diem 2002; Smith and Swisher 1986) makes the identification of farmers as information consumers particularly interesting (Holt 1989).

Previous studies focused on the identification of the profiles of producers who are most likely to adopt new technologies such as precision farming, Integrated Pest Management, conservation tillage, among others (Lambert et al. 2007; Roberts, English, and Larson 2002; Daberkow, Fernandez-Cornejo, and Padgitt 2002; Daberkow and

McBride 2003). These studies have focused on technology adoption, but not on the information sources influencing adoption. Few studies have focused on the importance of information sources in agricultural technology adoption (McNamara, Wetzstein, and Douce 1991; King and Rollins 1995; McBride and Daberkow 2003), and general decision making processes including market, production and financial decisions (Schnitkey et al. 1992, Just et al. 2002). But knowledge about the sources of information producers use, particularly in the context of the production decision process, is limited (Schnitkey et al. 1992).

The objective of this study is to determine the farm business, farmer characteristics, and regional factors influencing cotton farmers' choices of information sources when considering precision agriculture. The results can help information suppliers (such as Extension) to better adjust precision farming information to the needs of their clientele. For example, understanding why producers choose one or a combination of information sources as opposed to others may generate useful knowledge to information providers with respect to promoting precision farming technologies.

Conceptual Framework

Farmers face uncertainty when making production decisions. Information about field production characteristics, weather, new technologies, and prices helps reduce producer's uncertainty (Stigler 1961, Gould 1972, Clemen, Winkler, 1985; Bullock, Lowenberg-DeBoer, and Swinton, 2002). Farmers' production decisions, incorporating selection of information sources, can be modeled in three stages as described by Just et al. (2002). In the first stage, the producer decides how much information is needed to manage inputs subject to an availability constraint. In this first stage, producers face uncertainty associated with unobserved information benefits that are realized in the second stage when deciding whether to adopt precision farming technologies. In the second stage, producers use information acquired in the first stage to make decisions about inputs. Profits are realized in the third stage.

In the present study, Just et al.'s (2002) three stage approach was modified to include a stage antecedent to stage 1. That is, we hypothesized that before producers decide on the amount of information needed to make a management decision, they must decided which source or combination of sources they will use from a suite of available information sources (Extension, crop consultants, trade shows, farm dealers, and media). With the antecedent stage, the decision making process can be described as: 1) producers choose among sources of information available, 2) producers decide the amount of information to be used from the sources chosen in stage 1, 3) producers process information gathered in stage 2 to make production decisions, and 4) profits are realized, conditional on the production decisions made in stage three.

Cotton producers were assumed to be rational agents who maximize the discounted expected benefits from cotton, grain crops, and/or livestock production over a time horizon, and therefore weigh the costs of incorporating a new technology into their management portfolio. Producers make decisions about the sources of precision farming information they perceive will be useful to them with respect to making management decisions. Using a dynamic programming approach, we can define the optimal decisions made in stage one (the producer chooses among sources of information available) by through backward induction approach starting from the problem faced by the farmer in stage three (the farmer processes the information and makes a production decision).

Define I_{ij} as information source *j* used by producer *i* considering precision farming as an alternative production technology. Working backwards from the final stage, expected utility (E*U*) is maximized by choosing optimal input levels (x^*) to maximize profit (Π), given a selection of information sources I_{ij} made in stage 1; $\Pi^*(I_{ij}) = \Pi(x^*|I_{ij})$. The solution to this problem results from the third stage expected utility maximization problem,

(1) $$\underset{x}{Max}\ EU(\Pi(x) \mid I_{ij}, Z)$$ [stage 3]

Given the information gathered from source I_{ij}, farm household, business attributes and regional characteristics (Z), a farmer chooses an optimal combination of inputs.

Assumptions about uniqueness of an optimal expected utility for each possible choice of any information source allows us to identify the problem faced by a producer in stage two (Just et al. 2002). In stage two, a producer faces the following problem,

(2) $$\underset{I_{ij}}{Max}\ EU(\Pi^*(I_{ij}) \mid Z)$$ [stage 2]

A producer decides about the amount of information needed to maximize expected utility given optimal profits defined in stage three, $\Pi^*(I_{ij})$. In the context of formulation (2), information is perceived as an additional input in the decision making process (Just 2002, Babcock 1990).

Information from stages two and three is used to define the problem faced by a producer in stage one (1). In stage one, a producer chooses which information source or combination of information sources to be used in stages two and three. That is, in stage one the producer will choose the information source or combination of information sources I_{ij}, if $EU(\Pi^*(I_{jj}) \mid Z) > EU(\Pi^*(I_{ik}) \mid Z)$, where $j \neq k$. Defining

(3) $$U^*_{I_{ij}} = EU(\Pi^*(I_{ij}) \mid Z) - EU(\Pi^*(I_{ik}) \mid Z), \text{ [stage 1]}$$

a utility-maximizing producer will chose information source j if $U^*_{I_{ij}} > 0$.

Note that the difference $U^*_{I_{ij}}$ is an unobserved latent variable, but the decision of using a source of information (y_{ij}) is observable such that:

(4) $$y_{ij} = \begin{cases} 1 & \text{if } U^*_{I_{ij}} > 0 \\ 0 & \text{if } U^*_{I_{ij}} \leq 0 \end{cases},$$

where $y_{ij} = 1$ if the producer decides to use source of information j and $y_{ij} = 0$, otherwise. This identity provides an empirically tractable approach to estimate the factors influencing the selection of precision farming information sources.

Empirical Approach

The previous section framed the decision making process about the use of information sources in precision farming adoption decisions. The dichotomous variable defined in (4) is hypothesized to be a random function of observable exogenous variables such that:

(5) $$y_{ij} = z_{ij}\beta_j + \varepsilon_{ij},$$

where z_{ij} is a $1 \times k$ vector of observed variables that affect the decision to use a particular information source(Z in equations 1, 2, and 3), β_j is a $k \times 1$ vector of unknown parameters to be estimated, and ε_{ij} is the unobserved error term.

The decision to use a particular source of information defined in (5) might be hypothesized to be independent across information sources (e.g., Schnitkey et al. 1992). In other words, producers' decision of using Extension as a source of precision farming information is an independent process from the one that evaluates the use of farm consultants as a source of information. However, what is more likely is that producers combine various sources of information to make farm business decisions. It may therefore be important to take into consideration this correlated decision structure when analyzing the factors influencing the use of different information sources of precision farming information. Ignoring this correlation in analyzing the simultaneous use of information sources may lead to biased estimates of the choice probabilities and incorrect estimates of the standard errors of the parameters (Kiefer, 1982).

Assuming a multivariate normal distribution, the unknown parameters in (5) were estimated using maximum likelihood (ML). The probabilities that enter the likelihood function, as well as the derivatives needed for the ML procedure, were computed using the Geweke-Hajivassiliou-Keane (GHK) simulation procedure (Geweke 1989; Hajivassiliou 1991; Keane 1994), which produced approximations to the *m*-fold multivariate normal integrals:

(6) $$\int_{-\infty}^{z_1'\beta_1} \cdots \int_{-\infty}^{z_m'\beta_m} \phi(s_1, \ldots, s_m) ds_1 \ldots ds_m$$

where $\phi(\cdot)$ is the *m*-variate normal density of a random variable ***s*** with mean vector equal to zero and $m \times m$ positive definite covariance matrix. The log-likelihood for the model was then calculated as the sum of the logs of the probabilities of the observed outcomes defined as:

(7) $$\text{Prob}(y_1, \ldots, y_m | z_1, \ldots, z_m) = \text{MVN}(\mathbf{T}w, \mathbf{TRT}')$$

where ***w*** is a vector defined from $w_m = z_m'\beta_m$, **R** is the correlation matrix, **T** is a diagonal matrix with $t_{mm} = 2y_m - 1$, and MVN refers to the density being multivariate normal

(Greene 2007). Pairwise correlation of the error terms associated with each information-source decision was computed and its significance was tested.

A number of different marginal effects can be computed given the multivariate nature of the model (Greene 2003). The approach taken here was to first obtain the expected value of a positive-use decision for a particular information source (say, y_1=1), conditional on all other information sources also being used ($y_2,...,y_m$ =1):

(8) $$E(y_1 | y_2,\ldots,y_m) = \frac{\text{Prob}(y_1 = 1,\ldots,y_m = 1)}{\text{Prob}(y_2 = 1,\ldots,y_m = 1)} = \frac{P_{1\ldots m}}{P_{2\ldots m}} = E_1 .$$

Then, to get the marginal effects, the derivative of (8) was taken with respect to the explanatory variables of interest:

(9) $$\frac{\partial E_1}{\partial z} = \sum_{j=1}^{m} \left[\frac{1}{P_{2\ldots m}} \frac{\partial P_{1\ldots m}}{\partial w_m} \right] \gamma_m - E_1 \sum_{j=2}^{m} \left[\frac{1}{P_{2\ldots m}} \frac{\partial P_{2\ldots m}}{\partial w_m} \right] \gamma_m ,$$

where **z** is the union of all the regressors that appear in the model and γ_m is defined such that $w_m = z'\gamma_m = \beta_m' z_m$. The terms on the right hand side of equation (9) suggest that the parameter signs estimated in (7) are not necessarily the same as the signs of their respective marginal effects.

Survey and Secondary Data

A survey was mailed on January, 2005 to 12,243 cotton farmers in Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, Missouri, North and South Carolina, Tennessee, and Virginia. Out of 12,243 questionnaires mailed, 200 were returned either undeliverable or by farmers no longer producing cotton. A total of 1216 surveys were returned completed, for a response rate of 10%.

The survey data used in this study are representative of larger farms when compare with the 2002 Agricultural Census by the U.S. Department of Agriculture for the Southeastern United States (Walton et al. 2008). Given that larger farmers are more likely to consider the adoption of certain precision farming technologies (Daberkow and McBride, 2003) the survey data used in this study is representative of farmers interested in precision farming technologies (Walton et al. 2008).

Secondary data regarding factors outside farmers' production decision context (farm location, climate patterns affecting production, access to agriculture support services, among other) were also considered in the analysis. Information about different county farm characteristics were collected from data sources of the 2002 Agriculture Census (USDA), county agriculture related business information patterns were gathered from the 2002 County Business Pattern data (U.S. Census Bureau), and climate patterns information was collected from USDA/ERS natural amenities scale data set. A description of all the variables used in the analysis (survey and secondary data) is presented in Table 1.

Empirical Model

The three sources of information considered as dependent variables were private sources (PRMV), university Extension (ECMV), and media sources (MMV) as described in Table 1. Consistent with the conceptual framework described above, the independent variables (Z) included in our empirical specification are observable factors that are potentially related with the decision of using a particular source of information [see equations (3), (4), and (5)]. Different individual, farm, and local/regional characteristics should result in different access to information sources, abilities to process information from those sources, and therefore different information-source use patterns (Just et al 2002).

We posit socioeconomic and demographic factors, such as age, education, and off-farm income, to impact preferences about information-source use and therefore they were included in the empirical specification. Previous studies have evaluated the effect of human capital as a measure of ability to process information on the use of information sources in agriculture (Just et al. 2002; Schnitkey et al. 1992). Just et al. (2002) developed hypotheses about the complementary relationship between types of information used and human capital. They postulated that different human capital attributes favor the use of different sources of information, assuming normally distributed profits and constant absolute risk aversion (Just et al. 2002). They hypothesized that individuals with more education prefer public sources of information (media, and Extension), because these information sources provide general information that needs to be further processed to target a particular problem. Individuals with less education tend to prefer private sources of information, because these sources provide customized and simplified information to support the specific needs of the information consumers (Just et al. 2002). Thus, Just et al. (2002) considered private information sources to be less human-capital intensive than public sources. Based on these results, we expect education to be negatively related with private sources use, and positively related with public sources use (Extension and media, news of public access). Age is also considered as a potential determinate of information-source use patterns in production decision (Schnitkey et al. 1992). Older farmers are more likely to use Extension as a source of information, and they tend to prefer media over private sources, and printed media over other types of private sources (Schnitkey et al. 1992). On the other hand, older farmers might have lower ability to use information that needs to be further processed to target a particular problem, and therefore they might tend to prefer private over public sources such as Extension and media. In light of these characteristics, the relationship between age and preferences about different information sources appears ambiguous.

In our study, we use the percentage of income from farming to measure the level of part-time farming. Schnitkey et al. (1992) indicates that part-time farmers are more likely to prefer broadcast media sources over both printed media and production consultants. Hence, a farmer who diversifies income among multiple work activities is more likely to use broadcast media rather than printed media, and less likely to use private sources. Higher off-farm income may imply less time for farming activities, therefore farmers with higher off-farm income would tend to prefer private sources that provide customized and simplified information versus public sources providing information than needs further processing.

Schnitkey et al. (1992) considered the number of farm owners (single or multiple owners) in the information-source decision. They found that multiple owners prefer broadcast and Extension services as information sources. Preference for these public information sources suggests that multiple individuals have greater capacity to collect and process general information. Ownership can also be measured by whether a farmer owns or rents the farmland. The expectation is that farmers who own a larger portion of their farmland will have greater autonomy over the decision-making process and, thus, have greater preferences for public sources of information than private sources.

Therefore, the higher the percentage of owned acres, the higher the likelihood of using Extension and media sources, and the lower the probability of using private sources.

Local (county) and regional variables were considered in the information sources use analysis to control for factors outside the farmers' production decision context possibly affecting information-source use decisions. These variables include dummy variables for the state where the farm is located and variables associated with characteristics of the County where the farm is located—farm density (number of farms per acre), distance to a metro county from county centroid, temperature variables, number of farm/garden machinery and equipment merchant wholesalers, number of farm supply merchants and wholesalers in the County, changes in agricultural sales between 1997 and 2002, and changes in land in farm between 1997 and 2002.

Results and Discussion

Descriptive Statistics and Correlation Coefficient

Table 2 summarizes use patterns of information sources among the surveyed farmers. The percentage of producers in the sample using some form of private information source is 69%. Producers who utilize Extension and media comprise 66% and 64% of the sample, respectively. The detailed proportions of producers using different combinations of information sources are presented in Table 2. About 15% of producers used only one source of information (5.3%, 3.9%, and 5.2% cotton farmers using only private, only Extension or only media sources respectively). On the other hand, a 66.5% of the cotton producers in the sample used different combinations of information sources. About half (51.2%) of the producers used all the sources of information considered in the survey. This information suggests that the decision to use one source of information might be correlated with whether or not other information sources will be used. This hypothesis was evaluated by calculating pairwise correlation coefficients across the three information-sources (Table 3). These coefficients measure the correlation between the information sources, after controlling for the influence of the observed factors (Greene 2003). They are the pairwise correlations between the error terms in the system of equations in the multivariate probit model. All correlation coefficients were positive and statistically significant at the 1% level. This supports the hypothesis that the error terms in the information-source use equations are correlated, suggesting that the multivariate probit approach is appropriate in this case. Moreover, the positive signs of the correlation coefficients suggest that the decision to use one source of information makes it more likely that another source will be used. For example, a producer who uses the internet to obtain precision farming information may also tend to use farm dealers as a source of information.

Parameter Estimates and Marginal Effects: Multivariate Probit Model

The parameter estimates from the multivariate probit and (for comparison) the individual probit models are presented in Table 4. Table 5 presents the marginal effects for the variables that were significant in Table 4 for the multivariate probit approach. Conclusions about magnitude and sign of independent variables effects on the information use patterns are discussed using the marginal effect results (Table 5).

Based on the multivariate model approach, the observed factors that tend to be significantly affecting the use of private sources were age, income, farm size, and farm density in the County where the farm was located (Table 5). Older farmers were less likely to use private sources to obtain precision farming information, while farmers with income greater than $150,000 tend to use private sources for precision farming information. Larger farmers tended to use crop consultants, trade shows and/or farmer dealers as a source of precision farming information. Farmers with a Bachelor's degree were more likely to use private sources relative to those with a high school degree. Finally, the significant farm density parameter and its negative marginal effect suggest that farmers located in high farm-density counties were less likely to use private sources.

For the Extension information use equation, the significant variables in the multivariate probit approach were age, farm size, and distance to a metropolitan county from county centroid (Table 5). Older farmers tended to use Extension less as a source of precision farming information, similar to the effect of age on private-source use. Larger farmers tended to use Extension as source precision farming information. Additionally, distance to a metropolitan county has a negative impact on the likelihood of the use of Extension as source of information. Finally, the positive marginal effects for the dummy state variables associated with Alabama and Louisiana reflect a higher likelihood of Extension use for producers located in these states relative to farmers in Tennessee.

The significant variables in the multivariate probit approach for the media-use equation are age, income, and distance to a metropolitan county. As in the private and Extension information use equations, the estimated negative marginal effect for age implied that older farmers tend to use less information from media sources. Farmers with incomes larger than $150,000 were more incline to use media as a source of precision farming information. Additionally, distance to Metropolitan County had a negative impact on the likelihood of media use. As in the private information-source equation, farmers with a Bachelor's degree tend to use less media-source relative to those with a high school degree. Farmers located in Alabama, Arkansas, Louisiana, Mississippi, and Missouri were more likely to use media sources relative to farmers located in Tennessee.

In summary, older farmers tended to use private, Extension and media sources less than younger farmers in the sample. This result differs from the one presented by Schnitkey et al. (1992). However, Schnitkey et al. (1992) implicitly assumed independence among information-source uses by using a multinomial logit approach. Given that the present study showed that farmers seem to simultaneously decide over information-source use (Tables 2 and 3), the results suggest that older farmers in the sample seems to search less for precision farming information through private, Extension, and/or media information sources.

Farmers with incomes larger than $150,000 were more likely to use private information sources. This result suggests that farmers with higher incomes in the sample have more capacity to invest in private decision support services.

Farmers with more education in the sample tended to use media sources. This result is supported by Just et al. (2002) findings suggesting that individuals with higher levels of education tend to prefer information sources of public nature.

Finally, the significant effects of the state dummy variables for the private and Extension information use equations suggest that information suppliers from these sources might be able to differentiate their production (information) based on state differences.

Concluding Comments

Farmers have a number of options to obtain information about precision farming and many of them utilize these information sources simultaneously. The implicitly assumption is often made that the decision to use one information source is independent of the decision to use other information sources (Schnitkey et al. 1992). For example, the decision of using internet is independent from the decision of using crop consultants as a source of information when considering precision farming adoption. In this study, we specifically investigated the factors that affect farmers' use patterns of private, Extension, and media, while taking into account the potential for simultaneous use and/or correlation among the information-source use decisions using a multivariate probit approach. Using this approach, we found that information-source use decisions are indeed correlated even after controlling for observable factors. Furthermore, our analysis suggested that the decision to use one information source positively influences the decision to use other information sources.

Given the correlation of information-source use decisions, it appears more appropriate to investigate factors that affect information-source use decisions in a multivariate context rather than estimating each use equation individually. Future studies need to take the correlation among use decisions into account to provide more accurate parameter estimates and inferences.

Our empirical results from the multivariate probit approach pointed to the importance of age, education, and income as factors that determine use of private, Extension, and media sources.

Information suppliers (crop consultants, farm dealers, Extension educators and media information providers) may be able to tailor their services to clientele, based on the information found from the multivariate analysis. For example, since younger farmers with larger farms tend to use Extension and private information sources simultaneously, Extension educators can tailor a more comprehensive training/outreach program for this target population in conjunction with crop consultants and/or farm dealers. Using our results, information providers can better anticipate which types of farmers would use their information in combination with other information sources. This information might help different information suppliers to combine efforts to better serve precision farming information consumers.

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Table 1. Descriptive Statistics of Variables (n=989)

Variable	Description	Mean	Std Dev
A. Dependent variables:			
PRMV	= 1 if producer uses crop consultants, farm dealers, and/or trade shows zero otherwise	0.7159	0.4512
ECMV	= 1 if producer uses University Extension, zero otherwise	0.6855	0.4645
MMV	= 1 if producer uses media and/or Internet, zero otherwise	0.6754	0.4685
B. Independent variables:			
AL	= 1 if farm is located in Alabama, zero otherwise	0.1143	0.3183
AR	= 1 if farm is located in Arkansas, zero otherwise	0.0819	0.2744
FL	= 1 if farm is located in Florida, zero otherwise	0.0192	0.1373
GA	= 1 if farm is located in Georgia, zero otherwise	0.1820	0.3860
LA	= 1 if farm is located in Louisiana, zero otherwise	0.0698	0.2549
MS	= 1 if farm is located in Mississippi, zero otherwise	0.1355	0.3424
MO	= 1 if farm is located in Missouri, zero otherwise	0.0394	0.1947
NC	= 1 if farm is located in North Carolina, zero otherwise	0.1719	0.3775
SC	= 1 if farm is located in South Carolina, zero otherwise	0.0617	0.2407
TN	= 1 if farm is located in Tennessee, zero otherwise	0.0971	0.2962
VA	= 1 if farm is located in Virginia, zero otherwise	0.0273	0.1630
AGE	Age of producer as of 2004	49.6997	12.0334
HS	1=if Producer has a High School degree, zero otherwise	0.8231	0.3818
AS	1=if Producer has Associate's degree, zero otherwise	0.1769	0.3818
BS	1=if Producer has Bachelor's degree, zero otherwise	0.3549	0.4787
GD	1=if Producer has Graduate degree, zero otherwise	0.0738	0.2616
INC150	1=if Producer's income is greater than $150,000, zero otherwise	0.3478	0.4765
INCFP	Percentage of income from farming divided by 100	0.7219	0.2866
GC2Y	1=if the producer grew cotton either in 2003 or 2004, 0=if the producer did not grow cotton in either year	0.9949	0.0710
FARM SIZE	Owned acres plus rented acres divided by 100	13.6229	15.8422
LAND_TENURE	Owned acres divided by owned acres plus rented acres	0.3229	0.3184
TOTALEST	Total number of farm and garden machinery and equipment merchant wholesalers, plus farm supplies merchant and wholesalers in the county	5.6694	4.3273
FARMDENSITY	Number of farms in the county divided by acres of crop land in the county	0.0053	0.0042
ROADDIST	Distance to a metropolitan county from county centroid	32.8935	27.6147
JANSUNZ	January sunlight hours, normalize (0,1)	0.2049	0.4912
JULHUMZ	July Humidity, normalize (0,1)	-0.9222	0.4862
SALESLN	Natural log of sales per acre 2002 divided by sales per acre 1997	-0.2066	0.2413
LIFLN	Natural log of land in farm 2002 divided by land in farm 1997	-0.0600	0.0888

Table 2. Proportion of Producers Using Different Combinations of Information Sources

Possible Information Sources Combinations	Number of Farmers	Proportion
Use none of the sources considered in the survey	232	19.11%
Use only private sources	64	5.27%
Use only Extension sources	48	3.95%
Use only media sources	63	5.19%
Use private and Extension sources	94	7.74%
Use private and media sources	57	4..70%
Use Extension and media sources	35	2.88%
Use private, Extension, and media sources	621	51.15%

Table 3. Correlation Coefficients of Information-Source Use Decisions

Information Source Decision	Correlation Coefficient[a]	Standard Deviation
Private and Extension	0.80***	0.03
Private and Media	0.71***	0.04
Extension and Media	0.69***	0.04

[a] Correlation coefficients between the residuals from the multi-variate probit equations.
*** indicates statistical significance at the 1% level.

Table 4. Parameter Estimates from the Multivariate Probit and Individual Probit Approach for Estimating the Factors Influencing Sources of Precision Farming Information

	Parameters Estimates from the Multivariate Probit Approach			Parameter Estimates from the Individual Probit Approach		
	Usage Patterns Equations			Usage Patterns Equations		
Independent Variables	Private	Extension	Media	Private	Extension	Media
AL	0.0664 (0.2587)[a]	0.5721** (0.2520)	0.6778*** (0.2650)	0.0695 (0.2507)	0.6133** (0.2441)	0.6686*** (0.2489)
AR	0.0511 (0.2548)	0.3500 (0.2382)	0.6912*** (0.2364)	0.0764 (0.2496)	0.3637 (0.2287)	0.7079*** (0.2346)
FL	-0.7083 (0.5835)	-0.4904 (0.5788)	-0.6232 (0.5924)	-0.6853 (0.5253)	-0.4881 (0.5136)	-0.6466 (0.5229)
GA	-0.2312 (0.4093)	0.1538 (0.4165)	0.2411 (0.4299)	-0.2325 (0.3933)	0.1742 (0.3869)	0.2326 (0.3965)
LA	0.3532 (0.2921)	0.5609* (0.2901)	0.7554** (0.3012)	0.3256 (0.2946)	0.5681** (0.2777)	0.7198** (0.2870)
MS	0.0839 (0.2265)	0.3291 (0.2269)	0.6917*** (0.2279)	0.0941 (0.2262)	0.3445 (0.2154)	0.7091*** (0.2234)
MO	0.0219 (0.3550)	0.1315 (0.3138)	0.6201* (0.3287)	0.0273 (0.3310)	0.1679 (0.3039)	0.6395** (0.3120)
NC	-0.2247 (0.4267)	0.1353 (0.4369)	0.1607 (0.4452)	-0.2585 (0.4109)	0.1324 (0.4030)	0.1282 (0.4117)
SC	-0.4152 (0.4791)	-0.2814 (0.4813)	-0.0295 (0.4877)	-0.4207 (0.4561)	-0.2939 (0.4461)	-0.0247 (0.4550)
VA	-0.0522 (0.4779)	0.3709 (0.4730)	0.1652 (0.4680)	-0.0295 (0.4365)	0.4081 (0.4336)	0.1666 (0.4272)
AGE	-0.0247*** (0.0044)	-0.0171*** (0.0041)	-0.0282*** (0.0043)	-0.0245*** (0.0040)	-0.0165*** (0.0038)	-0.0280*** (0.0039)
AS	0.0295 (0.1282)	0.2088 (0.1323)	0.2002 (0.1246)	0.0266 (0.1209)	0.2164* (0.1205)	0.1869 (0.1207)
BS	0.2698** (0.1092)	0.1672 (0.1055)	0.4436*** (0.1036)	0.2872*** (0.1020)	0.1810* (0.0966)	0.4662*** (0.0993)
GD	0.0464 (0.2010)	0.2034 (0.1880)	0.1745 (0.1825)	0.0471 (0.1838)	0.1975 (0.1790)	0.1984 (0.1812)
INC150	0.2207** (0.1023)	0.1140 (0.0996)	0.2006** (0.1008)	0.1924** (0.0982)	0.1038 (0.0935)	0.1869** (0.0952)
INCFP	0.1499 (0.1742)	0.0259 (0.1748)	0.0546 (0.1707)	0.1622 (0.1645)	0.0312 (0.1592)	0.0922 (0.1615)
GC2Y	1.5848*** (0.3233)	1.2219*** (0.3107)	1.3680*** (0.2965)	1.4907*** (0.2906)	1.2044*** (0.2739)	1.3346*** (0.2809)
FARM SIZE	0.0142*** (0.0038)	0.0088*** (0.0033)	0.0082 (0.0035)	0.0181*** (0.0045)	0.0086** (0.0035)	0.0080** (0.0036)
LAND_ TENURE	0.0276 (0.1591)	-0.1246 (0.1534)	-0.0330 (0.1521)	0.0268 (0.1501)	-0.1403 (0.1439)	-0.0288 (0.1461)
TOTALEST	0.0196 (0.0147)	0.0046 (0.0111)	-0.0033 (0.0129)	0.0236* (0.0128)	0.0051 (0.0109)	-0.0036 (0.0112)

[a] Numbers in parenthesis are standard errors.
*, **, and *** represent statistical significance at 10%, 5%, and 1% levels, respectively.

Table 4. Continued.

Independent Variables	Parameters Estimates from the Multivariate Probit Approach			Parameter Estimates from the Individual Probit Approach		
	Usage Patterns Equations			Usage Patterns Equations		
	Private	Extension	Media	Private	Extension	Media
FARM DENSITY	-37.4328** (16.7266) [a]	-23.1326 (15.4785)	-1.6669 (15.5359)	-38.2750*** (14.9306)	-25.3627* (14.5074)	-3.1755 (14.8103)
ROADDIST	-0.0034 (0.0023)	-0.0043** (0.0021)	-0.0036* (0.0022)	-0.0036 (0.0022)	-0.0047** (0.0021)	-0.0042** (0.0021)
JANSUNZ	0.2088 (0.2933)	0.3501 (0.3054)	0.6364** (0.3098)	0.2010 (0.2902)	0.3670 (0.2875)	0.6349** (0.2910)
JULHUMZ	-0.0808 (0.2383)	0.1195 (0.2499)	0.2498 (0.2625)	-0.1165 (0.2355)	0.1248 (0.2306)	0.2248 (0.2431)
SALESLN	0.0038 (0.2320)	-0.0441 (0.2118)	-0.2820 (0.2322)	0.0129 (0.2142)	-0.0456 (0.2075)	-0.3099 (0.2124)
LIFLN	0.6703 (0.5484)	0.6046 (0.5513)	0.6782 (0.5564)	0.6624 (0.5245)	0.6419 (0.5161)	0.6508 (0.5203)

[a] Numbers in parenthesis are standard errors.
*, **, and *** represent statistical significance at 10%, 5%, and 1% levels, respectively.

Table 5. Marginal Effects from the Multivariate Probit Approach for Estimating the Factors Influencing Sources of Precision Farming Information

	Marginal Effects from the Multivariate Probit Approach		
	Usage Patterns Equations		
Independent Variables	Private	Extension	Media
AL		0.0923	0.1363
AR			0.1684
LA		0.0576	0.1385
MS			0.1666
MO			0.1707
AGE	-0.0013	-0.0001	-0.0047
AS			
BS	0.0069		0.0928
INC150	0.0199		0.0303
GC2Y	0.1021	0.0702	0.1538
FARMS_LTR	0.0014	0.0004	
TOTALEST			
FARM DENSITY	-5.0132		
ROADDIST		-0.0006	-0.0004
JANSUNZ			0.1361