IMPACT OF EFFICIENT IRRIGATION METHODS ON PRECISION AGRICULTURE ADOPTION IN TEXAS

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Abstract

High efficiency irrigation technologies like center-pivot and sub-surface drip are widely adopted by the cotton farmers in Texas. Since adoption of both the high efficiency irrigation technologies and Precision Agriculture (PA) enables the farmers to improve the input use efficiency, there may be a relationship between the adoption of the high efficiency irrigation technologies and PA technologies. In this study, a binary logit model was applied to the 2009 Southern Cotton Precision Farming Survey data to analyze the impact of the irrigation practices used by Texas cotton producers on their likelihood of adoption of PA practices. The explanatory variables also included other farm and farmer characteristics like farm size, farm location, age, farming experience, and number of years of formal education of the farmer, use of computers for farming operations, and farmer's exposure to extension activities. Adoption of efficient irrigation technologies like center pivot and sub-surface drip was found to enhance the likelihood of adoption of PA. Farm size, farm location, age of the farmer and exposure to extension activities were also found to influence the likelihood of PA adoption.

Introduction

Precision agriculture (PA) is a management system that allows producers to match the management practices according to the spatial and temporal variability in field conditions and crop requirements. Nowadays PA encompasses an array of practices such as automatic vehicle control, product quality management, environmental pollution management, identification and management of weeds, pests, and disease infestations, and farm record keeping with geo-referencing (Woebbecke et al., 1995; Pierce and Nowark, 1999; Erickson and Lowenberg DeBoer, 2000; Batte and Arnholt, 2003; McBratney et al., 2005). Adoption of PA technologies provides several potential advantages to producers such as higher crop yields, increased input use efficiency, and lower environmental impact of harmful agricultural chemicals (Pierce and Nowark, 1990; Batte and Arnholt, 2003; Mamo et al., 2003; Koch et al., 2004; Bronson et al., 2006).

Despite these potential advantages, the adoption of PA is very low among producers (Lowenberg-DeBoer, 1999; Daberkow, Fernandez-Conjero and Padgit, 2002; Reichardt and Jurgens, 2009; Reichardt et al., 2009). Researchers generally agree that this low level of adoption is mainly due to lack of evidence of economic advantages of PA adoption, high fixed cost required for equipment, and difficulties associated with learning and use of the technology (Khanna, Epouhe, and Hornbaker, 1999; Daberkow and McBride, 2000; Khanna, 2001; Reichardt and Jurgens, 2009; Reichardt et al., 2009). Studying the process of PA adoption and factors affecting it is very important because the usefulness of any technology is linked to the level of adoption by the end users.

Texas is the leading US state in both cotton acreage and production and the producers here are renounced for adopting efficient irrigation systems to manage their crops (Colaizzi, 2009). Since both PA and irrigation technologies like center pivot (CP) and sub-surface drip irrigation (SDI) are modern technologies that seek to improve the efficiency of agricultural inputs, assessing the relationship between adoption of these irrigation technologies and PA can provide more insights into the process of technology adoption.

The complete adoption of PA occurs when the producer acquires the within-field variability data, analyzes it to understand the extent and distribution of within-field variability and responds to it by matching agronomic practices to the field condition if appropriate. It is generally observed that most of the producers are partial adopters, i.e. they do not adopt variable rate technology even after adoption of technologies for acquiring the within field variability data (Khanna, 2001; Nair et al., 2011). Since both the partial and complete adoption of PA are observed among the farmers, there is a need to further understand if the partial and/or complete adoption of PA are influenced by the same set of characteristics. The objective of this study is to identify the impact of the adopted irrigation technology and other farm and farmer characteristics on the partial and complete adoption of PA among the cotton farmers in Texas.

Materials and Methods

The Data

The data for this analysis are from the 2009 Southern Precision farming Survey (Mooney et al. 2010). This extensive survey received 1692 usable responses from cotton producers of 12 southern states, of which 749 are from Texas. The survey provided information on the characteristics of the farmers, their farm, and their farming practices with special references to the different precision agriculture practices. Since the objective of this study is to analyze the influence of irrigation methods adopted by the Texas cotton farmers on their adoption of precision agricultural practices, only Texas' data was used in this study.

Empirical Model

A multinomial probit model was used to analyze the data. A multinomial probit model is a random utility model with discrete unordered choice sets that are mutually exclusive, exhaustive and finite. This model was used to estimate the probability of decision maker i choosing the alternative j (Cameron and Trivedi, 2010).

This model assumes that the decision maker will choose the alternative that provides him the highest utility from the available choice set. These utilities are unobservable but can be decomposed into a systematic observable part and an unobservable error part. Then the utility received by farmer i by choosing technology j can be written as

$$U_{ij} = x'_{ij}\beta + \varepsilon_{ij} \quad j = 1 \dots J, \left(\varepsilon_{i1} \dots \varepsilon_{iJ}\right) \sim MVN(0, \Sigma)$$

Here $x'_{ij}\beta$ is the systematic or observed part of the utility, ε_{ij} is the unobservable error term, and J is the number of alternatives available to the decision maker. Since the producer chooses the alternative with the highest utility, the choice of alternative k is observed only when $U_{ik} > U_{ij}\ for\ k \neq j$. Hence the probability of choosing alternative J can be written as

$$P_{ij} = \Pr(y_i = j) = Pr\left[\varepsilon_{ik} - \varepsilon_{ij} \leq \left(x_{ij} - x_{ik}\right)'\beta\right] \qquad \forall\ k$$

where *x* is the metrics of explanatory variables and β is the vector of coefficient estimates.

Based on the response to the questions concerning the adoption different component technologies of PA, the dependent variable *adopt* was constructed by grouping producers into three exhaustive and mutually exclusive groups. The definition of the choice set used as the dependent variables are provided in Table 1. Different farm and farmer's characteristics and adoption of irrigation technologies are used as the independent variables. The detailed description of the variables used in the study is provided in table 2.

Table 1. The definition of dependent variables (choice set) used in the study

No.	Choice	Definition
1	*Non-adopters*	Farmers from the state of Texas
2	*Partial adopters*	The producer adopted at least one component technology of PA among the variability data acquisition technologies but did not adopt variable rate application of any input
3	*Complete adopters*	The producer adopted at least one variability data acquisition technology and used the data to apply fertilizers, lime, seeds, growth regulator, harvest aids, fungicides, insecticides, or irrigation water at variable rate.

Table 2. The definition of independent variables used in the study

Number	Variable Name	Definition
1	*dry*	Dummy variable that assumes the value of 1 if the producer did not adopt any irrigation technology and 0 otherwise.
2	*furrow*	Dummy variable that assumes the value of 1 if the producer uses furrow irrigation only and 0 otherwise.
3	*cp*	Dummy variable that assumes the value of 1 if the producer has at least 50 acres of land under center pivot irrigation system and less than 50 acres of land under sub-surface drip irrigation system and 0 otherwise.
4	*sdi*	Dummy variable that assumes the value of 1 if the producer has at least 50 acres of land under sub-surface drip irrigation system and 0 otherwise.
5	*plains*	Dummy variable that assumes the value of 1if the farm is located in the agricultural statistical districts of Upper Coast (District 90), South Central (District 81), Coastal Bend (District 82), South Texas (District 96), or Lower Valley (District 97) and zero otherwise
6	*coast*	Dummy variable that assumes the value of 1 if the farm is located in the agricultural statistical districts of Upper Coast (District 90), South Central (District 81), Coastal Bend (District 82), South Texas (District 96), or Lower Valley (District 97)
7	*others*	Dummy variable that assumes the value of 1 if the farm is not located in the coast or plains region and 0 otherwise
8	*farmsize*	The average area planted to cotton in 2007 and 2008 in acres
9	*age*	Age of the primary decision maker of the farming operations in years
10	*exp*	Farming experience of the primary decision maker of the farming operations in years
11	*edu*	Number of years of formal education of the primary decision maker of the farming operations in years discarding the kindergarten (preschool) education
12	*comp*	Dummy variable that assumes the value of 1 if the farmer uses computers or laptops for farming operation and 0 otherwise
13	*ext*	Dummy variable that assumes the value of 1 if the farmer attended any extension seminars related to PA or has access to extension publications related to PA and 0 otherwise

Results and Discussion

The results of the empirical estimation analyzing the impact of different irrigation technologies, and farm and farmer characteristics on partial and complete adoption of PA technologies by cotton producers in Texas are provided in Table 3. For convenience, the results are described and discussed in three sections. The first section shows the impact of irrigation technologies adopted by the producers, the second section analyzes the regional differences in adoption and the third section provides the impact of farm and farmer characteristics on PA adoption

Impact of Irrigation Technologies

The producers who adopted only the low efficiency furrow irrigation system had a higher probability of partial adoption ($p>|z|=0.007$) compared to dryland farmers but did not have significantly higher probability of complete adoption ($p>|z|=0.51$). This shows that even though the producers with furrow irrigation system are more likely to adopt some component technologies compared to dryland farmers, the likelihood of complete adoption was on par with dryland farmers. This prevalence of partial adoption of PA was also reported by Khanna (1999) and indicates that farmers adopt some part of the technology first and may wait more to resort to complete adoption.

The adopters of highly efficient irrigation systems like CP and SDI were found to have significantly higher probability of both partial and complete adoption of PA compared to the producers practicing dryland farming. However the adoption of these two irrigation technologies influenced the partial and complete adoption differently. Further analysis of the average marginal impact of CP and SDI showed that the probability of partial adoption of PA was higher by 0.20 and 0.17, respectively, for producers having CP and SDI irrigation system compared to dryland farmers, whereas that of complete adoption was higher by 0.08 and 0.13, respectively for adopters of CP and SDI systems compared to dryland farmers. This shows that the producers with sub-surface drip irrigation system are relatively more likely to be complete adopters of PA compared to the producers with center pivot irrigation system.

Table 3. The coefficient estimates and standard errors for adoption of irrigation technologies

adopt	Variable	Coefficient	Std. Error
Partial Adopters	*furrow*	0.991*	0.541
	cp	1.227***	0.252
	sdi	1.169***	0.302
	plains	-0.322	0.329
	coast	0.451	0.442
	farmsize	9.00E-05	8.36E-05
	age	-0.009	0.013
	exp	-0.009	0.012
	edu	0.041	0.038
	comp	-0.168	0.197
	ext	0.503***	0.181
	Constant	-1.584*	0.839
Complete Adopters	*furrow*	0.253	0.381
	cp	1.293***	0.430
	sdi	1.765***	0.468
	plains	1.086*	0.656
	coast	1.971**	0.789
	farmsize	2.21E-04**	9.14E-05
	age	-0.082***	0.025
	exp	0.042*	0.023
	edu	-0.025	0.052
	comp	0.398*	0.233
	ext	1.073***	0.270
	Constant	-0.963	1.267
Non-adopters		Base	
N=550	LL=-374.66	Wald Chi square=88.11	P value<0.001

Regional Impact on PA adoption in Texas

The results showed that there were no significant regional differences in the likelihood of partial adoption among the three regions in Texas, whereas the probability of complete adoption was significantly influenced by geographical location of the farm. This shows that acquiring variability data was not influenced by the geographical location of the farm while the decision to apply input at variable rate differed among the regions. The regional differences in adoption of PA practices were reported by several researchers (see Lowenberg-DeBoer, 1999; Daberkow and McBride, 2000; Walton et al., 2010; Nair et al., 2011).

Effect of farm and farmer characteristics on PA adoption

The results indicated that farm size significantly influences the probability of complete adoption while its impact on partial adoption is not significant. Larger farms are generally regarded as agronomically less efficient because of the possible higher within-field variability of larger farms (Kramer, 1987) and hence there is a higher likelihood of deriving benefits from applying inputs at variable rates in larger farms. This may be one reason for higher likelihood of complete adoption of PA in larger farms.

Age of the farmer significantly and negatively influences the probability of complete adoption ($p>|z|<0.001$), but does not have significant influence on the probability of partial adoption of ($p>|z|=0.47$). The negative influence of age on the adoption of PA technologies was reported by several researchers (Daberkow and McBride, 2000; Daberkow and McBride, 2003; Larson et al., 2008; Walton et al., 2010). The awareness about existence of the technology, availability of a longer planning horizon, and lower level of risk aversion can be the reasons for higher level of adoption of new technologies by younger farmers (Batte and Johnson, 1993; Sevier and Lee, 2004).
Number of years of formal education of the producer has no significant influence the probability of either partial or complete adoption of PA. The role of education on technology adoption is reported to be through creating awareness about the existence of the technology and once we control for the awareness, education may not be a significant

factor influencing PA adoption (Daberkow and McBride, 2003). Since the precision agriculture technologies were commercially available since 1990 (Daberkow and McBride, 2003), most of the farmers may be are aware about the existence of PA technology nowadays. This high level of awareness among farmers may be a reason for education not to influence the PA adoption in Texas.

The number of years of farming experience significantly influences the probability of complete adoption ($p>|z|=0.07$), but does not influence the probability of partial adoption ($p>|z|=0.42$). Controlling for age and education, a higher experience indicate that the producer is more likely to be a full-time farmer and this may be the reason for the higher likelihood of PA adoption of more experienced farmers.

Use of computers or laptops for farming operations influences only the probability of complete adoption of PA. Within-field variability data can be acquired using many methods such as grid soil sampling, zone soil sampling, and yield monitors that do not demand computer skills from the adopters. However, analysis of the variability data and creating variable rate application maps required for applying inputs at variable rates requires computer skills from the part of producers and hence the producers using computers for farming operations may find it easier to adopt variable rate application of inputs than those who are not computer savvy.

Attending extension seminars or having exposure to extension publications significantly and positively influences both the partial and complete adoption of PA. Extension activities enhance the adoption of PA technologies by creating awareness about the existence the technology and by demonstrating its advantages (McBride, 2003). Hence farmers with exposure to extension publications or attending the extension seminars related to PA are more likely to adopt PA.

Summary

Adoption of PA is different from the adoption of other technologies, as PA is comprised of several component technologies and producers may or may not adopt them as a system. Many producers adopt one or more component technologies without adopting application of inputs at variable rate (partial adopters) while some producers adopt PA as a system (complete adopters). Irrigation plays a pivotal role in agricultural production especially in low rainfall areas like Texas. Our analysis seeks to understand the possible relationship with adoption of high efficiency irrigation systems and the partial or complete adoption of PA.

The results showed that both the partial and complete adoption of PA are influenced by the type of irrigation system adopted by the producers. Adoption of any type of irrigation system significantly increased the likelihood of adoption of PA practices. The producers who adopted high efficiency irrigation systems such as CP and SDI were found to have higher probability of both partial and complete adoption of PA. It is also interesting to note that the producers who adopted SDI are more likely to adopt PA as a system compared to the producers who adopted CP.

Apart from the irrigation technology used, several farm and farmer characteristics were found to significantly influence PA adoption, but these explanatory variables had dissimilar impact on partial and complete adoption. Among the farm and farmer characteristics, only the exposure to extension activities had a significant impact on the partial adoption of PA. However, farm size, exposure to extension activities, use of computers for farming operations, and number of years of farming experience by the produces were found to significantly enhance the likelihood of complete adoption of PA. Younger farmers were found to be more likely to adopt PA as a system.

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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