Precision Agric (2007) 8:127–137
DOI 10.1007/s11119-007-9033-1

Perceived importance of precision farming technologies in improving phosphorus and potassium efficiency in cotton production

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Abstract Site-specific information technologies (IT) provide knowledge about the spatial variability within a field to improve the efficiency of inputs through variable-rate (VR) applications. Identifying factors that influence farmers' perceptions of the importance of precision farming (PF) technologies in improving the efficiency of phosphorus (P) and potassium (K) fertilizer applications can help to determine why different groups of farmers adopt PF. Knowing these factors can be useful in targeting specific groups of farmers to adopt PF and increase fertilizer efficiency to meet crop needs and reduce P and K losses to the environment. Data were obtained from a 2001 mail survey of cotton (*Gossypium hirsutum* L.) farmers in six southeastern states in the United States of America. Ordered logit analysis was used to evaluate the level of importance to those who had adopted PF technologies placed on such technologies they had used to improve the efficiency of P and K applications. Results showed that such farmers found soil sampling by management zone or on a grid, and on-the-go sensing most important. Precision farmers who used mapping and remote sensing found PF technologies least important. Older precision farmers who rented larger proportions of their land and used computers for farm management were more likely than other precision farmers to place greater importance on PF technologies in improving the efficiency of P and K applications.

Keywords Cotton · Information technology · Ordered logit · Precision agriculture · Variable-rate-technology

Introduction

Understanding the factors that influence cotton farmers' perceptions about the importance of precision farming (PF) technologies in improving the efficiency of phosphorus (P) and

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potassium (K) fertilizer applications is important because this approach could potentially reduce costs and increase profits. In the southern United States of America, fields where crops are grown generally have considerable variability in the availability of soil nutrients. Fertility levels and amounts of nutrients removed by a crop by the end of the growing cycle are usually not uniform over the field (Mallarino and Wittry 2004). Uniform P and K applications are likely to lead to applications that are excessive in some areas and inadequate in others because of heterogeneity of nutrient levels in most agricultural fields.

Site-specific information technologies (IT) can provide a wealth of information about the spatial variability within a field. Farmers can use this information to make decisions about variable-rate (VR) applications of P and K, leading to increased efficiency in their use (Roberts et al. 2004). Cotton is a high-value, high-input crop requiring large applications of P and K in general. English et al. (2001) suggested that VR applications of fertilizer could lead to increased yields and/or lower levels of fertilizer use compared to uniform-rate applications.

Research has shown that more farmers have adopted VR application of P and K than other PF technologies (e.g., Batte and Arnholt 2003; Daberkow et al. 2002; Roberts et al. 2004). Discovering the factors that affect farmers' perceptions of PF technologies is important because they have the potential to result in more efficient P and K use. This knowledge can be used to target specific groups of farmers to adopt PF technologies for the reasons given above.

Numerous studies have analyzed the effects of farm and farmer characteristics on the adoption of PF technologies (e.g., Batte and Arnholt 2003; Daberkow et al. 2002; Khanna 2001; Plant 2001; Roberts et al. 2004; Swinton and Lowenberg-DeBoer 1998). Although these studies dealt with adoption, the utility farmers expect to derive from PF technologies is a factor that affects their decisions. Utility refers to overall satisfaction, which is influenced by factors, such as psychological attitudes and personal experiences (Nicholson 2005). A farmer's utility, therefore, could be affected by personal perceptions of PF technologies, which could influence any decisions to adopt them.

Larkin et al. (2005) analyzed the factors that affected farmers' perceptions of the environmental benefits from the use of PF technologies. They found that total area planted and yield had positive effects on farmers' perceptions of an environmental benefit. Profit and the current use of a computer positively affected farmer perceptions of environmental benefits. Their study showed that farmers may have positive perceptions of PF even if they receive little monetary benefit by adopting it.

Currently, more information is needed regarding the factors that affect farmers' perceptions of PF technologies in improving the efficiency of P and K applications. Other studies have analyzed factors affecting the adoption of PF technologies, whereas farmers in the current study had already adopted them. This enabled the current research to determine the factors that influenced farmers' perceptions of the importance of the PF technologies they had used to increase the efficiency of P and K applications. Such information will be useful for agricultural support personnel to target certain farmers with information on the potential of PF technologies to improve fertilizer efficiency and so increase profit and reduce the negative environmental impacts of fertilizers.

Data

Data were obtained from a survey of cotton farmers conducted in January and February of 2001 by mail (Roberts et al. 2002). Following Dillman's (1978) general mail survey procedures, the questionnaire, a postage-paid return envelope, and a covering letter to explain the purpose of the survey were sent to cotton producers in USA states of Alabama, Florida, Georgia, Mississippi, North Carolina, and Tennessee. In total, 6423 surveys were mailed, and of these 196 were returned as undeliverable and 251 indicated that they were not cotton farmers or they had retired. This meant that 5976 cotton producers received the survey in the six-state region, and of these 1131 responded, giving an aggregate response rate of 19% for the six states. Farmers were asked to indicate whether they had used the following IT: soil sampling on a grid; soil sampling in management zones; yield monitoring with GPS; yield monitoring without GPS; aerial photography; satellite imagery; plant tissue testing; on-the-go sensing; mapping topography, slope, soil depth, etc.; and soil survey maps. Farmers were also asked to indicate whether they had used VR application technologies for the following inputs: nitrogen, P and K, lime, seeds, growth regulator, defoliant, fungicide, herbicide, insecticide, and irrigation.

Farmers who indicated they had used PF technologies were asked to rate the decision-making value of them by indicating how important they thought the information was in reducing P and K use. The efficient use of P and K could lead to increased applications of P and K on some areas of a field, whereas other areas might receive substantially smaller amounts without reducing yield, which might lead to an overall decrease in field-average P and K use. Therefore, farmers' ratings of the importance of the decision-making value of PF technologies in reducing P and K use were used as proxies for their perceptions of P and K efficiency. Farmers could choose from 5 ratings: 1, not important, to 5, very important. The numbers of farmers who responded to this question with ratings of 1 to 5 were 8, 11, 37, 56, and 32, respectively (Roberts et al. 2002). Thus, 61% of the 144 respondents found PF technologies important or very important in reducing P and K applications.

Methods

An ordered logit model (Greene 2003) was used to determine the factors that affect farmers' perceptions of the importance of PF technologies. The model was specified as:

$$\mathbf{y}^* = \boldsymbol{\gamma}'\mathbf{x} + \boldsymbol{\varepsilon}, \tag{1}$$

where **y*** is a vector of unobserved values representing farmers' perceptions of the importance of PF technologies in improving the efficiency of P and K applications; **x** is a matrix of observed explanatory variables; $\boldsymbol{\gamma}$ is a parameter vector; and $\boldsymbol{\varepsilon}$ is a vector of random errors. What we observe from the survey data is:

$$\begin{aligned} y =& 0 \quad \text{if } y^* \leq 0 \\ =& 1 \quad \text{if } 0 < y^* \leq \mu_1 \\ =& 2 \quad \text{if } \mu_1 < y^* \leq \mu_2 \\ =& 3 \quad \text{if } \mu_2 < y^* \leq \mu_3 \\ =& 4 \quad \text{if } y^* > \mu_3. \end{aligned} \tag{2}$$

The μs are unknown parameters to be estimated with $\boldsymbol{\gamma}$. To estimate the parameters of this model, the dependent variable values must be integers ascending from 0 to allow for estimation of the intercept term. The $\boldsymbol{\mu}$s were calculated from estimates of $\boldsymbol{\gamma}'\mathbf{x}$, and -$\boldsymbol{\gamma}'\mathbf{x}$ is the threshold that divides the probability of a response being 0 from that of a response being 1, μ_1 - $\boldsymbol{\gamma}'\mathbf{x}$ is the threshold dividing the probabilities of a response being 1 or 2, and so on. This procedure provides estimates of the probabilities that an outcome will be 0, 1, 2, 3, or 4. Farmers have their own intensities of feeling that depend on the explanatory variables, $\mathbf{x}$, as well as unobservable factors $\boldsymbol{\varepsilon}$.

Empirical model and hypotheses

Empirical model

To conform with the format of an ordered logit model, responses to the P and K question in the survey (PK) were recoded to 0 to 4, which correspond with the farmers' original ratings of 1 to 5, respectively. The ordered logit model was specified as:

$$\begin{aligned}\mathrm{PK}_i =&\gamma_0 + \gamma_1\mathrm{YMGPS}_i + \gamma_2\mathrm{YMNOGPS}_i + \gamma_3\mathrm{REMOTE}_i + \gamma_4\mathrm{MAP}_i + \gamma_5\mathrm{SOILM}_i\\ &+ \gamma_6\mathrm{SOILG}_i + \gamma_7\mathrm{ONTHEGO}_i + \gamma_8\mathrm{TISSUE}_i + \gamma_9\mathrm{SOILSUR}_i + \gamma_{10}\mathrm{FARMSIZE}_i\\ &+ \gamma_{11}\mathrm{OWNRENT}_i + \gamma_{12}\mathrm{YIELD}_i + \gamma_{13}\mathrm{COLLEGE}_i + \gamma_{14}\mathrm{AGE}_i + \gamma_{15}\mathrm{COMPUTER}_i\\ &+ \gamma_{16}\mathrm{PROFITABLE}_i + \gamma_{17}\mathrm{IMPORTANCE}_i + \gamma_{18}\mathrm{AL}_i + \gamma_{19}\mathrm{FL}_i + \gamma_{20}\mathrm{GA}_i + \gamma_{21}\mathrm{MS}_i\\ &+ \gamma_{22}\mathrm{NC}_i + \varepsilon_i, \qquad (3)\end{aligned}$$

where variable definitions and means are given in Table 1; γ_0 to γ_{22} are parameters to be estimated; ε is a random error term; and i is a subscript representing the ith farmer. The binary location variable for Tennessee was excluded to allow comparisons of the perceptions of farmers in Tennessee with those of farmers in the other states. The unknown parameters in Eq. 3 were estimated using Greene (2002). A likelihood ratio chi-squared statistic was used to test the joint significance of the explanatory variables. Diagnostics to detect any multicollinearity were also performed (Belsley et al. 1980).

Coefficients that resulted from the estimation of Eq. 3 were the effects of changes in the explanatory variables on the dependent variable. Because the relationship between the dependent and explanatory variables is nonlinear, a coefficient for an explanatory variable determines the direction of the effect, not the magnitude of its effect on the probability that a farmer will select a given importance rating (Greene 2003). Therefore, marginal effects for the ordinal categories were calculated to determine the effects of a unit change in an explanatory variable on the probability that y equals 0, 1, 2, 3, or 4. The marginal effects of continuous variables were calculated by differentiating the probabilities with respect to the explanatory variables. The marginal effects of binary variables were computed as $\Pr[y|x_\mathrm{k} = 1] - \Pr[y|x_\mathrm{k} = 0]$, where y represents the importance rating, x_k is the binary variable being considered in Eq. 3, and $\Pr[\cdot]$ represents the probability of y given x_k equals 1 or 0 (Greene 2003).

Hypotheses

Table 1 shows the hypothesized signs of the coefficients ($\boldsymbol{\gamma}$) in Eq. 3. These *a priori* expectations specify the sign of the expected relationships between each of the independent variables and the probability of a farmer rating the importance of PF higher in improving the efficiency of P and K applications.

A review of the literature helped to identify the IT that potentially influenced farmers' perceptions of the importance of PF technologies. The signs of all IT variables were

Table 1 Means, hypothesized signs, and definitions of variables for the ordered logit model

Variable	Mean	Sign	Definition
Dependent variable			
PK	2.65		Farmer's rating of importance of information provided by PF technologies in reducing P and K use (unimportant = 0−very important = 4)
Explanatory variables			
Information technologies			
YMGPS	0.25	+	Used yield monitor with GPS (yes = 1; no = 0)
YMNOGPS	0.24	+	Used yield monitor without GPS (yes = 1; no = 0)
REMOTE	0.10	+	Used satellite images and/or aerial photos (yes = 1; no = 0)
MAP	0.08	+	Used mapping topography, slope, soil depth, etc. (yes = 1; no = 0)
SOILM	0.42	+	Used management zone soil sampling (yes = 1; no = 0)
SOILG	0.60	+	Used grid soil sampling (yes = 1; no = 0)
ONTHEGO	0.02	+	Used on-the-go sensing (yes = 1; no = 0)
TISSUE	0.38	+	Used plant tissue testing (yes = 1; no = 0)
SOILSUR	0.39	+	Used soil survey maps (yes = 1; no = 0)
Farm and farmer characteristics			
FARMSIZE	2.40	+	Total area planted (405 ha units)
OWNRENT	0.39	−	Area owned divided by total area planted
YIELD	0.70	+	Farm-average cotton lint yield (112 kg ha^{-1} units)
COLLEGE	0.79	+	Attended at least one year of college (yes = 1; no = 0)
OVER50	0.30	±	Age of farmer greater than 50 years (yes = 1; no = 0)
COMPUTER	0.79	+	Used a computer for farm management (yes = 1; no = 0)
PROFITABLE	0.60	+	Farmer thought PF was profitable on his/her fields (yes = 1; no = 0)
IMPORTANCE	3.89	+	Farmer thought cotton, corn, peanuts, rice, soybeans, tobacco, and wheat PF would be unimportant (1)–very important (5) in his/her state in 5 years; ratings were weighted by crop acreage
Farm location			
AL	0.22	±	Farm located in Alabama (yes = 1; no = 0)
FL	0.03	±	Farm located in Florida (yes = 1; no = 0)
GA	0.17	±	Farm located in Georgia (yes = 1; no = 0)
MS	0.22	±	Farm located in Mississippi (yes = 1; no = 0)
NC	0.26	±	Farm located in North Carolina (yes = 1; no = 0)

expected to be positive because these technologies are designed to improve knowledge about yield variability and its causes within a field. This improved knowledge allows farmers to address the causes of yield variability through VR fertilizer applications.

Yield monitoring with a GPS receiver (YMGPS) gives the yield of a crop at different locations within a field (Pierce et al. 1997; Plant 2001). Even without GPS (YMNOGPS), yield monitoring can improve a farmer's knowledge by observing yield changes on-the-go relative to known geographic features within the field. Improved knowledge of yield spatial variability can help a farmer to identify areas that might have P and K deficiencies or areas where P and K need not be applied. Remote sensing (REMOTE) can be used to identify spatial variation in soil properties and plant growth, and to detect environmental stresses that might limit crop productivity (e.g., Dobermann et al. 2004; Varvel et al. 1999).

Mapping topography (MAP) can help to determine the effects topographical features have on the spatial variability of soil P and K (Iqbal et al. 2005). Sampling the soil in uniform grids (SOILG) results in an even distribution of sampling points over a field. Methods include taking samples at the center point of a uniform cell and randomized sample locations within a grid cell (Adamchuk et al. 2004b). Soil information from each grid can be used to identify variation in crop needs for P and K applications. Soil sampling within management zones (SOILM) uses historical data, yield maps, aerial photos, and a farmer's general knowledge of variation within a field to divide it into zones with different yield response potentials (Rains et al. 2001). A variation of soil sampling in management zones is where sampling intensity is varied across a field based on spatial information from other IT (e.g., remote sensing or yield monitoring). On-the-go sensing of soil P and K (ONTHEGO) could cost less than soil sampling and result in more intensive sample data. Adamchuk et al. (2004a) analyzed different on-the-go sensing technologies, many of which were useful in identifying nutrient deficiencies in the soil. Bell et al. (2003) found that tissue sampling (TISSUE) was useful in identifying nutrient deficiencies in cotton. Tissue sampling can help farmers to determine whether crop nutrient needs are being met over the field.

A review of the literature also helped to identify farm and farmer characteristics that potentially influence farmers' perceptions of the importance of PF technologies (e.g., Batte and Arnholt 2003; Daberkow et al. 2002; Khanna 2001; Larkin et al. 2005; Plant 2001; Roberts et al. 2004; Swinton and Lowenberg-DeBoer 1998). Farm characteristics and their potential effects are discussed in the next paragraph, followed by a discussion of farmer characteristics.

Farmers with more area and fields (FARMSIZE) than others have greater opportunity to observe spatial variation in soil P and K, and are more likely to benefit from greater efficiency in P and K use through PF technologies. Land tenure (OWNRENT) might affect perceptions of the importance of PF if farmers increase their knowledge of spatial P and K requirements differently on rented than owned land. If farmers had less knowledge about P and K spatial variability on rented than owned land, the use of IT might increase their knowledge of spatial variability on rented land more than owned land. Through VR fertilizer application, this relative increase in spatial knowledge could translate into increased P and K efficiency on rented land relative to owned land, resulting in larger increases in farmers' perceptions of the importance of PF technologies on rented land. Larger farm-average yields (YIELD) might indicate greater opportunity to observe spatial yield variability, thus having a positive impact on perceptions as PF technologies are used to address that observed variability.

Farmers who have attended college (COLLEGE) might have higher perceptions of the importance of PF technologies if they can recognize and reap the benefits of PF technologies better than farmers with less education. Older farmers (OVER50) have typically shorter planning horizons, are resistant to change, and have less exposure to the technologies required for PF. These characteristics suggest that older farmers might be more risk averse than younger ones, which would have a negative impact on farmers' perceptions of PF technologies. In this study, however, older farmers had already adopted PF technologies, suggesting that they might have been less risk averse than older farmers in general. Older farmers in this study had generally been farming longer than younger farmers, and so were likely to have more experience in recognizing improvements in the efficiency of P and K use with PF technologies and were likely to rate their importance more highly. Computer use for farm management (COMPUTER) was expected to have a positive influence on perceptions of the importance of PF technologies because computers are integral components in the use of these technologies. Larger perceived profits (PROFITABLE) resulting from more efficient P and K use would be likely to lead to a perceived increase in farmer utility. The latter could result in farmers rating the importance of PF technologies more highly. Farmers who thought that PF of cotton, corn, peanuts, rice, soybean, tobacco, and wheat would be important in their state in 5 years time (IMPORTANCE) would be likely to have higher perceptions of the importance of PF technologies. Precision farmers who were more optimistic about the future of PF technologies might have benefited more from using them, so increasing their perceptions of the importance of PF technologies. Location variables AL, FL, GA, MS, and NC were included to test whether farmers using PF technologies in Alabama, Florida, Georgia, Mississippi, and North Carolina had higher or lower probabilities of having positive perceptions of the importance of PF technologies compared with farmers in Tennessee.

Results

Results from the estimation of Eq. 3 are given in Tables 2 and 3. The chi-squared statistic of 36.68 (Table 3) was significant at $\alpha = 0.05$ level of probability, and the null hypothesis that the regressors had no collective influence on perceptions was rejected. Condition indices below 30 from multicollinearity diagnostics indicated that multicollinearity was unlikely to have seriously inflated the standard errors of the coefficients (Belsley et al. 1980).

The coefficients and marginal effects for the IT variables are given in Table 2. Five of the nine IT variables were significant at the $\alpha = 0.05$ or 0.10 levels of probability. The signs of three statistically significant variables (SOILM, SOILG, and ONTHEGO) were as hypothesized. These results are not surprising because these three IT factors are designed to measure spatial variation in soil P and K directly. Coefficients for both management zone (SOILM) and grid soil sampling (SOILG) were positive, suggesting that farmers who used such soil sampling perceived greater importance of PF technologies than those who did not. The signs of the marginal effects for SOILM and SOILG show that farmers who used these soil-sampling methods were more likely to have higher perceptions (e.g., $y = 4$ or 5) of the importance of PF technologies than the converse. The positive coefficient for ONTHEGO suggests that farmers who used on-the-go sensing found it important in improving P and K efficiency. The marginal effects show that farmers who used on-the-go sensing were likely to rate the decision-making value of PF technologies as very important ($y = 4$) with a marginal effect of 0.412. Nevertheless, the results for ONTHEGO should be interpreted with caution because of the small number of respondents in the sample who used this technology.

Two statistically significant coefficients for IT variables have signs opposite to those hypothesized. The negative coefficients for MAP and REMOTE suggest that precision farmers did not find mapping topography, slope, soil depth, etc., or remote sensing important. Although contrary to what was expected, these negative coefficients might be explained because these IT methods are used indirectly to identify VR prescriptions for P and K fertilizer application. Marginal effects for both variables show that farmers who used these technologies were more likely to have lower perceptions of the importance of PF technologies. Results from the Agricultural Resource Management Survey by the US Department of Agriculture indicated that crop area in the USA on which remotely sensed imagery was used was declining at the time of the survey in 2001 (Griffin et al. 2004).

Table 2 Ordered logit estimates and marginal effects for information technologies

Variable	Coefficient	Marginal effects for ordinal categories				
		$y = 0$	$y = 1$	$y = 2$	$y = 3$	$y = 4$
CONSTANT	−2.177*					
YMGPS	0.525	−0.017	−0.026	−0.076	0.035	0.084
YMNOGPS	0.493	−0.016	−0.024	−0.072	0.033	0.079
REMOTE	−1.372**	0.085	0.102	0.143	−0.190	−0.140
MAP	−1.586**	0.110	0.123	0.141	−0.225	−0.149
SOILM	0.887**	−0.031	−0.045	−0.126	0.066	0.136
SOILG	0.990**	−0.040	−0.057	−0.136	0.097	0.137
ONTHEGO	1.908*	−0.033	−0.053	−0.216	−0.110	0.412
TISSUE	−0.085	0.003	0.005	0.012	−0.008	−0.012
SOILSUR	−0.233	0.009	0.013	0.034	−0.021	−0.034

** and * indicate statistical significance at the $\alpha = 0.05$ and 0.10 levels, respectively

Factors that might have influenced the decline in the use of remotely sensed imagery include a lack of perceived usefulness, a paucity of reliable services to process the data into information that is useful for decision-making, and the need to purchase maps of bare soil infrequently because some soil properties do not change rapidly over time (Griffin et al. 2004). These factors might explain the negative sign on the coefficient for REMOTE.

Table 3 Ordered logit estimates and marginal effects for farm and farmer characteristics

Variable	Coefficient	Marginal effects for ordinal categories				
		$y = 0$	$y = 1$	$y = 2$	$y = 3$	$y = 4$
FARMSIZE	-0.025	0.001	0.001	0.004	−0.002	−0.004
OWNRENT	−1.255**	0.045	0.067	0.183	−0.111	−0.184
YIELD	−0.362	0.013	0.019	0.053	−0.032	−0.053
COLLEGE	−0.512	0.016	0.025	0.074	−0.033	−0.082
OVER50	1.295***	−0.038	−0.058	−0.178	0.054	0.222
COMPUTER	0.631*	−0.026	−0.037	−0.089	0.065	0.086
PROFITABLE	0.300	−0.011	−0.016	−0.043	0.028	0.043
IMPORTANCE	0.154	−0.006	−0.008	−0.022	0.014	0.023
AL	−0.451	0.018	0.026	0.064	−0.048	−0.061
FL	−0.618	0.029	0.040	0.082	−0.077	−0.075
GA	0.163	−0.006	−0.008	−0.024	0.013	0.025
MS	−0.132	0.005	0.007	0.019	−0.012	−0.019
NC	−0.300	0.115	0.017	0.043	−0.029	−0.042
μ_1	1.046***					
μ_2	2.755***					
μ_3	4.779***					
n	144					
χ^2 22 df	36.68**					

***, **, and * indicate statistical significance at the $\alpha = 0.01$, 0.05, and 0.10 levels, respectively

Nevertheless, since 2001 several commercial firms have begun to provide remote sensing services to farmers (e.g., InTime Inc., 2007; Brown and Wesch 2006).

Yield monitoring with GPS (YMGPS) and without GPS (YMNOGPS), plant tissue testing (TISSUE), and soil survey maps (SOILSUR) had no effect on farmers' perceptions of the importance of PF technologies. Except for plant tissue testing, these technologies are indirectly related to the measurement of soil P and K concentrations and to their amelioration. The lack of significance of TISSUE is somewhat surprising, given that this technology is designed to measure P and K deficiencies directly in plants.

The coefficients and marginal effects for farm and farmer characteristics are given in Table 3. The coefficient for COMPUTER is positive as hypothesized, suggesting that farmers who used computers for farm management were more likely to have greater perceptions of the importance of PF technologies. The marginal effects show that such farmers were more likely to give high ratings. The coefficient for OWNRENT is negative as hypothesized, suggesting that farmers who owned larger portions of the land they farmed were less likely to have higher perceptions of the importance of PF technologies. This suggests that they found PF technologies more useful in increasing their knowledge of the spatial variation in P and K on rented land than on owned land. Farmer age (OVER50) has a positive sign and the marginal effects show that older farmers were more likely to have higher perceptions of the importance of PF technologies. The higher perceptions of older precision farmers may have come from greater experience and ability to recognize improvements in the efficiency of P and K fertilizer application than younger precision farmers.

The coefficients for two farm characteristics, three farmer characteristics and all location binary variables were not significantly different from zero at the $\alpha = 0.1$ level of probability. Results suggest that farm size (FARMSIZE) and yield (YIELD) did not influence perceptions of the importance of PF technologies, nor did education (COLLEGE) and perceptions of the current profitability (PROFITABLE) and future importance (IMPORTANTCE) of PF technologies in the respondent's state. Results for the location variables (AL, FL, GA, MS, and NC) indicate that farmers in all six states had similar perceptions of the importance of PF technologies in improving the efficiency of P and K use, other things being constant.

Summary and conclusions

Precision farmers were asked to rate the decision-making value of the technologies that they had used by indicating from 1 (not important) to 5 (very important) how important they felt the information from using these technologies was in reducing P and K use. Results from an ordered logit model showed that precision farmers found management zone soil sampling, grid soil sampling, and on-the-go sensing important in increasing P and K efficiency. Older precision farmers who used computers were more likely to have positive perceptions of the importance of PF technologies. These findings suggest that older precision farmers might have more experience and ability to recognize improved P and K efficiency than younger ones and that computer use might have improved their ability to track changes in efficiency. Precision farmers who rented larger proportions of the land they farmed were more likely to have positive perceptions of the importance of PF technologies in improving P and K efficiency. This result suggests that precision farmers find PF technologies more useful in increasing knowledge about spatial variation in soil P and K on rented land than on owned land.

The results of this research have implications for agricultural support personnel with an interest in reducing the negative environmental impacts of fertilizers. If positive perceptions of precision farmers are related to increased utility from PF adoption, these results can guide the targeting of certain farmers with information on the potential for PF adoption to improve fertilizer efficiency. Educational efforts would be most likely to succeed with farmers who use computers and rent more land relative to owned land. Results suggest that educational efforts would be most successful if emphasis were placed on the IT that directly measures soil properties, such as soil sampling by grid and management zone, and on-the-go sensing. Even though this research shows that older precision farmers have higher perceptions of the importance of PF in improving P and K efficiency, other research has shown that older farmers are less likely to adopt PF technologies, so targeting them for PF adoption would be unlikely to be fruitful.

Acknowledgments The authors wish to thank Cotton Incorporated and the Tennessee Agricultural Experiment Station for funding this research. Appreciation is also expressed to the anonymous reviewers and the editor for their useful suggestions.

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