THE ADOPTION OF INFORMATION TECHNOLOGIES AND SUBSEQUENT CHANGES IN INPUT USE IN COTTON PRODUCTION

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ABSTRACT

Understanding the factors influencing farmer perceptions of changes in input use as related to precision agriculture (PA) technologies is important because of the potential economic and environmental benefits of PA. Summary statistics were evaluated for data from the 12-state 2009 Southern Cotton Precision Farming Survey to identify farm operation characteristics, farm decision maker characteristics, and sources of PA information used by the farm decision maker that influence farmer decisions to adopt and subsequent farmer perceptions of changes in input use. Results suggest that adopters were generally younger, more educated, more likely to use a computer, and grew larger areas of cotton. They also were more likely to grow picker cotton and use irrigation. The majority of farmers in the sample perceived fertilizer use to decrease with PA technologies. These farmers generally grew larger areas of picker cotton. The majority of farmers in the sample also perceived lime use to decrease. Among those with this perception were higher income, full-time farmers who grew larger areas of cotton. Lastly, the majority of farmers in the sample perceived plant growth regulator use to not change or decrease with PA technologies. These farmers were generally more educated and grew picker cotton.

Keywords: Adoption, information technology, input use, precision agriculture

INTRODUCTION

Precision agriculture (PA) affords farmers the potential to improve input productivity by taking advantage of knowledge about in-field variability. Prior to the advent of PA, farmers typically applied inputs using uniform rate technology (URT). The inability to identify and act on spatial disparity within fields with URT commonly leads to inefficiencies in input application. Hence, improvements in input productivity with PA provide the opportunity for economic and environmental benefits. Knowledge of the factors affecting changes in input use are important given the role they play in understanding the potential benefits of PA.

Before farmers are able to perceive changes in input use, they must first choose to adopt information technologies and variable rate technology (VRT) input management. The factors affecting adoption of PA technologies has been evaluated extensively (e.g., Batte and Arnholt, 2003; Daberkow and McBride, 1998; Griffin et al., 2004; Khanna, 2001; Kotsiri et al., 2011; Lambert et al., 2007; Larson et al., 2008; Marra et al., 2010; Popp and Griffin, 2000; Roberts et al., 2004; Walton et al., 2008; Walton et al., 2010). While the majority of prior research has evaluated the adoption of individual PA technologies, this research evaluates the adoption of a group of technologies.

Subsequently, farmers who choose to adopt are self-selected into a group who have the potential to realize increased input productivity. The literature provides evaluation of the factors influencing increased input productivity (Khanna, 2001; Torbett et al., 2007, 2008); increased profit (Lambert and Lowenberg-DeBoer, 2000; Swinton and Lowenberg-DeBoer, 1998); and improved environmental quality (Larkin et al., 2005) with information technologies and VRT. However, the factors affecting directional changes (i.e., increase, no change, or decrease) in overall input use affected by PA use have not been evaluated.

The results of this research identify the farm business characteristics, operator characteristics, and information sources that influence farmer decisions to adopt selected information technologies for VRT management and their subsequent perceptions of changes in overall use of selected inputs. Identification of the factors influencing farmer perceptions of changes in input use expands currently available knowledge and may provide further understanding of the benefits of PA. The USDA Natural Resource Conservation Service and others may be interested in the findings of this research, given the environmental effects of fertilizer and chemical application.

DATA

Primary data for this analysis were from the 2009 Southern Cotton Precision Farming Survey (Mooney et al., 2010). The survey collected information concerning cotton grower use and perceptions about PA in 12 southern states: Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, Missouri, North Carolina, South Carolina, Tennessee, Texas, and Virginia. Following the general mail survey procedures of Dillman (1978), a questionnaire, postage paid return envelope, and a cover letter explaining the importance of the survey were sent on February 20, 2009 with a reminder postcard sent two weeks later, and a follow-up mailing on March 27, 2009, to producers who had not responded. The mailing list was comprised of 14,089 potential cotton producers based on the 2007-2008 marketing year lists of the Cotton Board in Memphis, TN. Excluding surveys returned undeliverable and those who indicated they no longer farmed cotton, the total number of cotton growers surveyed was 13,579. With 1,692 valid responses, the survey response rate was 12.5%.

Given the initial overrepresentation of survey data for larger farms, post-stratification (PS) survey weights, estimated by Harper et al. (2011), were used to align the survey data with USDA 2007 Agricultural Census population of cotton producers by state and farm size class. Post-stratification weights can adjust for over or underrepresentation of survey respondents within strata (e.g., state or farm size class), but do not necessarily remedy non-response bias (Lohr, 1999).

Secondary data for the number of farm input suppliers were included in the analysis, based on the North American Industry Classification System (NAICS) codes identifying farm input suppliers. The business establishment data is from the U.S. Census Bureau's 2007 County Business Patterns (U.S. Census, 2011).

METHODS AND PROCEDURES

Characteristics describing the farm operation, farm decision maker, and sources of PA information used by the farm decision maker were compared between subsets of the population using summary statistics. Weighted means were calculated using the following equation:

$$\overline{x} = \frac{\sum_{i=1}^{n} x_i w_i}{\sum_{i=1}^{n} w_i} \tag{1}$$

where $\overline{x}$ is the mean of variable *x* and *w* is the PS weight associated with observation *i*. Tests were conducted to identify statistical differences in the means of various subsets of the population using linear combinations (side-by-side *t*-tests):

$$t = \frac{\overline{x}_1 - \overline{x}_0}{se(\overline{x}_1 - \overline{x}_0)} \tag{2}$$

where the *t*-statistic is estimated as the difference in the means of variable *x* for two sub-sets of the population, 0 and 1 (e.g., adopters and non-adopters), divided by the standard error of the difference in the means of the two sub-populations.

These summary statistics were first estimated for adopters and non-adopters of select information technologies for VRT management: yield monitors, satellite or aerial photography, personal digital assistant or handheld global positioning system devices, and electrical conductivity. For farmers choosing to adopt these information technologies, summary statistics were evaluated for perceptions of increased, unchanged, and decreased use of select inputs: fertilizer, lime, and plant growth regulators. Explanatory variables, hypothesized to influence adoption and perceptions of changes in input use, include: characteristics describing the farm operation, farm decision maker, and sources of PA

Table 1. Variable Definitions

Variables	Definition
AGE	Age of the primary operator in years
EDUC	Farmer held a Bachelors degree (yes=1; else=0)
INC	Household income over $100,000 (yes=1; else=0)
INCFRM	Percentage of income from farming
COMP	Used a computer for farm operations (yes=1; else=0)
LIVSTK	Owned livestock (yes=1; else=0)
COTAREA	Area of cotton farmed (405 hectare units)
OWNRENT	Percentage of cotton acreage owned
IRRIG	Irrigation was present (yes=1; else=0)
PICKER	Farmer grew picker cotton (yes=1; else=0)
FRMSPLY	Number of farm input suppliers
FRMDLER	Farmer used farm dealers for PA information (yes=1; else=0)
CRPCSLT	Farmer used crop consultants for PA information (yes=1; else=0)
OFRMER	Farmer used other farmers for PA information (yes=1; else=0)
EXTEN	Farmer used University Extension for PA information (yes=1; else=0)
TRDSHW	Farmer used trade shows for PA information (yes=1; else=0)
INTER	Farmer used the internet for PA information (yes=1; else=0)
MEDIA	Farmer used news or media for PA information (yes=1; else=0)
NOINFO	Farmer did not utilize and of the information sources (yes=1; else=0)

information used by the farm decision maker. Definitions for these variables can be found in Table 1.

RESULTS

Information Technology Adoption

Mean comparisons of adopters and non-adopters are reported in Table 2. Of the cotton farmers in the sample, 161 (13%) choose to adopt one or more of the select information technologies for VRT input management.

Results suggest that adopters of information technologies for VRT management were younger, more educated, more likely to use a computer for farm management, and grew larger areas of cotton. Younger farmers are often expected to have longer planning horizons, which may ensure a larger return on this investment (Batte et al., 2000; Daberkow and McBride, 1998). Computer technology is integrated into PA, and thus, it is common to find that computer use influences the adoption of PA technologies (Walton et al. 2010). Farmers growing larger areas of cotton have the advantage of being able to spread the fixed cost of PA technology investment over more area, which also appears to influence the adoption decision (Roberts et al., 2004).

Results suggest that adopters were more likely to use irrigation and grow picker cotton. Both irrigated cotton and picker cotton are generally associated with higher yields and the potential need to facilitate VRT management of higher

Table 2. Comparisons of Characteristics between Adopters and Non-Adopters of One or More Selected Information Technologies Used for Variable Rate Technology Application of Inputs in Cotton Production

Variables†	Adopter Mean‡	Non-Adopter Mean	*t*-value§
AGE	51.50	56.60	−3.50**
EDUC	0.53	0.38	3.04**
INC	0.50	0.46	0.90
INCFRM	0.71	0.67	1.43
COMP	0.70	0.46	5.11**
LIVSTK	0.25	0.34	−2.22*
COTAREA	0.80	0.55	3.09**
OWNRENT	0.38	0.38	0.17
IRRIG	0.53	0.42	2.24*
PICKER	0.77	0.58	4.36**
FRMSPLY	7.67	8.45	−1.16
FRMDLER	0.76	0.53	5.47**
CRPCSLT	0.42	0.27	3.47**
OFRMER	0.61	0.57	0.81
EXTEN	0.45	0.36	1.95
TRDSHW	0.51	0.28	4.87**
INTER	0.41	0.20	4.82**
MEDIA	0.47	0.32	3.14**
NOINFO	0.01	0.18	−9.94**
n	161	1,043	
Expanded Population¶	1,545	11,096	

* Significant at the 0.05 probability level.
** Significant at the 0.01 probability level.
†Variables are defined in Table 1.
‡An adopter was defined as having adopted one or more of the following information technologies: yield monitors, passive remote sensing, personal digital assistant or handheld global positioning system devices, active remote sensing, or electrical conductivity.
§*t*−values are the result of a side-by-side *t*-test of the weighted means of adopters and non-adopters.
¶The expanded population is the sum of the weights across observations.

input levels than their alternatives (dryland cotton and stripper cotton) (Larson et al., 2004; Monks et al., 2007). Higher yields associated with irrigated cotton and picker cotton increase profit potential, which may also encourage investment in PA technologies.

Precision agriculture technology adopters were more likely to use farm input dealers, crop consultants, trade shows, the internet, and news or media as sources of PA information. While the use of each of these sources may influence the adoption decision individually, previous research has found that combinations of these and other sources, such as University Extension, play an important role in farmer perceptions of PA (Jenkins et al., 2011)

Perceived Changes in Fertilizer Use

Mean comparisons of farmer perceptions regarding increased, unchanged, and decreased fertilizer use after practicing PA are reported in Table 3. The majority of farmers in the sample (57%) perceived a decrease in fertilizer use.

Results suggest that farmers who perceived no change in fertilizer use were more likely to hold a Bachelor's degree or higher. Higher levels of analytical ability associated with a college degree likely enable farmers to understand that

Table 3. Comparisons of Characteristics between Perceptions of Directional Changes in Fertilizer Use Following the Adoption of One or More Information Technologies for Variable Rate Technology Application of Inputs in Cotton Production

Variables†	Changes in Overall Fertilizer Use‡		
	increase	no change	decrease
AGE	53.36 a	50.26 a	49.22 a
EDUC	0.44 a	0.82 b	0.61 a
INC	0.63 a	0.34 a	0.55 a
INCFRM	0.75 a	0.65 a	0.74 a
COMP	0.77 a	0.64 a	0.84 a
LIVSTK	0.30 a	0.19 a	0.26 a
COTAREA	0.60 a	0.76 ab	1.07 b
OWNRENT	0.52 a	0.53 a	0.29 a
IRRIG	0.66 a	0.30 b	0.54 a
PICKER	0.58 a	0.92 b	0.95 b
FRMSPLY	9.91 a	7.32 a	6.61 a
FRMDLER	0.75 a	0.82 a	0.79 a
CRPCOSLT	0.47 a	0.42 a	0.50 a
OFRMER	0.45 a	0.61 a	0.67 a
EXTEN	0.41 a	0.85 b	0.41 a
TRDESHW	0.53 a	0.51 a	0.56 a
INTER	0.34 a	0.63 a	0.38 a
MEDIA	0.54 a	0.48 a	0.52 a
NOINFO	0.02 a	0.00 a	0.00 a
n	25	18	56
Expanded Population§	275	191	465

†Variables are defined in Table 1.

‡Means followed by the same letter in each row are not statistically different at the 0.05 probability level based on the results of side-by-side *t*-tests.

§The expanded population is the sum of the weights across observations.

fertilizer use may change differently in various sections of a field, with increased fertilizer efficiency and no change in overall fertilizer use (Roberts et al., 2004; Walton et al., 2008).

Results suggest that farmers who perceived increased fertilizer use were less likely to grow picker cotton. Excess nitrogen in cotton production often reduces yield and fiber quality as a result of excessive vegetative growth (Kohli and Morrill, 1976). Hence, the inverse relationship between increased fertilizer use and farmers growing higher valued picker cotton is likely an effort to avoid discounts for lint quality and the need for excess plant growth regulators and harvest aids.

Farmers who perceived no change in fertilizer use after adopting PA were more likely to use University Extension as a source of PA information. These perceptions may have been influenced by the general information generated by University Extension for a given region when compared to other sources of PA information that may provide farmers with detailed information customized for their particular operation (Jenkins et al., 2011; Velandia et al., 2010). Also, the objectivity associated with University Extension may lend to more equable deduction of perceptions of changes in fertilizer use on the part of farmers (Jenkins et al., 2011; Larson et al., 2008).

Perceived Changes in Lime Use

Mean comparisons of farmer perceptions of increased, unchanged, and decreased lime use with PA are reported in Table 4. A majority of the farmers in the sample for perceptions of changes in lime use (76%) perceived that overall lime use decreased with PA.

Results suggest farmers who perceived no change in lime use were more likely to report household income under $100,000 per year and receive a smaller portion of this income from farming. Assuming farmers who earn a larger portion of their income from farming spend more time attending to their operations, it follows that lower income, part-time farmers may have less time to commit to learning and realizing the full potential of PA technologies (D'Souza et al., 1983).

Results suggest that farmers who perceived decreased lime use grew significantly larger areas of cotton. Larger cotton areas are likely subject to increased spatially variability, providing the potential for decreased lime use (Torbett et al., 2007, 2008).

Perceived Changes in Plant Growth Regulator Use

Mean comparisons of farmer perceptions of increased, unchanged, and decreased plant growth regulator use with PA are reported in Table 5. As perceived by farmers in the sample, plant growth regulator use did not change for 41% of farmers, and decreased for 35% of farmers.

Results suggest those farmers who perceived an increase in plant growth regulator use were less likely to hold a Bachelor's degree. The higher level of analytical ability associated with a college degree may aid farmers in coordinating

Table 4. Comparisons of Characteristics between Perceptions of Directional Changes in Lime Use Following the Adoption of One or More Information Technologies for Variable Rate Technology Application of Inputs in Cotton Production

Variables†	Changes in Overall Lime Use‡		
	increase	no change	decrease
AGE	46.21 a	47.40 a	49.80 a
EDUC	0.39 a	0.67 a	0.68 a
INC	0.66 a	0.21 b	0.53 a
INCFRM	0.69 a	0.40 b	0.75 a
COMP	1.00 a	0.68 ab	0.87 b
LIVSTK	0.31 a	0.20 a	0.23 a
COTAREA	0.47 a	0.74 a	1.00 b
OWNRENT	0.38 a	0.39 a	0.29 a
IRRIG	0.48 ab	0.24 a	0.55 b
PICKER	0.80 a	0.94 a	0.98 a
FRMSPLY	8.44 a	8.28 a	5.88 a
FRMDLER	0.80 ab	1.00 a	0.78 b
CRPCOSLT	0.42 a	0.43 a	0.52 a
OFRMER	0.25 a	0.53 a	0.78 b
EXTEN	0.44 ab	0.80 a	0.50 b
TRDESHW	0.26 a	0.67 a	0.54 a
INTER	0.34 a	0.52 a	0.37 a
MEDIA	0.41 a	0.39 a	0.46 a
NOINFO	0.00 a	0.00 a	0.00 a
n	13	9	68
Expanded Population§	143	106	592

†Variables are defined in Table 1.
‡Means followed by the same letter in each row are not statistically different at the 0.05 probability level based on the results of side-by-side *t*-tests.
§The expanded population is the sum of the weights across observations.

production decisions for the entire growing season, which may limit the need for plant growth regulators (Roberts et al., 2004; Walton et al., 2008).

Farmers who perceived plant growth regulator use to increase were less likely to grow picker cotton. Farmers growing higher valued picker cotton typically apply fertilizers to avoid discounts for lint quality from increased vegetative growth. Accordingly, this effort implicitly reduces the need for increased plant growth regulator application (Fritschi et al., 2003).

Farmers who perceived increased plant growth regulator use were less likely to use the internet as a source of PA information.

Table 5. Comparisons of Characteristics between Perceptions of Directional Changes in Plant Growth Regulator Use Following the Adoption of One or More Information Technologies for Variable Rate Technology Application of Inputs in Cotton Production

Variables†	Changes in Overall Plant Growth Regulator Use‡		
	increase	no change	decrease
AGE	52.72 a	48.06 a	51.12 a
EDUC	0.23 a	0.83 b	0.71 b
INC	0.62 a	0.52 a	0.61 a
INCFRM	0.71 a	0.78 a	0.72 a
COMP	0.72 a	0.93 a	0.79 a
LIVSTK	0.25 a	0.25 a	0.24 a
COTAREA	0.69 a	1.19 a	0.98 a
OWNRENT	0.56 a	0.38 a	0.26 a
IRRIG	0.61 a	0.60 a	0.73 a
PICKER	0.48 a	0.91 b	0.95 b
FRMSPLY	12.26 a	5.74 a	7.10 a
FRMDLER	0.75 a	0.81 a	0.76 a
CRPCOSLT	0.43 a	0.64 a	0.53 a
OFRMER	0.37 a	0.64 ab	0.76 b
EXTEN	0.36 a	0.59 a	0.28 a
TRDESHW	0.38 a	0.56 a	0.76 a
INTER	0.18 a	0.56 b	0.59 b
MEDIA	0.51 a	0.53 a	0.51 a
NOINFO	0.00 a	0.00 a	0.00 a
n	12	21	18
Expanded Population§	142	146	175

†Variables are defined in Table 1.
‡Means followed by the same letter in each row are not statistically different at the 0.05 probability level based on the results of side-by-side *t*-tests.
§The expanded population is the sum of the weights across observations.

SUMMARY

This research provided a preliminary analysis of the factors that affect farmer perceptions of changes in overall use of selected inputs with the use of selected information technologies and VRT input management.

Key findings were that farmers growing larger areas of picker cotton were less likely to perceive increases in the use of the evaluated inputs from practicing PA. Larger areas of cotton are expected to be subject to increased variability, which may explain the lower chance of perceiving increased input use. In addition, farmers growing higher valued picker cotton typically avoid excess nitrogen applications that may reduce yields, diminish fiber quality, and increase the need for plant growth regulators and harvest aids prior to harvest. These results and other key findings of this research may be of interest to cotton farmers and the USDA Natural Resource Conservation Service who are interested in the environmental impacts of decreased fertilizer use among cotton farmers. University Extension may also be interested in the results of this research to tailor educational programs to better reach farmers who are more likely to realize the economic benefits of PA.

Finally, the result this research lay the groundwork for future research on directional changes in input use after practicing PA. For example, future research could use discrete-choice models to evaluate the factors influencing decisions to adopt PA technologies and subsequent perceptions of changes in input use.

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