ADOPTION OF PRECISION AGRICULTURE PRACTICES BY COTTON GROWERS IN TEXAS

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Abstract

Precision farming has gained considerable importance among scientists and progressive farmers alike because of its potential to save inputs and reduce the negative environmental impacts of agricultural production. Understanding farmers' adoption decision of precision agriculture practices is an essential step for developing the technology and management practices that best serve the farming community. In this study, the linear probability and binary logit models are employed to analyze the effects of demographic and economic factors on the adoption of various precision agriculture practices. The results indicated that younger farmers are more likely to adopt precision agricultural practices in general. Farm size was found to be a significant factor in adoption of aerial imagery for assessing field variability as use of that technology is more economical for larger-size farms. Farmers in the highest income group are more likely to employ a consultant.

Introduction

Simply speaking, precision agriculture is a farming method aimed at taking the right action at the right place at the right time. Precision management practices apply inputs according to the need of the plant, taking into account the spatial and temporal variability in the field. Natural and acquired variability in production capacity within the field implies that uniform agronomic management practices are correct in some parts and inappropriate in others. To achieve the ultimate goal of sustainable cropping systems, variability must be considered both in space and time (Basso *et al.*, 2003).

Map and sensor-based assessment of field variability are the two basic methods of implementing precision agriculture through site specific management or the variable rate application of crop inputs. The majority of map-based technologies are based on grid soil sampling, soil analysis, map generation, and variable rate application. One problem of this approach is that a time lag exists between the collection of information and application of inputs. On the other hand, sensor-based methods permit real time detection of input requirements and therefore timely action. Use of areal imagery during the cotton growth period to decide on the amount of pix to be applied is an example of this approach.

Common precision agriculture practices include use of yield monitor, soil map, soil grid sampling, aerial photos, or satellite imagery to identify the variability in soil fertility, pH of the soil, crop vigor, or moisture stress. Then this information is used in application of such inputs as fertilizers, lime or pix or irrigation water in a way that each portion of the field receives the input in required quantities.
The main objectives of precision agriculture are to increase the profitability of crop production and reduce the negative environmental impact by adjusting application rates of agricultural inputs according to local needs (Pierce and Nowark, 1990). The adoption of precision agriculture strategies is important not only to increase the profitability and sustainability of the farm, but also helps to protect the environment as the inputs are not applied in excessive quantities, which limits the potential of leaching of the chemicals to water streams.

In general, farmers decide on whether to adopt a new technology based on the economic benefit received from that technology, which in turn depend on the characteristics of the decision maker, and farm, crop markets, and the cost of the new technologies (Daberkow et al., 2002). This paper examines the effect of farm size and characteristics of the decision maker like age, experience, education, and income on adoption of some precision agriculture practices. The results from our study may help to identify the type of technologies more likely to be adopted by cotton growers in Texas and can be used to decide on further research initiatives. Identification of the factors affecting the adoption of the technologies can help the design of better extension strategies.

Materials and Methods

The data for this analysis are from the 2009 Southern Precision farming Survey. The survey received 1981 responses from cotton farmers in 12 southern states, of which 880 are from Texas. This study includes only the Texas data; data from other states are being analyzed by colleagues in those states. Table 1 includes a list of explanatory variables used in the regression analysis of the adoption decision. Table 2 includes the precision farming technologies examined in the regression analysis. Figure 1 presents the percentage of cotton farmers in the sample who had adopted each of those technologies.

The linear probability model (LPM) and binary logit model were used to analyze adoption behavior of farmers for different precision agriculture practices.

The following LPM was used in this study.

$$P(ADOPT)_n = \beta_0 + \beta_1 age + \beta_2 agesq + \beta_3 exp + \beta_4 educ + \beta_5 size + \beta_6 inc2 + \beta_7 inc3 + \beta_8 inc4 + \beta_9 inc5 + \beta_{10} inc6$$

Where $P(ADOPT)_n$ is the probability of adoption of the nth technology.

The binary logit model used in this study is as follows.

$$P(ADOPT)_n = \Lambda(\beta_0 + \beta_1 age + \beta_2 agesq + \beta_3 exp + \beta_4 educ + \beta_5 size + \beta_6 inc2 + \beta_7 inc3 + \beta_8 inc4 + \beta_9 inc5 + \beta_{10} inc6)$$

Where $P(ADOPT)_n$ is the probability of adoption of the nth technology and $\Lambda(z) = \left(\frac{\exp(z)}{1+\exp(z)}\right)$.

To avoid perfect multicolleniarity, the dummy variable *inc1* was excluded from the model. Hence, the coefficient estimates of other income dummies will be relative to the coefficient estimate of the dummy for farmers with household income less than $50,000.

Table 1. The definitions of the explanatory variables used in regression analysis.

Variable	Definition
AGE	Age of the decision maker in years
AGESQ	Square of the age of the decision maker
EXP	Experience of the decision maker in years
EDUC	Number of years of formal education received by the decision maker in years
SIZE	Area planted to cotton in 2008 in acres
INC1	Annual household income less than $ 50,000
INC2	Annual household income between $ 50,000 and $ 99,999
INC3	Annual household income between $ 100,000 and $ 149,999
INC4	Annual household income between $ 150,000 and $ 199,999
INC5	Annual household income between $ 200,000 and $ 500,000
INC6	Annual household income greater than $ 500,000

Table 2. The definitions of the dependant variables used in regression analysis.

Variable	Definition
MAPBSD	Adoption of map based precision agriculture practices
SNSRBSD	Adoption of map sensor precision agriculture practices
ANYPREC	Adoption of either map based or sensor based precision agriculture practices
YLDMNTR	Adoption of yield monitor to asses yield variability in the field
SOILMAP	Adoption of soil maps to asses variability in the field
AERPHOTO	Adoption of aerial photographs to asses variability in the field
GRIDSMPL	Adoption of grid soil sampling to asses variability in the field
CONSULT	Employing a consultant to asses variability in the field
COTMAN	Adoption of COTMAN to asses variability in the field

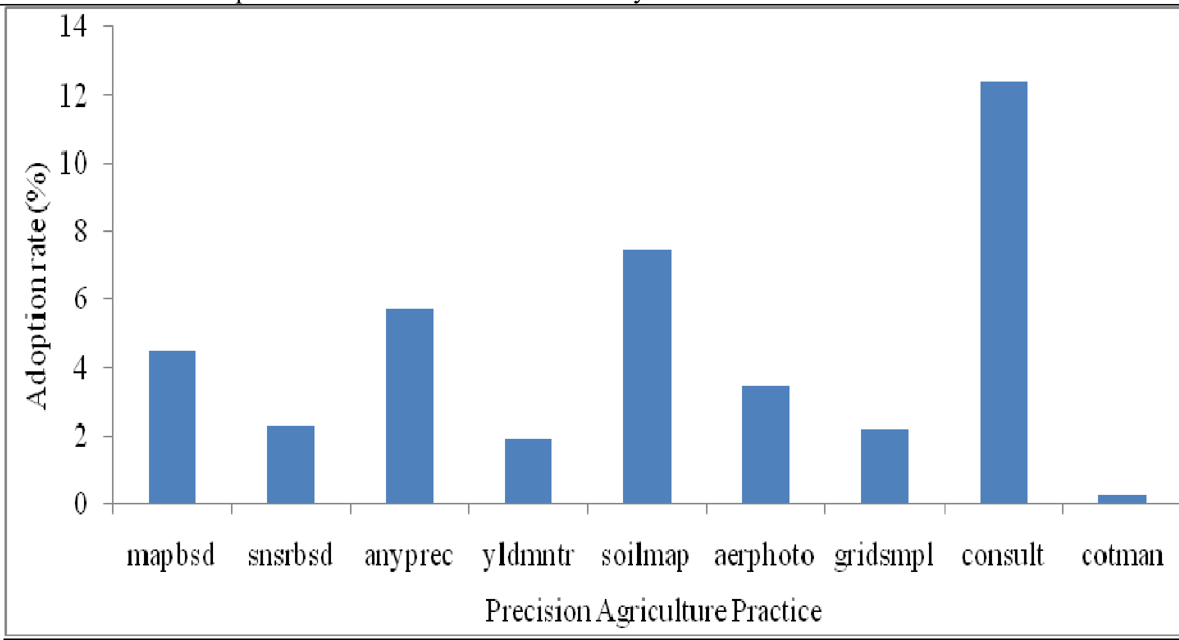

Figure 1. Percentage of farmers in the sample who have adopted each precision agriculture practice in Table 2.

Results and Discussion

Adoption of map-based precision agriculture practices

A total of 649 farmers answered this question, and among them only 29 (4.47%) adopted map based precision agriculture practices. The parameter estimates revealed that only *age* and *agesq* are significant in both the model at the 5% level. Results in the LPM model indicate that a one-year increase in the age of the farmer reduces the probability of adoption of map-based precision agriculture practices by 0.0181. The significant and positive squared term for *age* indicates that the age effect is stronger among young farmers than among old farmers. Results in the logit model indicate that for every one-year increase in age, the odds of adoption (versus non-adoption) decreases by a factor of 0.737.

Adoption of sensor-based precision agriculture practices

A total of 650 farmers answered this question, and among them only 15 (2.31%) adopted sensor-based precision agriculture practices. None of the independent variables had a significant impact on adoption of sensor-based precision agriculture practices. This might have occurred because of very scattered adoption of this technology.

Adoption of either map-based or sensor-based precision agriculture practices

There were 650 responses for this question and 37 (5.69%) farmers adopted either map- or sensor-based precision agriculture practices. In this case also only *age* and *agesq* are significant in both the models at the 5% level. A one-year increase in the farmer's age decreases the probability of adoption by 0.020 in the LPM and decreases the odds ratio of adoption by 0.762 in the logit model. Unit increase in square of the age of farmer resulted in an increase of probability of adoption by 0.00015 and increase in odds ratio of adoption by a factor of 1.002.

Adoption of yield monitor to assess field variability

Among the 726 farmers who responded to this question, only 14 (1.93%) adopted cotton yield monitor to assess the yield variability in the field. Parameter estimates in both the LPM and logit models show that none of the independent variables has a significant impact on adoption of yield monitor for assessment for yield variability. Farm size however is significant in the LPM model at the 10% level. A hundred acre increase in farm size will increase the probability of adoption of yield monitor only by 0.001. This result is in line with the general observation that yield monitor is generally only suitable for a small group of very large farms.

Adoption of soil maps to asses field variability

Soil maps were used by 54 (7.45%) out of the 725 farmers who responded to this question. Education, farm size and *inc4* were found to influence the adoption of this technology. The LPM model indicates that an additional year of schooling slightly increases the probability of adoption of soil sampling for assessing variability in soil fertility by 0.0084. An increase in farm size by 100 acres increases the probability of adoption by 0.0039. Farmers with income between $150,000 and 199,999 have a 0.091 higher probability of adoption compared to farmers with income below $50,000. We found in the logit model that an additional year of schooling increases the odds of adoption (versus non adoption) by a factor of 1.147, and that for each one acre increase in farm size, the odds of adoption (versus non adoption) increases by a factor of 1.001. Farmers with income between $ 150,000 and 199,999 have better odds of adoption by a factor of 3.532 compared to farmers with income below $50,000.

Adoption of aerial photographs to assess field variability

Only 25 farmers (3.45%) used aerial imagery for assessing the variability in crop growth among the 725 respondents. In this case, the only significant factor is farm size. In general, aircrafts are used for assessment of crop growth variability only when the area cultivated is very large and manual assessment is cost prohibitive. Hence it makes perfect sense that farm size is the most important determinant of the use of aerial imagery for assessing yield variability. The LPM model indicates that when farm size increases by 100 acres the probability of using aircraft imagery increases by 0.055. Similarly, the odds of adoption (versus non adoption) of the aerial imagery increases by a factor of 1.001 for a one-acre increase in farm size.

Adoption of grid soil sampling to assess field variability

A total of 726 farmers answered this question and among them only 16 (2.2%) used grid sampling to assess the variability in soil fertility. No independent variable in Table 1 had a significant influence on the adoption of grid sampling.

Employing a consultant to assess field variability

Out of the 725 farmers who responded to this question 90 (12.41%) employed a consultant to assess the variability in the field. Only *inc6* had a significant impact on employing a consultant to assess the yield variability. It seems that only the highest income group can afford to employ a consultant. From the LPM estimates the probability of hiring a consultant is 0.8766 higher in farmers with income above $500,000 when compared to farmers with income less than $50,000. The corresponding estimate in the logit model is an increase in the odds of adoption by a factor of 2.403.

Adoption of COTMAN to assess field variability

Only 2 farmers out of the 726 respondent (0.28%) used COTMAN to assess the field variability. With few farmers adopting that technology little can be said about the adoption patterns.

Conclusions

In general, the farmer's age was found to be an important determinant in adoption of precision agricultural technologies. In particular, younger farmers seemed more receptive to new technologies. Farm size was important in adoption of aerial imagery as the use of such technology is only economical for larger farms. Use of soil maps for variable application of fertilizers was strongly associated with education. This may be due to the easiness of educated people to handle computers and generate soil maps. Hiring a consultant was found to be prohibitive to most income groups except for that with income above $500,000.

Acknowledgements

Financial support for this project was provided by Cotton Incorporated under grant contract # 09-557. The assistance of Daniel Mooney with data cleaning is greatly appreciated.

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