Factors Influencing the Selection of Precision Farming Information Sources by Cotton Producers

Amanda Jenkins, Margarita Velandia, Dayton M. Lambert, Roland K. Roberts, James A. Larson, Burton C. English, and Steven W. Martin

Precision farming information demanded by cotton producers is provided by various suppliers, including consultants, farm input dealerships, University Extension systems, and media sources. Factors associated with the decisions to select among information sources to search for precision farming information are analyzed using a multivariate probit regression accounting for correlation among the different selection decisions. Factors influencing these decisions are age, education, and income. These findings should be valuable to precision farming information providers who may be able to better meet their target clientele needs.

Key Words: Extension, information-source-use decisions, media, multivariate probit, precision agriculture technologies, private sources.

Producer demand for information about agricultural technologies has increased with the increased complexity of production technologies (Schnitkey et al. 1992, Ortmann et al. 1993). Precision farming entails the use of site-specific technologies to gather information about yield and/or soil characteristics at different locations in a field. The information is used to develop more efficient management strategies. Precision agriculture technology may improve efficiency but may also make the decision-making process more complex, requiring additional guidance on how information may be incorporated into management plans (Griffin and Lambert 2005). Previous studies have focused on the factors affecting awareness, perception of importance, adoption, and abandonment of precision farming technologies (Walton et al. 2008, Torbett et al. 2007, McBride and Daberkow 2003), but few studies have focused on the factors affecting producer preferences for precision farming information sources.

Demand for precision farming information is provided by private and public sources including crop consultants, farm input dealerships, University Extension systems, and mass media (McBride and Daberkow 2003). In the context of farm business decision making (e.g., marketing, production, and financial decisions), several studies have focused on the effects of farmer/farm business characteristics on preferences for information sources (Schnitkey et al. 1992, Ortman et al. 1993, Just et al. 2002, 2006). Producers commonly use multiple information sources to increase their knowledge about precision agriculture technologies. Yet studies about the factors influencing preferences for agricultural information sources have not typically analyzed the combination of information sets that farmers search for simultaneously. Most of this literature has implicitly assumed that the decisions to search for information sources are mutually exclusive, ignoring

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the possibility that numerous information sources may be complements or substitutes and may be pursued at the same time. Using a multinomial logit regression, which implicitly assumes independence between alternative information sources, Schnitkey et al. (1992) studied the factors influencing farmers' use and perceived usefulness of information with respect to production, marketing, and financial decisions. Ortmann et al. (1993) studied the factors influencing the use of a single information source (consultants) among Corn Belt farmers but not the potential influence of other information sources on the use of consultants. One exception is Just et al.'s (2006) study, where the possibility of substitute and complementary relationships between sources was analyzed. Just et al. (2006) suggested that the search for information sources might be correlated. However, the econometric models used to analyze the choices of farmers were single equation probit regressions.

The objective of this study is to examine factors influencing cotton farmer choices of precision farming information sources, taking into account the possibility that the selection of information sources may occur simultaneously, reflecting perceived notions of complementarity or substitutability. In particular, we examine the factors influencing the decision to search for precision farming information through crop consultants, farm input dealerships, Extension, and media sources using a multivariate probit regression. Data from cotton farmers in Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, Missouri, North and South Carolina, Tennessee, and Virginia are used in the analysis. The results contribute to the understanding of producer preferences for precision farming information sources. Findings may be useful to precision farming information providers, including industry and outreach. For example, identifying the types of producers more likely to choose crop consultants as a source of precision farming information may help companies offering these services better target potential clientele. Hence, different information providers may be able to tailor information dissemination to the needs of producers. More efficient delivery of information may also help farmers improve their data collection and management skills, increase their production efficiency, and in turn increase the likelihood of wider profit margins from precision farming.

Data Description

This study uses data from a 2005 mail survey of cotton farmers in Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, Missouri, North and South Carolina, Tennessee, and Virginia. The list of cotton farmers was obtained from the Cotton Board in Memphis, Tennessee. Of the 12,243 questionnaires mailed, 200 were returned either undeliverable or by farmers no longer producing cotton. Of the remaining questionnaires, 1,215 were returned completed for a response rate of 10 percent. The low response rate might be due to the complexity and length of the questionnaire and the fact that, at the time of the survey, cotton prices were low and therefore cotton farmers may not have been interested in making investments in new technologies (Walton et al. 2010).

The survey requested information about the use, profitability, and perceived benefits of precision farming technologies and farm business and farmer characteristics. A question about sources of information used to obtain information about precision farming was also asked. Answers about the use of crop consultants, farm input dealerships, Extension, Internet and news media, and other farmers were grouped into four categories based on the characteristics of the information and service provided. Crop consultants and farm input dealerships were classified as private sources, and information from media and the Internet were classified as media sources. A third category included Extension. Finally, a fourth category included other farmers and was called "indirect" information sources. The latter category refers to information sources that do not directly produce information or whose purpose is not to produce information for farmers. For example, other farmers may have obtained information directly from other sources or through experience with precision farming technologies and therefore have this indirect information available if a farmer decides to seek it from other farmers. This study focuses on use patterns of private, media, and Extension information sources among cotton farmers using precision agriculture.

After eliminating observations with missing data, 959 responses were available for analysis (Table 1). An assessment of how well this sample represented the population of cotton farmers in the southeastern United States was made by comparing the sample data with data from the

Table 1. Definitions and Descriptive Statistics of Variables (n=959)

Variable	Description	Mean	Weighted Mean
A. Dependent variables:			
y_1	= 1 if producer selects crop consultants and/or farm dealers, zero otherwise	0.7247	0.6602
y_2	= 1 if producer selects University Extension, zero otherwise	0.6934	0.6296
y_3	= 1 if producer selects media and/or Internet, zero otherwise	0.6851	0.6356
B. Independent variables:			
AL	= 1 if farm is located in Alabama, zero otherwise	0.1157	0.1029
AR	= 1 if farm is located in Arkansas, zero otherwise	0.0824	0.0919
FL	= 1 if farm is located in Florida, zero otherwise	0.0198	0.0214
GA	= 1 if farm is located in Georgia, zero otherwise	0.1804	0.2443
LA	= 1 if farm is located in Louisiana, zero otherwise	0.0678	0.0804
MS	= 1 if farm is located in Mississippi, zero otherwise	0.1376	0.1259
MO	= 1 if farm is located in Missouri, zero otherwise	0.0396	0.0461
NC	= 1 if farm is located in North Carolina, zero otherwise	0.1721	0.1569
SC	= 1 if farm is located in South Carolina, zero otherwise	0.0605	0.0363
TN	= 1 if farm is located in Tennessee, zero otherwise	0.0959	0.0686
VA	= 1 if farm is located in Virginia, zero otherwise	0.0282	0.0252
AGE	Age of producer in 2004 (in years)	49.5308	50.0433
HS	=1 if producer has high school degree or less, zero otherwise	0.4880	0.5433
AS	=1 if producer has associate's degree, zero otherwise	0.1293	0.1152
BS	=1 if producer has bachelor's degree, zero otherwise	0.3087	0.2686
GD	=1 if producer has graduate degree, zero otherwise	0.0740	0.0729
INC150	=1 if producer's income greater than $150,000; zero otherwise	0.3525	0.2740
INCFP	Proportion of income from farming	0.7275	0.6379
FARM SIZE	Total acres farmed	1147.34	758.0025
TENURE	Owned acres divided by owned acres plus rented acres	0.3199	0.3582
TOTALEST	Total number of farm and garden machinery and equipment merchant wholesalers, plus farm supply merchants and wholesalers in the county	5.6872	5.7253
DENSITY	Number of farms in the county divided by acres of crop land in the county	0.0053	0.0052
ROADDIST	Distance to a metropolitan county	32.8393	34.2911
JANSUNZ	January sunlight hours, standard normal (0,1)	0.2033	0.2152
JULHUMZ	July humidity, standard normal (0,1)	-0.9197	-0.9534
SALESLN	Natural log of product sales per acre in 2002 divided by sales per acre in 1997	-0.2061	-0.2102
LIFLN	Natural log of land in farms in 2002 divided by land in farms in 1997	-0.0601	-0.0663

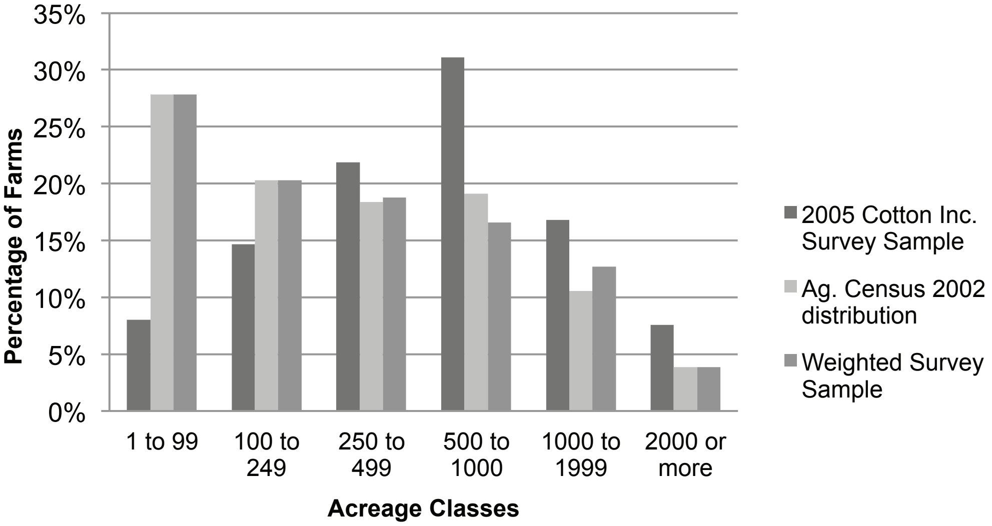

Figure 1. Cotton Acreage Distribution for the Survey Sample Data Compared with the 2002 Census of Agriculture, and the Survey Weighted Sample

2002 Census of Agriculture, U.S. Department of Agriculture, National Agricultural Statistics Service (USDA/NASS 2004). Figure 1 compares the distribution of the cotton acres planted between 2003 and 2004 by survey respondents with the distribution of cotton acres harvested from the 2002 Census of Agriculture (USDA/ NASS 2004). Producers with 500 or more cotton acres represented a larger proportion of respondents (55 percent) than enumerated by the Census of Agriculture (33 percent). Conversely, the share of farmers with cotton acreage of 249 or below was lower (23 percent) than the Census of Agriculture figures (48 percent). Those producing cotton on 250 acres and 499 acres were approximately identical in terms of representation between the Census of Agriculture (18 percent) and the survey (22 percent). These results suggest that respondents were likely more representative of larger cotton farms (>500 acres). Given this response pattern, post-stratified survey weights were estimated to summarize the data and in a weighted multivariate probit regression. Post-stratification weights can adjust for over- or underrepresentation of survey respondents within strata based on known population counts (e.g., among states or farm sizes) but do not attenuate potential nonresponse bias (Lohr 1999). Respondents were classified into h=1 to 66 strata depending on farm location (by state) and cotton acreage [11 states × 6 acreage classes (1–99, 100–249, 250–499, 500–999, 1000–1999, or 2000+ acres)]. Weights (ω_{ih}) were estimated using the raking procedure suggested by Binder and Théberge (1988). The weighted distribution of cotton acres harvested for the sample is presented in Figure 1. As expected, the weighted distribution of the survey responses closely approximates the distribution of cotton farmers based on the 2002 Census of Agriculture data.

Information about farm density, percentage change in agricultural sales between 1997 and 2002, and percentage change in land in farms between 1997 and 2002 were calculated using the 2002 Census of Agriculture (USDA/NASS 2004). County agriculture-related business information patterns (number of merchant wholesalers, plus farm input supply dealers and wholesalers, distance to metropolitan counties) were gathered from the 2002 County Business Patterns (U.S. Census Bureau 2002). January sunshine hours and July humidity data were collected from the USDA, Economic Research Service natural amenities scale data set (USDA/ERS 2004). Demographic, farm, and regional characteristics used in the empirical model are described below.

Empirical Model

The objective of the study is to examine the factors that affect cotton producers' preferences for alternative sources of precision farming information. Given this objective, the empirical specification of the information selection problem (e.g., private sources, Extension, and media) is:

$$(1)\quad \begin{aligned} y_{i1} &= \beta_1' z_{i1} + e_{i1}, \\ y_{i2} &= \beta_2' z_{i2} + e_{i2}, \\ y_{i3} &= \beta_3' z_{i3} + e_{i3}, \end{aligned}$$

where $y_{i1} = 1$ if a producer selects crop consultants and/or farm input dealerships as sources of precision farming information (0 otherwise); $y_{i2} = 1$ if a producer selects information from Extension sources (0 otherwise); and $y_{i3} = 1$ if a producer selects media sources (0 otherwise); β_1, β_2, and β_3 are parameters associated with each information source selection decision; e_{i1}, e_{i2}, and e_{i3} are random disturbances for each equation; and z_{i1}, z_{i2}, and z_{i3} are vectors of observed farmer/farm business characteristics and regional variables potentially affecting the selection of information sources. It is hypothesized that different individual, farm, and local/regional characteristics are correlated with access to different information sources, the ability to process information from those sources, and therefore different information-source search patterns (Just et al. 2002, 2006).

A description of the variables used in this analysis is presented in Table 1. Private sources are defined as crop consultants and farm input dealerships providing precision agriculture services. Extension sources compile all activities and sources provided by universities to inform farmers about precision farming, including field days, workshops, and educational materials developed by Extension about precision farming technologies. Media sources are defined as communication channels providing precision farming information through radio, newspapers, magazines, and Internet sources. Information formats used by private and Extension sources (e.g., online information and printed media) may overlap. Additionally, there may be complementary relationships between information sources, given that private sources may use Extension information to complement the information they provide and vice versa (Just et al. 2006).

Socioeconomic and demographic factors including education, age, income, percentage of income from farming, land tenure, and farm size were hypothesized to correlate with preferences for precision farming information sources. Previous studies have evaluated the influence of human capital on the use of agricultural information sources (Just et al. 2002, Schnitkey et al. 1992). Just et al. (2002, 2006) developed hypotheses about the complementary relationship between types of information used and human capital, hypothesizing that individuals with more education are more likely to use information sources that provide relatively unprocessed data, raw statements, or facts (e.g., media sources). It is expected that farmers with more education may have more analytical capability to use unprocessed information and translate it into an input used to make management decisions (Just et al. 2002).

Age is also a potential determinate of information-source selection patterns (Schnitkey et al. 1992). A farmer's interest in acquiring information about precision farming may decrease as age increases. As age increases, a farmer's planning horizon shortens, making the farmer less likely to spend time and/or money searching for information about new technologies. Age is correlated with farming experience (Schnitkey et al. 1992), and it is possible that as experience with precision farming technology increases, the utility from precision farming information-source use decreases, given that information has already been acquired through experience.

Income is expected to be positively associated with information-source selection. The selection process may require time to search and process information (e.g., opportunity costs), and access fees for information services. In this study, farmers reporting household incomes greater than $150,000 were considered high-income farmers (Walton et al. 2008, 2010). Higher income levels may facilitate access to consulting services complementing new technologies (Rogers 1983). Crop consultants and farm dealers may specialize in services complementing precision farming technologies, while Extension may focus on the needs of a particular region. Specific information about precision farming provided by crop consultants may be more detailed and customized to particular operations, but may also come at higher costs. Therefore, farmers with relatively higher incomes may be more likely to select crop consultants and/or farm input dealerships as information sources, while lower income farmers may be more likely to select Extension as a source of precision farming information. On the other hand, farmers with higher incomes may also have, on average, more resources to invest to search for precision farming information. Therefore, income could be positively correlated with the decision to select among the various information sources to obtain precision farming information.

Less income from farming may suggest less time spent managing the farm. Therefore, farmers reporting lower levels of income from farming may prefer information sources that provide customized information, requiring less processing time (Just et al. 2002). Media sources that provide information needing additional processing to support decision-making processes may be less preferred by farmers with lower income from farming. Alternatively, farmers whose income is highly dependent on farming are more likely to select information sources that provide information they consider useful for management decisions, even if using those sources implies increased investment in time and money (e.g., crop consultants and/or farm input dealerships).

The percentage of total acres owned is hypothesized to be positively correlated with the selection of all information sources. Planning horizons may be longer for landowners relative to land renters (Soule, Tegene, and Wiebe 2000). Therefore, farmers who own more of the land they farm may be more likely to obtain information from a variety of sources than farmers who rent more of the land they farm.

Previous studies found a positive correlation between farm size and an interest in precision farming technologies (e.g., Daberkow and McBride 2003). It is hypothesized that farm size will also be positively correlated with the selection of all precision farming information sources.

Location and regional variables were included to control for factors outside the farmer's management-decision context that possibly affect information-source-selection decisions. Dummy variables for the state where the respondent's farm was located were hypothesized to control for general differences across states, including prices and growing conditions (Khanna 2001). Tennessee was chosen as the reference state. Variables representing the number of wholesalers, plus farm supply merchants and wholesalers in the county, were hypothesized to control for differences with respect to access to agricultural services. It was expected that the likelihood of selecting farm input dealerships as a source of precision farming information is higher in counties where there were relatively more farm input dealerships. Distance to metropolitan counties was hypothesized to control for access to information technologies and general access to information services typically associated with metropolitan counties. Variables measuring January sunshine hours and July humidity were hypothesized to control for growing season conditions, which could influence information needs. Variables measuring the percentage change in agricultural sales between 1997 and 2002, and the percentage change in land in farms between 1997 and 2002, were hypothesized to control for differences in levels of agricultural activity among counties. A variable representing farm density (number of farms per acre) in the county was included to control for differences in farm distribution. Farmers in higher farm-density counties were expected to interact more frequently than farmers in low farm-density counties (Lambert, Wojan, and Sullivan 2009); therefore farmers may be more likely to use other producers as a source of precision farming information and therefore less likely to use private, Extension, and/or media sources. Farm density also accounts for regional differences in average farm size. Counties with higher farm densities may have, on average, smaller farms than counties with relatively low farm densities.

Estimation Methods

The decision to pursue the use of various sources of information is hypothesized to be a function of observable exogenous variables as stated in equation (1). Choice decisions over the three alternatives presented in equation (1) can be framed in the context of a multinomial probit model. A restrictive assumption of multinomial models is Independence of Irrelevant Alternatives (IIA), which assumes that the error terms of the choice equations are independent (Greene 2003). This assumption does not allow the possibility of unobserved factors shared across different choices (McFadden 1984). On the other hand, a plausible assumption in the context of the search for precision farming information is that some information sources may share similar attributes because they provide complementary services (Just et al. 2006). Precision farming information sources may not only share similar attributes; they may complement each other when providing information to final users. Therefore, the random components of the information-source selection decisions may be correlated. The multinomial model implies that choices are mutually exclusive, but the assumption of nonexclusive choices of information sources seems more plausible.

Given that the decisions to select sources of precision farming information are not likely mutually exclusive and that the decisions to use these sources may be correlated, a multivariate probit regression was used to model the decision-making process between information sources. Assuming a multivariate normal distribution, the unknown parameters in equation (1) were estimated using maximum likelihood (ML). The probabilities entering the likelihood function, as well as the first and second order conditions of the log-likelihood function, were computed using the Geweke-Hajivassiliou-Keane (GHK) simulation procedure (Geweke 1989, Hajivassiliou 1993, Keane 1994), which produces approximations to the threefold multivariate normal integrals:

$$(2) \qquad \int_{-\infty}^{z_1'\beta_1} \int_{-\infty}^{z_2'\beta_2} \int_{-\infty}^{z_3'\beta_3} \varphi(s_1, s_2, s_3)\, ds_1\, ds_2 ds_3 ,$$

where $\varphi(\cdot)$ is the 3-variate normal density of a random variable s with mean vector equal to zero and 3×3 positive definite covariance matrix. The log-likelihood for the model is calculated as the sum of the log probabilities of the observed outcomes:

$$(3) \quad \text{Prob}(y_1, y_2, y_3 | z_1, z_2, z_3) = MVN(\mathbf{T}\boldsymbol{W}, \mathbf{TRT}')$$

where $\boldsymbol{W}$ is a vector defined as

$$w_{im} = \beta_m' z_{im} ,$$

for m = 1, 2, 3; **R** is a correlation matrix; **T** is a diagonal matrix with

$$t_{im} = 2y_{im} - 1 ,$$

for m = 1, 2, 3; and MVN is the multivariate normal density (Greene 2007). Pairwise correlations between the error terms associated with each information source equation were computed and their significance tested.

Post-stratified survey weights were included in the likelihood function to adjust for underrepresentation of small farms. The weighted log-likelihood function for the three-alternative (i.e., Extension, media, and private sources) multivariate probit model is:

$$(4) \quad \ln L = \sum_{i=1}^{n} \sum_{h=1}^{H} \omega_{ih} \ln \Phi_3 (t_{ih1} w_1, t_{ih2} w_2, t_{ih3} w_3; \Omega)$$

where ω_i is the post-stratified survey weight for observation I; w_m for m = 1, 2, 3 is defined in equation (3); and Ω has constituent elements, Ω_{jm},

$$(5) \quad \begin{aligned} &\Omega_{jj} = 1 \; for \; j = 1,2,3 \\ &\Omega_{21} = \Omega_{12} = t_{ih1} t_{ih2} \rho_{21} \\ &\Omega_{31} = \Omega_{13} = t_{ih3} t_{ih1} \rho_{31} \\ &\Omega_{32} = \Omega_{23} = t_{ih3} t_{ih2} \rho_{32} . \end{aligned}$$

Marginal effects are computed given the multivariate nature of the model (Greene 2003). The approach taken here was to first obtain the expected value of a selection decision for a particular information source (say, $y_1 = 1$), conditional on all other information sources also being selected ($y_2, y_3 = 1$):

$$(6) \quad E(y_{i1} | y_{i2}, y_{i3}) = \frac{\text{Prob}(y_{i1} = 1, y_{i2} = 1, y_{i3} = 1)}{\text{Prob}(y_{i2} = 1, y_{i3} = 1)}$$

$$= \frac{P_{123}}{P_{23}} = E_{i1}.$$

The derivative of equation (6) was taken with respect to the explanatory variables of interest to estimate the marginal effects:

$$(7)\quad \frac{\partial E_{i1}}{\partial \boldsymbol{Z}_i} = \sum_{m=1}^{3}\left[\frac{1}{P_{23}}\frac{\partial P_{123}}{\partial w_m}\right]\gamma_m - E_1\sum_{m=2}^{3}\left[\frac{1}{P_{23}}\frac{\partial P_{23}}{\partial w_m}\right]\gamma_m,$$

where $\boldsymbol{Z}_i$ is the union of all regressors appearing in the model, and γ_m is defined such that

$$w_m = \gamma_m'\boldsymbol{Z}_i = \beta_m' z_{im};$$

γ_m will have some zeros in it unless all regressors appear in all m equations. The terms on the right-hand side of equation (7) suggest that the parameter signs estimated in equation (1) are not necessarily the same as the signs of their respective marginal effects.

Multicollinearity Tests

Multicollinearity may compromise inferences by inflating variance estimates (Greene 2003, Judge et al. 1988). A condition index was used to detect collinear relationships (Belsley, Kuh, and Welsch 1980). Condition indexes between 30 and 100 indicate that explanatory variables have moderate to strong association with each other. A condition index accompanied by a proportion of variation above 0.5 indicates a potential collinearity problem (Belsley, Kuh, and Welsch 1980).

Exogeneity Tests

In survey analysis it is common to find respondent attributes and farm business characteristics to be jointly determined with the dependent variables (Walton et al. 2008). The number of establishments (TOTALEST) providing farm input services in a county may be codetermined with the information-source-selection decisions. For example, the likelihood of selecting crop consultants and/or farm input dealerships as a source of precision farming information might be higher in a county where there are more firms of that nature. Input supply firms may attract farm input dealerships and/or crop consultants that provide precision farming information services. More business may lead to increased availability of information sources, which would heighten competition between these sources and potentially lower the costs of these consulting services. At the same time, increased demand for crop consultants and/or farm input dealerships by farmers might attract input supply firms to locate in a particular county.

A data-driven approach was used to statistically test for the exogeneity of the total number of establishments variable (TOTALEST). The total number of establishments in a county was obtained from the county business patterns statistics prepared by the U.S. Census Bureau (U.S. Census Bureau, County Business Patterns 2002). Given that TOTALEST is a variable that can only take nonnegative integer values, a weighted negative binomial model was used to regress TOTALEST against a set of instrumental variables. The instruments included all exogenous variables in the information-source-selection equations along with additional predetermined variables including: 1) a dummy variable measuring whether a particular county was classified as micropolitan according to the Bureau of Economic Analysis definition (U.S. Census Bureau, U.S. Office of Management and Budget 2000); 2) county population density in 2000 (U.S. Census Bureau 2000); 3) county average wage in 2000 (U.S. Census Bureau 2000); and 4) a dummy variable reflecting the county's dependence on farming (USDA/ERS 2004a). The selected instrumental variables were hypothesized to be correlated with the TOTALEST but uncorrelated with the error terms in equation (1) since they are outside the production decision-making framework but are correlated with the number of farm dealerships in a county. The residuals from this regression were included in the baseline weighted multivariate probit model. A Wald statistic was estimated to test the joint significance of the residual terms across the three equations (Wooldridge 2002). Failing to reject the null hypothesis of exogeneity provides evidence that TOTALEST is exogenous.

Results and Discussion

Descriptive Statistics, Correlation Coefficients, and Specification Tests

Table 1 presents the weighted and unweighted means of selected variables of the survey. Results for the weighted and unweighted data are similar, except for farm size. Since the post-stratification weights are based on cotton acres harvested, the smaller farms in the survey sample are given

Table 2. Proportions of Producers Selecting Different Combinations of Information Sources

Possible Information Source Combinations	Percentage	Weighted Percentage (estimates)
Selected none of the sources considered in the survey	13.97%	18.82%
Selected only private sources	4.59%	4.96%
Selected only Extension sources	3.65%	3.88%
Selected only media sources	5.01%	6.49%
Selected private and Extension sources	7.61%	6.72%
Selected private and media sources	5.21%	4.87%
Selected Extension and media sources	3.23%	2.75%
Selected private, Extension, and media sources	55.05%	49.46%
Selected only indirect sources of information	1.68%	2.05%

Table 3. Correlation Coefficients between Information-Source-Selection Decisions

Information Source Decision	Correlation Coefficient[a]	Standard Deviation
Private and Extension	0.71***	0.04
Private and Media	0.72***	0.04
Extension and Media	0.56***	0.05

[a] Correlation coefficients between the residuals from the multivariate probit model.
*** Indicates statistical significance at the 1 percent level.

weight. The weighted average farm size decreased from 1,147 acres to 758 acres. Table 2 summarizes the information selection patterns for the weighted and unweighted survey data. The percentage of producers who selected private sources to obtain precision farming information (i.e., crop consultants and/or farm input dealerships) was about 72 percent. Producers who selected Extension and media sources comprised 70 percent and 69 percent of the sample, respectively. About 15 percent selected only one source of information. On the other hand, 71 percent of cotton producers selected combinations of information sources. About half (55 percent) selected all sources of information. The weighted average of information-source choice patterns changed slightly. The percentage of producers who did not select any source increased to 19 percent. This result suggests that a higher proportion of small operations did not choose any of the information sources presented in the survey. On the other hand, the percentage of farmers selecting only one source of information increased to 17 percent. The percentage of cotton producers who selected different combinations of information sources decreased to 64 percent, suggesting that operators of smaller farms may not choose combinations of sources as much as operators of large farms. In general, these findings suggest that the decision to select one source of information might be correlated with the decision to select other sources of precision farming information. This hypothesis was tested by calculating pairwise correlation coefficients across the residuals of the equation system for the three information-source selection decisions after controlling for the influence of the

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

	Parameter Estimates from the Multivariate Probit Model		
	Selection Pattern Equations		
Independent Variables [a]	Private	Extension	Media
CONSTANT	1.5907*** (0.3361)	1.2468*** (0.3171)	1.2187*** (0.3052)
AL	0.2199 (0.2927)[b]	0.7030** (0.2903)	0.7169** (0.2907)
AR	-0.1086 (0.2818)	0.2473 (0.2623)	0.7478*** (0.2609)
FL	-0.6926 (0.5885)	0.1124 (0.6009)	0.0653 (0.6156)
GA	-0.1144 (0.4260)	0.4002 (0.4252)	0.7186 (0.4441)
LA	0.4929 (0.3151)	0.6218** (0.3143)	0.8186** (0.3186)
MS	0.1221 (0.2616)	0.3393 (0.2499)	0.7428*** (0.2522)
MO	0.1188 (0.3745)	0.4995 (0.3387)	0.4215 (0.3509)
NC	-0.1265 (0.4477)	0.5596 (0.4481)	0.8205 (0.4609)
SC	-0.1806 (0.5150)	0.3963 (0.5181)	0.6685 (0.5243)
VA	0.0887 (0.5257)	0.7792 (0.5232)	1.0358** (0.5029)
AGE	-0.0263*** (0.0045)	-0.0228*** (0.0041)	-0.0299*** (0.0043)
AS	0.1463 (0.1545)	0.2169** (0.1583)	0.4139** (0.1614)
BS	0.2739** (0.1174)	0.2163* (0.1115)	0.6639*** (0.1163)
GD	0.2748 (0.2109)	0.3841* (0.1979)	0.7640*** (0.1978)
INC150	0.2766** (0.1090)	0.1912* (0.1068)	0.2562** (0.1097)
INCFP	0.0596 (0.1627)	0.0631 (0.1583)	-0.1441 (0.1631)
FARM SIZE	0.0002*** (0.0001)	0.0001*** (0.0001)	0.0001*** (0.0001)

(Continued)

[a] For variable definitions see Table 1.
[b] Numbers in parenthesis are standard errors.
*, **, and *** represent statistical significance at 10 percent, 5 percent, and 1 percent levels, respectively.

Table 4. (Continued)

	Parameter Estimates from the Multivariate Probit Model		
	Selection Pattern Equations		
Independent Variables [a]	Private	Extension	Media
TENURE	-0.0451 (0.1462)	0.0617 (0.1444)	-0.0317 (0.1466)
TOTALEST	0.0225 (0.0151)	0.0052 (0.0123)	0.0118 (0.0127)
FARMDENSITY	-48.859*** (17.6054) [b]	-27.6074* (15.7506)	-9.3356 (15.4686)
ROADDIST	-0.0019 (0.0023)	0.0013 (0.0022)	-0.0011 (0.0022)
JANSUNZ	0.1981 (0.3192)	0.3261 (0.3357)	0.2675 (0.3416)
JULHUMZ	-0.0868 (0.2467)	0.3615 (0.2469)	0.3380 (0.2673)
SALESLN	0.2152 (0.2254)	0.2554 (0.2094)	0.0282 (0.2360)
LIFLN	0.2499 (0.5454)	0.0569 (0.5739)	1.0336* (0.5746)
Likelihood value		-1433.5980	
AIC		2.944	
BIC		3.345	

[a] For variable definitions see Table 1.
[b] Numbers in parenthesis are standard errors.
*, **, and *** represent statistical significance at 10 percent, 5 percent, and 1 percent levels, respectively.

observed factors (Table 3). The correlation coefficients of the residuals were positive and statistically significant at the 1 percent level, supporting the hypothesis that the error terms in the information-source-selection equations were correlated, and also suggesting that the multivariate probit approach appears appropriate. The positive correlation between the disturbances suggests that the decision to select one source of information increases the likelihood that another source will be selected. For example, a producer who uses the Internet to collect information may also tend to select farm input dealerships as a source of precision farming information.

Parameter Estimates and Marginal Effects

The estimates of the multivariate probit are presented in Table 4. Table 5 presents the marginal effects from the multivariate probit model for the significant explanatory variables.

Factors correlated with the decision to select private sources to obtain precision farming information (y_1—crop consultants and/or farm input dealerships) were age (*AGE*), attainment of a bachelor's degree (*BS*) relative to a high school diploma or less (*HS*), income (*INC150*), and farm density (*FARM DENSITY*) (Table 5). Older farmers were less likely to use private sources to obtain precision farming information. Farmers with incomes greater than $150,000 were more likely to select, on average, private information sources. Farmers with a bachelor's degree were less likely to use private sources relative to those with a high school diploma or less formal education. As hypothesized, farmers with less education may be more likely to select private sources of precision farming information. The significant relationship

Table 5. Marginal Effects from the Weighted Multivariate Probit Model

	Marginal Effects from the Multivariate Probit Approach		
	Selection Patterns Equations		
Independent Variables	Private	Extension	Media
AL		0.1765 (0.0125)	0.1409 (0.0070)
AR		0.0805 (0.0137)	0.2097 (0.0027)
LA		0.1189 (0.0173)	0.1489 (0.0079)
MS		0.0679 (0.0127)	0.1768 (0.0036)
MO		0.1837 (0.0101)	
VA		0.1972 (0.0157)	0.2397 (0.0066)
AGE	-0.0001 (0.0015)	-0.0013 (0.0004)	-0.0048 (0.0003)
AS		0.0379 (0.0077)	0.0920 (0.0024)
BS	-0.0314 (0.0243)	0.0044 (0.0115)	0.1515 (0.0031)
GD		0.0531 (0.0126)	0.1708 (0.0044)
INC150	0.0097 (0.0126)	0.0136 (0.0055)	0.0368 (0.0031)
FARMSIZE	0.0001 (0.0001)	0.0001 (0.0001)	0.0001 (0.0001)
FARMDENSITY	-5.7778 (1.0602)	-3.0726 (0.5397)	
LIFLN			0.2694 (0.0034)

with *FARM DENSTY* suggests that operations located in high farm-density counties were less likely to select private information sources. The negative effect of *FARM DENSITY* could be explained by farmers in these counties using other farmers as a source of information. This result may also suggest that, on average, smaller farm operators do not search for precision farming information as frequently as operators of larger farms, to the extent that high farm-density counties are likely comprised of many smaller farms (Daberkow and McBride 2003).

Age, attainment of an associate's degree (*AS*), bachelor's degree (*BS*), and a graduate degree (*GD*) relative to a high school diploma or less (*HS*), income, and farm density were associated with the decision to select Extension as a source of precision farming information (Table 5). As hypothesized, farmers with more education were more likely to select information sources that provide relatively unprocessed data or raw statements or facts (e.g., the information that may be disseminated at field days or through Extension publications). Older farmers were less likely to select Extension as a source of precision farming information. Similar to the selection of private sources, the negative effect of farm density may suggest that counties with higher farm densities represent a farm distribution structure where distance between farms is small and therefore farmers may be more likely to rely on other farmers to obtain precision farming information rather than Extension.

Age, attainment of an associate's degree, bachelor's degree, and a graduate degree relative to a high school diploma or less formal education, income, and change in land in farms between 1997 and 2002 were associated with the selection of media sources to gather information about precision farming. The negative effect of age suggests that older farmers were less likely to select media as a source of precision farming information. Farmers with an associate's, bachelor's, or a graduate degree tended to prefer media as a source of precision farming information more than those with a high school diploma or less. Farmers with incomes greater than $150,000 were more inclined to select media as a source of precision farming information.

In summary, older farmers were less likely to select private entities, Extension, and media outlets as sources of precision farming information. Farmers with income greater than $150,000 were more likely to choose private, Extension, and media sources for information. Farmers with higher incomes were more likely to select information sources that may require extra search and processing time (e.g., media sources), or access fees (e.g., crop consultants and farm input dealerships). Farmers with higher educational attainment (associate's, bachelor's, or a graduate degree) tended to select Extension, private, and media resources for precision farming information. The findings also suggest that younger, well-educated cotton farmers with larger operations use nonfarm institutional information sources (i.e., Extension, private, and media sources) simultaneously to obtain precision farming information.

Conclusions

Farmers have a number of options for obtaining information about precision farming, and simultaneous selection of information sources is not uncommon. This study investigated the factors associated with cotton farmers' preferences for private, Extension, and media information sources, taking into account the potential correlation among alternative information sources using a multivariate probit regression. Results suggest that information-source-selection decisions were correlated even after controlling for observable factors.

The findings point to the importance of age, education, and income as factors determining the selection of private, Extension, and media as information sources. Information suppliers—including crop consultants, farm input dealerships, Extension educators, and media information providers—may be able to tailor their services to clientele based on these findings. Older cotton farmers do not have a preference toward any of the information sources examined in this study, suggesting that others methods of reaching older farmers regarding precision farming technologies would have to be tried. It seems that younger, well-educated cotton farmers with larger operations tend to use Extension, media, and private sources simultaneously to obtain precision information. These synergies between information source selection decisions may suggest that private sector and University Extension systems should continue to cooperate on field days, demonstrations, and other educational events. This cooperation increases attendance and improves the objectivity of the information presented at these functions (Ford and Babb 1989). Additionally, resources can be used more efficiently because private and Extension sources appear to target similar clientele. Private and public information providers could leverage synergies to collaborate in the development of new strategies to deliver information, identification of technology-related information needs, and specifically the development of networks linking information and education on how to use precision farming information (Ford and Babb 1989). For example, private and Extension sources could share the costs of preparing precision farming outreach activities since they are targeting the same clientele.

Although it is important to acknowledge the benefits from collaboration between public and private sources, it is also important to understand that farmers may find the objectivity of land-grant Extension agents and university researchers a valuable asset. Therefore, University Extension systems should collaborate with private sources while maintaining their independence when providing recommendations to cotton farmers about precision farming technologies.

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