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Reasons for Adopting Precision Farming: A Case Study of U.S. Cotton Farmers

Mahesh Pandit, Ph.D. student
Department of Agricultural Economics and Agribusiness
Louisiana State University
101 Martin D. Woodin Hall, Baton Rouge, LA 70803
Tel: 225-578-2728
Fax: 225-578-2716
E-mail: mpandi2@tigers.lsu.edu

Ashok K. Mishra, Professor
Krishna P. Paudel, Associate Professor
Department of Agricultural Economics and Agribusiness
Louisiana State University, Baton Rouge, Louisiana

Sherry L. Larkin, Associate Professor
Department of Food and Resource Economics
University of Florida, Gainesville, Florida

Roderick M. Rejesus, Associate Professor
Department of Agricultural and Resource Economics
North Carolina State University, Raleigh, North Carolina

Dayton M. Lambert, Assistant Professor
Burton C. English, Professor
James A. Larson, Associate Professor
Margarita M Velandia, Assistant Professor
Roland K. Roberts, Professor
Department of Agricultural and Resource Economics
University of Tennessee, Knoxville, Tennessee

Sofia Kotsiri, Graduate Student
Department of Agricultural and Resource Economics
North Carolina State University, Raleigh, North Carolina

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Reasons for Adopting Precision Farming: A Case Study of U.S. Cotton Farmers

Abstract

We used survey data collected from cotton farmers in 12 southern U.S. states to identify factors influencing cotton farmers' decisions to adopt precision farming. Using a seemingly unrelated ordered probit model, we found that younger, educated and computer literate farmers chose precision farming for profit reason. Farmers who perceived precision farming to be profitable adopt it to be at the forefront of agricultural technology. We also found that farmers who were concerned with environment emphasize precision farming adoption as a reason to improve environmental quality. Our results also indicate that farmers in coastal states such as Alabama, Mississippi, and North Carolina chose environmental benefits as a reason for precision farming technology adoption.

Keywords: precision technologies, seemingly unrelated ordered probit, cotton

JEL Classifications: Q16, C35

Reasons for Adopting Precision Farming: A Case Study of U.S. Cotton Farmers

Precision farming (PF) (also known as precision agriculture) consists of farming using site specific technologies such as global positioning system (GPS) and computer-controlled variable rate technology (CVRT). Cotton farmers in the U.S. adopt these technologies for various reasons: maximizing profit, environmental benefits and to be at the forefront of agricultural technology. We identify characteristics of cotton farmers who provided these different reasons to adopt precision farming technology. We estimate the model using a seemingly unrelated ordered probit method on cotton data collected from 12 southern U.S. states in 2009.

Precision farming technologies are used to obtain information about yield and soil characteristics at different points in a field. PF can potentially help farmers to establish a profitable crop management system and reduce environmental hazards by applying optimal inputs at different parts of the field (Bongiovanni and Lowenberg-DeBoer, 2004; Roberts et al., 2004; Torbett et al., 2007; Watson et al., 2005). It can also help to decrease production cost and maximize profit (Swinton and Lowenberg-DeBoer, 1998). Farmers who depend on profitability of practice evaluate returns from the adoption of technology ex ante. Uses of site-specific technologies are profitable in many crops (Griffin et al., 2004; Swinton and Lowenberg-DeBoer, 1998).

Precision farming is considered as an important technology since it can reduce environmental burdens (Auernhammer, 2001). Farmers who are environmentally aware focus on the adoption of technologies that help to mitigate environmental hazards. For example, farmers who believe water quality is important are likely to adopt precision agriculture that helps to reduce water pollution. A desire to be at the forefront of agriculture technology could be a reason for practicing precision agriculture. Innovative farmers are likely to adopt PF at the beginning to take advantage of new technology (Lowenberg-DeBoer, 1996).

Many studies have analyzed factors affecting the adoption of PF (Daberkow and McBride, 2003; Larkin, 2005; Roberts et al., 2004). Our contribution is to identify farmers' perceptions on why they adopt PF using recently collected data from U.S. cotton farmers. Results should be helpful for agricultural support personnel and policy makers to target farmers to improve efficiency, increase profit and reduce negative environmental impacts.

Method

The main reasons provided by cotton farmers for adopting precision farming include profit, environmental benefits, and to be at the forefront of agricultural technology. Cotton farmers rated the importance of these three reasons affecting their decision to adopt precision farming technologies on a scale of 1 (not important) to 5 (very important). Given the ordinal nature of the dependent variable, the simplest approach to analyze the data is using each choice in an ordered probit model. However, we have three major reasons for adopting precision agriculture so we should estimate them jointly as the error term in these equations could potentially be partially correlated. We use a seemingly unrelated ordered probit model based on the latent variable model. Assume that three latent variables are: $\mathrm{y}_{1\mathrm{i}}^{*}$ for profit, $\mathrm{y}_{2\mathrm{i}}^{*}$ for environmental benefit and $\mathrm{y}_{3\mathrm{i}}^{*}$ for to be at the forefront of agricultural technology. These are continuous measure of importance of reasons for precision farming chosen by cotton farmers. The explanatory variable could be different in these equations. Suppose z denotes the matrix of all common explanatory variables across three equations, x_1 denotes the matrix of additional explanatory variable for profit equation, x_2 denotes the matrix of additional explanatory variables for environmental benefits equation and $x_3$denotes the matrix of additional explanatory variables for to be at the forefront of agricultural technology equation. Then functional forms for these choice patterns can be represented as follow:

$$
\begin{aligned}
y_{1i}^{*} &= z_i'\alpha_{11} + x_{1i}'\alpha_{12} + \varepsilon_{1i} \\
y_{2i}^{*} &= z_i'\alpha_{21} + x_{2i}'\alpha_{22} + \varepsilon_{2i} \qquad (1) \\
y_{3i}^{*} &= z_i'\alpha_{31} + x_{3i}'\alpha_{32} + \varepsilon_{3i}
\end{aligned}
$$

Where α_{ij} $(i = 1,2,3;\ j = 1,2)$ are vectors of unknown parameters and ε_1 , ε_2 and $\varepsilon_3$are the errors terms. Explanatory variables are cotton farmers' sociodemographic characteristics, farm characteristics and other specific factors associated with each reason in the three equations.

Suppose $w_1 = [z \quad x_1], w_2 = [z \quad x_2], w_3 = [z \quad x_3]$, $\beta_1 = \begin{bmatrix}\alpha_{11}\\ \alpha_{12}\end{bmatrix}, \beta_2 = \begin{bmatrix}\alpha_{21}\\ \alpha_{22}\end{bmatrix}$ and $\beta_3 = \begin{bmatrix}\alpha_{31}\\ \alpha_{32}\end{bmatrix}$

Then equation (1) can be written as

$$
\begin{aligned}
y_{1i}^{*} &= w_{1i}'\beta_1 + \varepsilon_{1i} \\
y_{2i}^{*} &= w_{2i}'\beta_2 + \varepsilon_{2i} \qquad (2) \\
y_{3i}^{*} &= w_{3i}'\beta_3 + \varepsilon_{3i}
\end{aligned}
$$

The explanatory variables in the model satisfy the conditions of exogeneity such that

$$
\begin{aligned}
&E(w_{1i}, \varepsilon_{1i}) = 0, \\
&E(w_{2i}, \varepsilon_{2i}) = 0, \text{ and} \qquad (3) \\
&E(w_{3i}, \varepsilon_{3i}) = 0,
\end{aligned}
$$

But, we assume that the errors in these equation are partially correlated so,

$$
\mathrm{Cov}(\varepsilon_{1i}, \varepsilon_{2i}, \varepsilon_{3i}) \neq 0 \qquad (4)
$$

The observed discrete reasoning for technology adoption y_1, y_2 and y_3 is determined from the model below.

$$y_{1i} = \begin{cases} 1 & \text{if} \quad y_{1i}^* \le c_{11} \\ 2 & \text{if} \quad c_{11} \le y_{1i}^* \le c_{12} \\ \vdots & \vdots \qquad \vdots \\ J & \text{if} \quad c_{1J-1} \le y_{1i}^* \end{cases} \tag{5}$$

$$y_{2i} = \begin{cases} 1 & \text{if} \quad y_{2i}^* \le c_{21} \\ 2 & \text{if} \quad c_{21} \le y_{2i}^* \le c_{22} \\ \vdots & \vdots \qquad \vdots \\ K & \text{if} \quad c_{2K-1} \le y_{2i}^* \end{cases} \tag{6}$$

$$y_{3i} = \begin{cases} 1 & \text{if} \quad y_{3i}^* \le c_{31} \\ 2 & \text{if} \quad c_{31} \le y_{3i}^* \le c_{32} \\ \vdots & \vdots \qquad \vdots \\ L & \text{if} \quad c_{3L-1} \le y_{3i}^* \end{cases} \tag{7}$$

The $c_{m,n}$ (where $m = 1,2,3$ and $n = 1, \dots 4$) are thresholds at different levels to be estimated with β_m. The unknown cutoffs (thresholds) parameters satisfy $c_{11} < c_{12} < \cdots < c_{1J-1}$, $c_{21} < c_{22} < \cdots < c_{2K-1}$and $c_{31} < c_{32} < \cdots < c_{3L-1}$. We assume that $c_{10} = c_{20} = c_{30} = -\infty$ and $c_{1J} = c_{2K} = c_{3L} = \infty$ in order to avoid handling the boundary cases separately (Sajaia, 2011). Assuming errors terms follow normal distributions, the probability of coded responses varies with orders. So, the probability that $y_{1i} = j, y_{2i} = k$ and $y_{3i} = l$ is:

$$\begin{aligned} \Pr(y_{1i} = j, y_{2i} = k, y_{3i} = l) &= \mathrm{pr}\left(c_{1j-1} \le y_{1i}^* \le c_{1j}, c_{2k-1} \le y_{2i}^* \le c_{2k}, c_{3l-1} \le y_{3i}^* \le c_{3l}\right) \\ &= \Pr\left(y_{1i}^* \le c_{1j}, y_{2i}^* \le c_{2k}, y_{3i}^* \le c_{3l}\right) \\ &- \Pr\left(y_{1i}^* \le c_{1j}, y_{2i}^* \le c_{2k}, y_{3i}^* \le c_{3l-1}\right) \\ &- \Pr\left(y_{1i}^* \le c_{1j}, y_{2i}^* \le c_{2k-1}, y_{3i}^* \le c_{3l}\right) \\ &- \Pr\left(y_{1i}^* \le c_{1j-1}, y_{2i}^* \le c_{2k}, y_{3i}^* \le c_{3l}\right) \\ &- \Pr\left(y_{1i}^* \le c_{1j-1}, y_{2i}^* \le c_{2k-1}, y_{3i}^* \le c_{3l-1}\right) \\ &+ \Pr\left(y_{1i}^* \le c_{1j}, y_{2i}^* \le c_{2k-1}, y_{3i}^* \le c_{3l-1}\right) \\ &+ \Pr\left(y_{1i}^* \le c_{1j-1}, y_{2i}^* \le c_{2k}, y_{3i}^* \le c_{3l-1}\right) \end{aligned}$$

$$+ \Pr\left(y_{1i}^* \leq c_{1j-1}, y_{2i}^* \leq c_{2k-1}, y_{3i}^* \leq c_{3l}\right) \qquad (8)$$

If the error term in the three regressions equations on reasoning for technology adoption are correlated i.e. $\varepsilon_{1i}, \varepsilon_{2i}$ and ε_{3i} are correlated with correlation coefficient ρ_{12}, ρ_{23} and ρ_{31}.and their expected values are zero then $\varepsilon_{1i}, \varepsilon_{2i}$ and ε_{3i} are distributed as a trivariate standard normal distribution. So the individual contribution to the likelihood function under the seemingly unrelated assumption could be expressed as:

$$\begin{aligned}
\Pr(y_{1i} = j, y_{2i} = k, y_{3i} = l) = {} & \Phi_3\left(c_{1j} - w_1'\beta_1, c_{2k} - w_2'\beta_2, c_{3l} - w_3'\beta_3, \rho_{12}, \rho_{23}, \rho_{31}\right) \\
& - \Phi_3\left(c_{1j} - w_1'\beta_1, c_{2k} - w_2'\beta_2, c_{3l-1} - w_3'\beta_3, \rho_{12}, \rho_{23}, \rho_{31}\right) \\
& - \Phi_3\left(c_{1j} - w_1'\beta_1, c_{2k-1} - w_2'\beta_2, c_{3l} - w_3'\beta_3, \rho_{12}, \rho_{23}, \rho_{31}\right) \\
& - \Phi_3\left(c_{1j-1} - w_1'\beta_1, c_{2k} - w_2'\beta_2, c_{3l} - w_3'\beta_3, \rho_{12}, \rho_{23}, \rho_{31}\right) \\
& - \Phi_3\left(c_{1j-1} - w_1'\beta_1, c_{2k-1} - w_2'\beta_2, c_{3l-1} - w_3'\beta_3, \rho_{12}, \rho_{23}, \rho_{31}\right) \\
& + \Phi_3\left(c_{1j} - w_1'\beta_1, c_{2k-1} - w_2'\beta_2, c_{3l-1} - w_3'\beta_3, \rho_{12}, \rho_{23}, \rho_{31}\right) \\
& + \Phi_3\left(c_{1j-1} - w_1'\beta_1, c_{2k} - w_2'\beta_2, c_{3l-1} - w_3'\beta_3, \rho_{12}, \rho_{23}, \rho_{31}\right) \\
& + \Phi_3\left(c_{1j-1} - w_1'\beta_1, c_{2k-1} - w_2'\beta_2, c_{3l} - w_3'\beta_3, \rho_{12}, \rho_{23}, \rho_{31}\right) \quad (9)
\end{aligned}$$

The log-likelihood equation of an observation i is then

$$\ln L_i = \sum_{j=1}^{J} \sum_{k=1}^{K} \sum_{l=1}^{L} I(y_{1i} = j, y_{2i} = k, y_{3i} = l)\ \Pr(y_{1i} = j, y_{2i} = k, y_{3i} = l) \qquad (10)$$

Under assumptions that observations are independent, we can sum (10) across observations to get the log likelihood for the entire sample of size N:

$$\ln L \quad = \sum_{i=1}^{N} \sum_{j=1}^{J} \sum_{k=1}^{K} \sum_{l=1}^{L} I(y_{1i} = j, y_{2i} = k, y_{3i} = l) \Pr(y_{1i} = j, y_{2i} = k, y_{3i} = l) \qquad (11)$$

Here I(.) is an indicator function. This model is estimated using a new STATA estimation command “cmp”, which was developed by Roodman (2009). This command can fix multi-equation models such as mix probit, tobit, ordered probit and “continuous” dependent variables

(Roodman, 2009). Since we have three equations to be estimated, we need to use a special algorithm to maximize the likelihood function. One of these algorithms GHK (Geweke, 1989; Hajivassiliou and McFadden, 1998; Keane, 1994) has been found to compute higher-dimensional cumulative normal distributions. We use this algorithm in “cmp” to estimate the seemingly unrelated ordered probit model.

Data, Variables Used and Justifications

The 2009 Southern Cotton Precision Farming Survey data collected from farmers in twelve U.S. states (Alabama, Arkansas, Florida, Georgia, Louisiana, Missouri, Mississippi, North Carolina, South Carolina, Tennessee, Texas, and Virginia) is used for this study. The objective of the survey is to obtain cotton farmers’ attitudes toward the use of precision farming technologies. Survey method suggested by (Dillman, 1978) was used to collect information about precision farming technologies adoption. The mailing list of potential cotton farmers for the year 2007-08 marketing year was obtained from the Cotton Board in Memphis, Tennessee (Mooney et al., 2010). The survey was mailed in February of 2009. Of the 14089 questionnaires mailed, 306 were returned undeliverable, 204 respondents were no longer cotton farmers, and 1,692 respondents provided usable information for a response rate of percent. The survey response rate of 12.5% for the twelve-state region was considered as the number of valid responses for this analysis. We tested for a nonresponse bias and found it to be nonsignificant in our data.

The variables to explain the adoption pattern are based on human capital theory, farm and production characteristics, and other variables used in adoption literature. Education and farming experience are measures of human capital that reflect the ability to innovate ideas. We expect that human capital has positive influence in the decision to adopt a new technology. Previous studies (Paxton et al., 2010; Roberts et al., 2004; Velandia et al., 2010; Walton et al., 2010) have shown that age, income, farming experience are widely accepted human capital variable that affect adoption decisions. Most of these studies have shown that age has negative influence on technology adoption (Soule et al., 2000). Young farmers are educated and willing to innovate and adopt new technologies that reduce time spent on farming (Mishra et al., 2002). Therefore, education and farming experience positively influence technology adoption because farmers with those attribute are exposed to more ideas and have more experience making decisions and effectively using the information (Caswell et al., 2001).

Farm characteristics are important variable for understanding a farmer's decision to adopt (Prokopy et al., 2008). If a farmer perceives that the adoption of technology would be profitable prior to making decision, he will be likely to adopt precision agriculture (Napier et al., 2000; Roberts et al., 2004). We also use financial and location variables as reasons for precision agriculture technology adoption.

University publications are helpful to cotton producer to obtain precision farming information. Extension services convey information about university research and publication that help farmers to make informed decision which can influence profitability (Hall et al., 2003). Producers tend to use multiple sources of information to increase their knowledge about precision agriculture (Velandia et al., 2010). Therefore, information is expected to be positively related to technology adoption because exposure to knowledge about precision agriculture leads some farmers to adopt new technology (Rogers, 2003).

Farmers with larger farms or higher yields are more likely to believe they will observe positive externalities associated with precision farming (Larkin, 2005). In addition, Larkin (2005) found that farmers who found PF profitable or who believed input reduction was important had higher probabilities of adopting the PF technologies. Farmers with larger farms and higher than average county yield were more likely to adopt precision technology (Banerjee, 2008). Computer is essential to keep financial record and to find information about use of precision agriculture. It has been found that farmers who kept computerized financial records were more likely to be successful (Mishra et al., 1999).

Use of excessive chemical fertilizer could leach or runoff causing water pollution. Thus, use of manure could be an important factor in choice of precision technology that reduces water pollution. If a farmer perceives that fertilizer efficiency can be increased by adopting PF technologies, he would adopt those. (Torbett et al., 2007).

An agricultural easement (AE) is a legal agreement limiting the use of land to predominantly agricultural use, so landowners who sign for agricultural easement agree to use the land only for agricultural purposes and permanently relinquishes the right to develop the land for non-agricultural activities (Brinkman, 2011). Hence, the main propose of AE is to maintain agricultural areas by preserving good agricultural soils under intermediate development pressure. We expect that agricultural easement has negative effect on technology adoption for profit but positive effect for environment; because landowner receives payment for the development value of the land, and they care more about environment than profit.

Although these studies provide some reasons for the adoption of PF technologies, there could be other possible variables affecting farmers' decision making process Many farmers are uncertain to use available technology due to environmental regulations, public concern, and economic gains from reduced inputs and improved managements, and hence these factors determine success of precision farming (Zhang et al., 2002).

Table 1 provides definitions and summary statistics for the variables used in empirical model. Summary statistics show that the average age of cotton farmers in the twelve states is 54 years. Cotton farmers have an average of 14 year of schooling and 31 years of farming experience. Seventy eight percent of household income comes from cotton farming. Additionally, 77% percent of cotton farmers thought precision agriculture would be profitable in the future. Almost 75% farmers use computer for their farm management.

Results

Figure 1 provides percentage of cotton farmers giving ranking to each of three criteria considered in the study. They reported that profit is the most important motivation behind the precision farming adoption (4.4 average score), with 70% of respondents considering it very important and only 7% indicates that profit is not important to their decision. Environmental benefits were the second most important factor (3.3 average score). Here, 23% of respondents indicated environmental benefits to be very important, while 14% viewed them as not important. By contrast, a desire to be at the forefront of agricultural technology was least likely to influence farmers to practice precision farming (2.8 average score). Only 16% viewed this reason as very important and 29% viewed it as not important. Ten percent farmers gave all three choices as very important, and only 3% farmers gave all three choices as not important.

The common independent variables used in all three equations are age, education, farming experience, farm size, computer, farm plan, farm income, farming information and state. The additional variables included for profit equation are agricultural easement and yield. Similarly, ‘profitable’ is used as an additional variable in the equation describing the desire “to be at forefront of agricultural technology". Variables "manure apply", "improvement in environment" and "agricultural easement" are included in the environmental equation.

First, a likelihood ratio test is conducted to test the independence of three univariate probit equations. The likelihood ratio test statistics (Table 3) for 2 degree of freedom is 85.35 with p-value 0.000 implying the rejection of null hypothesis that three equations are independent. Therefore, we estimated the regression equations jointly using a seemingly unrelated ordered probit model. The estimated coefficients with their marginal effects for highest order are shown in Table 2. Estimated threshold effects parameters are shown in Table 3.

The estimated coefficient of age in all three equations are negative and significant at a 5% level indicating that older farmers provide any of the stated three reasons to be not important determinants for their choice to adopt precision farming. The highest negative significant coefficient of age in profit equation tells us that profit is not an important reason for older cotton farmers. In particular, an additional increase in age of cotton farmers decreases the choice of profit as a reason for precision farming by 1% (marginal effects are interpreted here and throughout the result section). Similarly, an additional year of age decreases choice of environmental benefit and to be at the forefront of agricultural technology as reasons for precision agriculture adoption by 0.4% and 0.7%, respectively. This finding indicates that older farmers are less likely to adopt precision farming.

Positive and significant coefficient of educational attainment in profit equation suggests that educated cotton farmers provide profit is an important reason to practice precision farming. In contrast, the coefficient is negative and significant in 'to be at the forefront of agricultural technology' equation indicating that educated cotton farmers feel it to be a less important reason for adopting PF. Marginal effects implies that an additional year of schooling increases importance of profit for their decision to adopt precision agriculture by 1.5%, but decreases by 1.3% to be at the forefront of agricultural technology.

We found that a coefficient associated with farm size is negative and significant in profit and to be at forefront of technology equation. This outcome indicates that cotton farmers who have larger farm size reflect profit and to be at the forefront of technology are less important to their choice to adopt precision farming. The possible explanation for this effect is that if larger farmers have already adopted other traditional technologies in order to manage their farm, it is expensive to replace the existing technology so they may not be interested in adopting new technologies. In fact, an increase of 1000 acres in farm size decreases profit being the reason for adoption by 2.8% in their decision to adopt precision farming and 1.6% in case of to be at the front of agricultural technology.

The coefficient associated with variable computer is positive and significant in profit equation implying farmers who use computer provide profit to be important determinants for their choice to adopt precision farming. In addition, marginal effect shows that cotton producer who use computer for their farm management rate profit as a very important reason by 7% more than who do not use computer.

The positive and significant coefficient of farming experience tells us that cotton farmers who have more farming experience consider environmental benefit as an important reason for their choice for precision farming. The marginal effect for experience indicates that an additional year in farming experience increases importance of environmental benefit for their choice for precision farming by 0.7%. This result shows that more experienced cotton farmers know the environmental degradation from their traditional farming, so they want to adopt precision farming for environment benefits. In addition, the coefficient of improvement in environment is positive and significant. So, the cotton farmers who experienced improvements in environmental quality are more likely to consider environmental benefits as their reason for practicing precision farming. In fact, marginal effect shows that farm operators who experienced improvement in environmental quality from precision agriculture consider environmental benefit is very important for precision farming by 18% more than who have not experienced improvements in environment quality.

It is hypothesized that cotton farmers who want to operate their farm for a long period in future are likely to adopt precision agriculture. The estimated coefficients of farm plan in all three equations are positive and significant. This results show that cotton farmers who want to prolong their farm operation far into the future consider all three reasons to be important for precision agriculture adoption. This outcome implies that precision farmer who were more optimistic about future of precision farming might have benefited more from using them from all three aspects of profit, environmental benefit and to be at the forefront of technologies (Torbett et al., 2007). More over an additional increase in farm operation years (Farm Plan) increases importance of profit by 3% in decision to practice precision farming, and by 1.2% and 2.2% for to be at the forefront of agricultural technology and environmental benefits, respectively. Moreover, these values also indicate that farmers who want to operate their farm for a long period in future consider profit as the most important reason followed by environmental benefit.

The coefficient of agricultural easement in profit equation is negative and significant which indicates that cotton farmers who have participated in an agricultural easement program provide profit as a less important reason in decision to practice precision farming. The result is consistent with our expectation that cotton farmers who have an agricultural easement received payment, so they are less worried about profit. University research publications are very helpful for farmers in the decision making in a technology adoption process. Our results show that cotton farmers who utilize precision farming information from university sources provide profit and environmental benefits as important reasons to practice precision farming. The marginal effect associated with this variable in profit equation shows that farmers chose profit as well as environmental benefits as important reasons for precision farming almost 8% more than who do not use university educational information. Hence, we can say that university educational events or presentations have played an important role to practice precision farming decision.

Farm location also is an important determinant for decision for technology adoption. Texas has many cotton farmers compared to other states, so we use Texas as a benchmark state in the regression model. Our result shows that only few states have significant coefficients. Louisiana has positive significant effect on technology adoption in profit equation. This result implies that cotton farmers who are in Louisiana provide profit as an important reason in decision to practice precision farming. The marginal effect tells us that Louisiana cotton farmers' rate profit as a very important reason (5% more) to practice precision farming compared to Texas. And Florida has negative and significant effect on technology adoption to be at forefront of technology as a less important reason and hence farmers in that state consider being at the forefront of technology as12% less important than Texas.

Many farmers decide to adopt precision agriculture for environmental reasons. Our results suggest that farmers in Alabama, Arkansas, Georgia, Mississippi, North Carolina and Tennessee provide environmental benefit to be very important reason in their decision to practice precision farming. In contrast, we found that farmers in Florida have negative effect on importance of environmental benefit in their decision for technology adoption for environmental benefit. In fact, farmers in North Carolina and Alabama have the highest marginal effect indicating that farmers in these two states chose environmental benefit as a very important reason for adopting precision farming technologies. Specifically, we found that farmers in North Carolina and Alabama are 26% and 21% more aware about importance of environmental benefits in their decision to practice precision farming than farmers in Texas.

Conclusions

Our analysis indicated that cotton farmers' ranking of importance to practice precision farming depends on different factors such as age, farm size, farming experience, education, ability to work with computer and information received from different sources. In particular, we found that a more educated and computer literate farmers provided profit to be important determinant in cotton farmers' decision to practice precision farming. However, farmers who were concerned about environmental quality emphasized environmental benefit as an important reason for their choice to adopt precision farming. We also found that farmers in coastal states such as Alabama, Mississippi, and North Carolina chose environmental benefits as a very important reason for a precision farming technology adoption.

Farmers have different reasons to adopt a new technology although it is well known that profit is a major reason for adopting precision farming. We found that other reasons also play important roles in their decision to practice precision farming. Environmental benefit was an equally important reason for precision farming technology adoption. Finally, outcomes from this study can assist policy-makers to identify attributes associated with choice of important reasons in cotton farmer's decision to practice precision farming.

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Appendix

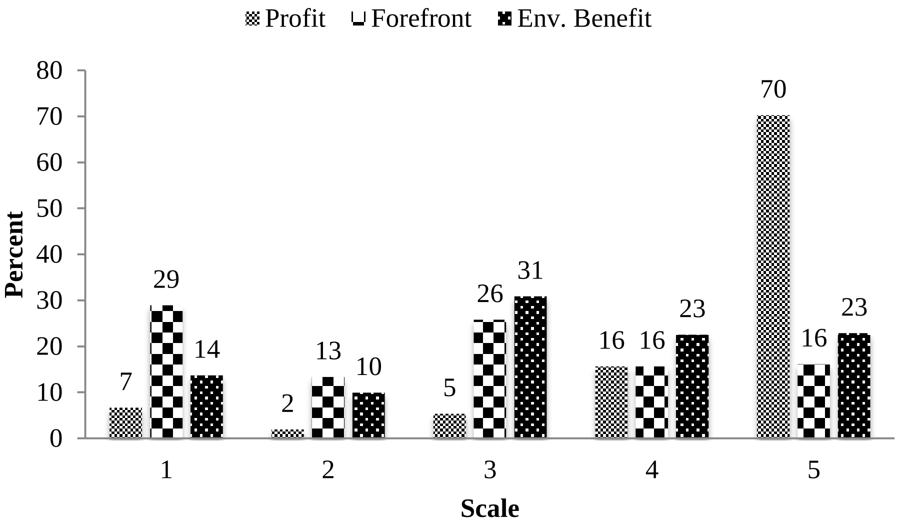

Figure1: Percentage of different levels of responses for three reasons in cotton farmer's decision to practice precision farming. (1=Not important, 5=Very important, N= 612)

Table 1: Definition of variables and summary statistics.

Variable	Definition	Obs.	Mean	Std. dev	Min	Max
Profit	Profit	663	4.38462	1.1536	1	5
Environment	Environmental benefits	620	3.32258	1.3021	1	5
Forefront	To be at the forefront of agricultural technology	624	2.77885	1.4320	1	5
Age	Age of farm operator (years)	1660	54.09036	12.6997	21	93
Education	Formal education of farm operator (years)	1592	14.16080	2.5212	0	25
Experience	Farming experience (years)	1644	31.63747	13.5212	0	79
Farm Size	Cotton acreage grown in 2007 (1000s acres)	1970	0.90654	1.3247	0	18.425
Computer	=1 if farmer uses computer for farm management	1664	0.53786	0.4987	0	1
Farm Plan (years)	Future plan of farming (years)	1642	3.74909	1.5536	1	5
Yield	Average cotton yield per acres	1970	837.29340	735.3887	0	3600
Farm Income	Percentage of farm income in total household income	1611	72.24829	29.4538	0	100
Agricultural Easement	=1 if the farm currently have agricultural easement	1648	-37.45995	48.1170	0	1
Farming Information	=1 if the farm uses university publication to obtain precision farming information	1634	0.34884	0.4767	0	1
Profitable	=1 if the farm operator thinks it would be profitable to use precision technology in the future	1078	0.79314	0.4052	0	1
Manure	=1 if the farm apply manure on fields	1699	0.18128	0.3854	0	1
AL	Dummy variable, =1 if state is Alabama	1981	0.06360	0.2441	0	1
AR	Dummy variable, =1 if state is Arkansas	1981	0.04139	0.1992	0	1
FL	Dummy variable, =1 if state is Florida	1981	0.01615	0.1261	0	1
GA	Dummy variable, =1 if state is Georgia	1981	0.09894	0.2987	0	1
LA	Dummy variable, =1 if state is Louisiana	1981	0.04493	0.2072	0	1
MO	Dummy variable, =1 if state is Missouri	1981	0.02221	0.1474	0	1
MS	Dummy variable, =1 if state is Mississippi	1981	0.07269	0.2597	0	1
NC	Dummy variable, =1 if state is North Carolina	1981	0.09591	0.2945	0	1
SC	Dummy variable, =1 if state is South Carolina	1981	0.03079	0.1728	0	1
TN	Dummy variable, =1 if state is Tennessee	1981	0.05603	0.2300	0	1
VA	Dummy variable, =1 if state is Virginia	1981	0.01161	0.1072	0	1
TX	Dummy variable, =1 if state is Texas	1981	0.06360	0.2441	0	1

Table 2: Parameter estimates of seemingly unrelated ordered probit model for important reasons of technology adoption.

	Profit		Environmental benefits		Be at the forefront of ag. technology	
Variables	Coeff.	Marg. Eff.	Coeff.	Marg. Eff.	Coeff.	Marg. Eff.
Age	-0.0296***	-0.0101 ***	-0.0255**	-0.0077**	-0.0192**	-0.0042**
	(0.0102)	(0.0035)	(0.0101)	(0.0031)	(0.0094)	(0.0021)
Education	0.0467*	0.0159 *	-0.0127	-0.0039	-0.0595***	-0.0130***
	(0.0245)	(0.0083)	(0.0273)	(0.0083)	(0.0221)	(0.0050)
Farming Experience	0.0150	0.0051	0.0234**	0.0071**	0.0054	0.0012
	(0.0093)	(0.0032)	(0.0095)	(0.0029)	(0.0088)	(0.0019)
Farm size	-0.0821***	-0.0279**	-0.0125	-0.0038	-0.0708*	-0.0155*
	(0.0412)	(0.0140)	(0.0381)	(0.0116)	(0.0395)	(0.0087)
Computer	0.2215*	0.0772*	0.0484	0.0146	0.1528	0.0321
	(0.1221)	(0.0435)	(0.1452)	(0.0434)	(0.1289)	(0.0260)
Farm Plan (years)	0.0878**	0.0298**	0.0758*	0.0230*	0.0582*	0.0127
	(0.0354)	(0.0120)	(0.0429)	(0.0129)	(0.0347)	(0.0078)
Farming Information	0.2336**	0.0792**	0.2579**	0.0781**	0.1649	0.0360
	(0.1112)	(0.0377)	(0.1296)	(0.0390)	(0.1077)	(0.0236)
Farm Income	-0.0004	-0.0001	0.0004	0.0001	-0.0014	-0.0003
	(0.0022)	(0.0007)	(0.0022)	(0.0007)	(0.0022)	(0.0005)
Agricultural Easement	-0.0020*	-0.0007*	-0.0002	-0.0001		
	(0.0012)	(0.0004)	(0.0013)	(0.0004)		
Yield	-0.0290	-0.0099				
	(0.0001)	(0.0000)				
Improvement in Environment			0.6061***	0.1839***		
			(0.1152)	(0.0342)		
Manure Apply			-0.0569	-0.0173		
			(0.1325)	(0.0403)		
Profitable					0.5780*	0.1263*
					(0.3053)	(0.0658)
AL	-0.1524	-0.0536	0.7287***	0.2613**	-0.1330	-0.0272
	(0.2240)	(0.0813)	(0.2687)	(0.1059)	(0.2435)	(0.0465)
AR	0.5472	0.1555*	0.6005**	0.2126**	-0.2260	-0.0439
	(0.3982)	(0.0888)	(0.3009)	(0.1167)	(0.2610)	(0.0447)
FL	0.2595	0.0813	-0.6592**	-0.1504***	-0.9059*	-0.1161***
	(0.3863)	(0.1103)	(0.2735)	(0.0455)	(0.5220)	(0.0319)
GA	-0.0327	-0.0112	0.5471**	0.1895**	-0.1241	-0.0256
	(0.1985)	(0.0684)	(0.2283)	(0.0866)	(0.1933)	(0.0376)

Standard errors in parentheses

* $p<0.10$, ** $p<0.05$, *** $p<0.01$

Table 2: Contd.

	Profit		Environmental benefits		Be at the forefront of ag. technology	
Variables	Coeff.	Marg. Eff.	Coeff.	Marg. Eff.	Coeff.	Marg. Eff.
LA	0.5151^{*}	0.1484^{*}	0.1953	0.0630	-0.1119	-0.0231
	(0.2862)	(0.0667)	(0.2687)	(0.0916)	(0.2612)	(0.0509)
MO	-0.3668	-0.1349	0.4759	0.1655	-0.6232	-0.0950
	(0.3525)	(0.1373)	(0.3888)	(0.1489)	(0.4272)	(0.0412)
MS	0.1209	0.0399	0.4184^{**}	0.1411^{**}	0.1612	0.0377
	(0.1888)	(0.0603)	(0.1920)	(0.0702)	(0.1544)	(0.0383)
NC	-0.1031	-0.0358	0.6184^{***}	0.2157^{***}	0.1814	0.0428
	(0.1918)	(0.0680)	(0.2144)	(0.0820)	(0.1808)	(0.0457)
SC	0.2414	0.0763	0.0886	0.0277	-0.3042	-0.0564
	(0.2678)	(0.0781)	(0.3049)	(0.0981)	(0.2361)	(0.0371)
TN	0.3339	0.1033	0.4947^{**}	0.1704^{*}	-0.0011	-0.0002
	(0.2455)	(0.0678)	(0.2381)	(0.0898)	(0.2181)	(0.0476)
VA	-0.4262	-0.1584	0.2453	0.0806	0.7208^{*}	0.2157^{**}
	(0.3884)	(0.1530)	(0.4478)	(0.1575)	(0.4204)	(0.1554)

Standard errors in parentheses

* $p<0.10$, ** $p<0.05$, *** $p<0.01$

Table 3: Thresholds and correlation estimates of factors affecting reasons in cotton farmers' decision to practice precision farming.

Parameter Name	Coefficients
atanh ρ12	0.25674^{***}
	(0.07104)
atanh ρ13	0.76849^{***}
	(0.09382)
atanh ρ23	0.46889^{***}
	(0.08025)
c11	-1.40413^{**}
	(0.57236)
c12	-1.23829^{**}
	(0.57108)
c13	-0.89374
	(0.57488)
c14	-0.35772
	(0.57706)
c21	-1.51968^{***}
	(0.58013)
c22	-1.14851^{**}
	(0.58078)
c23	-0.42191
	(0.58294)
c24	0.16798
	(0.58137)
c31	-0.87274
	(0.60995)
c32	-0.58387
	(0.60802)
c33	0.29867
	(0.60860)
c34	1.04759^{*}
	(0.61115)
ρ12	0.25124^{***}
	(0.06656)
ρ13	0.64605^{***}
	(0.05466)
ρ23	0.43730^{***}
	(0.06490)
Total Number of Observations	608
Wald chi square	53.52
Log-pseudolikelihood	-1562.0322
Likelihood ratio test for independence of equation	85.35

Standard errors in parentheses

* p<0.10, ** p<0.05, *** p<0.01