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ECONOMICS AND MARKETING

Precision Farming Adoption Trends in the Southern U.S.

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ABSTRACT

Studies investigating temporal and geographic adoption of precision farming technologies (PFT) are valuable for researchers, consultants, and farmers to make more informed production decisions. Focusing on southern U.S. cotton producers, the objective of this study was to assess the timing trends and geographic patterns of PFT adoption. Data were obtained from a mail survey of cotton producers in 14 southern states in 2013. The overall PFT adoption level was 73.5%. Specifically, the adoption level was 40.9% for information gathering (IG), 67% for global positioning system-guidance (GPSG), 25.3% for variable rate application (VRA), and 29.3% for automatic section control technologies (ASC). The cumulative adoption level across years generally fit the logistic function curve for the various PFT evaluated in this study. The peak annual adoption growth was 4.0% in 2008 for IG, 6.8% in 2010 for GPSG, 4.4% in 2010 for VRA, and 7.2% in 2010 for ASC. Geographically, cotton farmers in the Corn Belt region had the highest PF adoption level (91.7%), followed by the Mississippi Delta region (80.7%) and the Northern and Southern Plains region (75.4%). The lowest PF adoption level was in the Southeast region (65.2%). Of the four PFT categories, GPSG was the most widely adopted. The geographic technology adoption patterns are valuable for farm input dealers to target potential buyers of PFT. This study provides researchers with valuable PFT adoption trends among southern cotton farmers and helps producers make more informed adoption decisions.

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Precision farming (PF) entails a series of spatial information technologies that have the potential to improve farm profitability by increasing yields and lowering input costs (Larson et al., 2016; Velandia et al., 2010). Those PF technologies (PFT) include spatial information gathering (IG), variable rate application (VRA), global positioning system-guidance (GPSG), and automatic section control (ASC) (Bongiovanni and Lowenber-Deboer, 2004) (Fig. 1). PFT brings within-field site-specific information about soil and crop input requirements and allows producers to apply the right amount of input in the right place at the right time (Bongiovanni and Lowenber-Deboer, 2004). Traditionally, uniform field management can provide excessive amounts of inputs at one site but inadequate amounts at another site because variation in soil attributes requires varying amounts of inputs for crop production at different sites within a farm field (Torbett et al., 2007). In addition, input inefficiency also occurs when an input applicator overlaps an area that has already received inputs (Larson et al., 2016). To avoid input inefficiency, farmers have incentives to use PFT to provide site-specific inputs matching soil and crop needs (Roberts et al., 2004). As farmers face rising input costs of fertilizer, seed, chemical, equipment, and labor (McKinion et al., 2001), PFT can decrease costs and/or increase yields for fields with high soil and yield variability that can offset the adoption cost (Batte and Arnholt, 2003; Larson et al., 2016; Roberts et al., 2000).

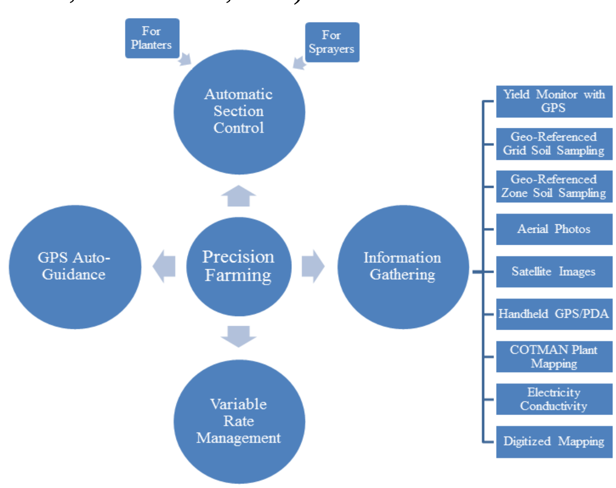

Figure 1. Precision farming technologies (PFT).

PFT is especially useful for cotton producers in the southern U.S. Most cotton in the southern U.S. is produced in fields with irregular shapes where input application overlaps if PFT is not used (Larson et al., 2016). Also, cotton is a high-valued crop that requires significant amounts of inputs (Roberts et al., 2013). The average per-acre value of cotton in the U.S. in 2012 (USDA, 2014) was higher than corn, soybeans, or wheat. The high value and cost of cotton production provide incentives for the adoption of PFT to improve profitability by reducing cost and/or improving yields (Zhou et al., 2015).

Results from this study contribute to the literature on PFT adoption trends among southern cotton farmers and can help them develop more knowledgeable production strategies. It describes PFT adoption from the perspectives of time and location. Adoption level was used to describe the use of PFT. Adoption level was determined by dividing the number of survey respondents who adopted a technology by the total number of farmers who responded to the survey in a geographic area (assuming the technology employed by respondents was representative of the technology employed by nonrespondents) (Cochran et al., 2006; Larson et al., 2008; Mooney et al., 2010; Ryan and Gross, 1943, 1950; Watcharaanantapong et al., 2014; Winstead et al., 2010; Zhou et al., 2015) instead of calculating the percentage of farm acres on which the technology was used (Erickson and Widmar, 2015; Lambert et al., 2015; Schimmelpfennig and Ebel, 2011).

The first contribution of this study is the analysis of adoption timing for the various PFT. The adoption timing is valuable for researchers, consultants, and farmers to learn how each PFT was disseminated among southern cotton producers. Those farmers who are most likely to adopt PFT sooner than others can use the information to make more informed production decisions. Researchers and consultants can use the information to help those farmers benefit from the adoption (Watcharaanantapong et al., 2014).

The analysis of time trends associated with new technology adoption goes back to Ryan and Gross (1943, 1950) and Ryan (1948). They studied the adoption of hybrid seed corn among farm operators in two communities of central Iowa in 1941. They found two-thirds of the farmers adopted the hybrid seed during a four-year period between 1936 and 1939. Ryan and Gross (1943, 1950) suggested the diffusion (defined as "the process by which an innovation is communicated through certain channels over time among the members of a social system" [Rogers, 2003]) pattern of adoption for the hybrid seed included three periods: 1) long-time slow initial growth, 2) fast increase, and 3) decline. They reported most adopters tried the new seed in small quantities of acres at first and then gradually increased their use. Finally, they found a skewed distribution of diffusion pattern for hybrid seed corn adoption that cannot be described accurately by a normal distribution.

The groundbreaking work on the adoption of new technologies by Griliches (1957) found an S-shaped curve for adoption of hybrid corn over time. Specifically, data on the cumulative adoption percentage of total corn acreage across years generally fit a logistic function (S) curve. The S-curve includes the origin (year when the S curve reaches 10%), slope (annual adoption growth), ceiling (maximum level of adoption), and inflection (maximum annual adoption growth) (Dixon, 1980; Griliches, 1957; Marsh et al., 2000). Since then, the S-curve approach has been used widely for time-trend adoption analyses of new technologies in agriculture (Dixon, 1980; Doessel and Strong, 1991; Feder and Umali, 1993; Gore and Lavaraj, 1987; Knudson, 1991; Mansfield, 1961; Valente, 1993). Recent S-curve studies on the adoption of new agricultural technologies involved conservation tillage, integrated pest management, nutrient management practice (Fuglie and Kascak, 2001), broad bed maker (Jabbar et al., 2003), genetically engineered crops (Fernandez-Cornejo and Wechsler, 2012; Fernandez-Cornejo et al., 2014), and other new crops (Marsh et al., 2000).

Little research has been published on using the S-curve approach to describe PFT adoption time trends among cotton producers. Watcharaanantapong et al. (2014) described S-cumulative adoption percentages for three IG technologies, including grid soil sampling, yield monitors, and remote sensing from 1995 through 2009 using data from a survey of cotton producers in 12 southern U.S. states conducted in 2009. Schimmelpfennig and Ebel (2011) examined the S-curve timing trend in the use of yield monitors, VRA, GPSG, and GPS maps on corn, soybean, and winter wheat acres using Agricultural Resource Management Survey data from years 1996 through 2009. Our study used the S-curve approach to summarize recent PFT adoption trends from 2000 through 2012.

The second contribution of our study is the geographic presentation of PFT adoption levels by

USDA farm production region. Adoption by region illustrates the geographic differences in cotton farmers' use of PFT in the southern U.S., which has not been documented from the perspective of adoption levels. This information is valuable for farm input dealers as they might be able to better target potential buyers of PFT.

The research objective of this study was to assess adoption trends and geographic patterns of PFT adoption by southern U.S. cotton producers. We used data from a survey of cotton farmers in 14 southern U.S. states to achieve this objective.

MATERIALS AND METHODS

The population of interest was cotton producers in 14 southern U.S. states: Alabama, Arkansas, Florida, Georgia, Kansas, Louisiana, Mississippi, Missouri, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, and Virginia (Fig. 2). The list of 13,838 potential cotton producers located in these 14 states for the 2011 marketing year was provided by the Cotton Board in Memphis, TN. After removing 272 duplicate addresses and the addresses of research and education centers, a list of 13,566 cotton producers remained (Zhou et al., 2015).

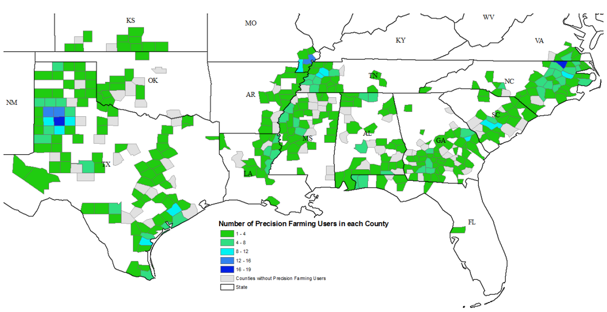

Figure 2. Study area and number of precision farming users by county for the 2013 Southern Cotton Farm Survey.

Following Dillman's (1978) mail survey procedures, the questionnaire, a postage-paid return envelope, and a cover letter explaining the purpose of the survey were sent to potential respondents. Of the 13,566 addresses, 1,811 usable responses were received by 15 July 2013. The survey response rate of 13.7% for the 14-state region was calculated as the number of usable responses divided by the number of farmers receiving the survey (13,237), which was the number of mailed questionnaires (13,566) minus those that were undeliverable (66) and those who had retired, were deceased, or did not grow cotton (263) (Zhou et al., 2015).

Producers were asked in which years from 2008 through 2012 they grew cotton and whether they used PFT for cotton production during those years. Second, they were asked whether they used GPSG, IG technologies, ASC, and VRA, and to list the years they began using those technologies. In addition, the questionnaire asked cotton farmers to check the primary reason (obstacle) for using (not using) PFT. Responses were analyzed using Stata (StataCorp, College Station, TX) and ArcView (Esri, Redlands, CA) to assess temporal and spatial trends of PFT adoption. The adoption level for each technology was obtained by dividing the number of respondents indicating using a specific technology by the number of usable responses.

The USDA farm production regions were used to divide the 14 states into five geographic regions: Northern and Southern Plains (Kansas, Texas, Oklahoma), Appalachian (Tennessee, North Carolina, Virginia), Southeast (Florida, Georgia, South Carolina, Alabama), Mississippi Delta (Louisiana, Arkansas, Mississippi), and Corn Belt (Missouri).

RESULTS AND DISCUSSION

Overall PF Adoption Level. The overall PF adoption level was 73.5% for the 14 states in this study. From 1,811 survey responses, 1,331 respondents used at least one or more PFT. Previous studies reported adoption levels of 62.7% for southern U.S. cotton producers in 2009 (Mooney et al., 2010), 47.7% in 2005 (Cochran et al., 2006), and 23% in 2001 (Roberts et al., 2002). Thus, the overall PF adoption level increased 2.1 times between 2001 and 2005 (Roberts et al., 2002), 1.3 times between 2005 and 2009 (Cochran et al., 2006), and 1.2 times between 2009 and 2012 (Mooney et al., 2010). Approximately 37% of respondents indicated profitability as the most important reason for adopting PFT. Approximately 1% and 3% (18 and 54 respondents, respectively) indicated environmental benefits and being at the forefront of new technologies as the most important reasons for adopting PFT, respectively. This result is consistent with previous studies that suggest farmers adopt PFT primarily to obtain economic benefits, specifically to decrease costs of production and/or increase yields (Adrian et al., 2005; Batte and Arnholt, 2003).

Adoption Level for Each PFT Category. Adoption level of the 1,811 respondents for each PFT category was 40.9% (740 respondents) for IG, 67% for GPSG (1,214 respondents), 25.3% (459 respondents) for VRA, and 29.3% (531 respondents) for ASC. Previous studies reported adoption levels of 35.4% for IG, 46.5% for GPSG, and 22% for VRA in 2009 (Mooney et al., 2010) and 38.9%, 65.1%, and 21.9%, respectively, in 2005 (Cochran et al., 2006). Thus, the adoption levels for IG, GPSG, and VRA in this study are slightly higher relative to those levels reported in the 2005 and 2009 studies. The top adoption IG technologies consisted of georeferenced grid soil sampling (22.3%), yield monitor with GPS (20.2%), soil survey maps (13.2%), georeferenced zone soil sampling (12.6%), aerial photos (11.8%), and handheld GPS/PDA (8.2%) (Table 1). By contrast, the estimated adoption level for yield monitors with GPS among cotton producers in the southern U.S. region in 2001 was 2.8% (Lambert et al., 2015; Larson et al., 2005; Roberts et al., 2002). This low GPS yield monitor adoption level can be explained by early problems in the development of yield monitors for cotton production. The introduction of on-board module builders on cotton harvesters bundled with yield monitor technology in 2007 increased subsequent adoption of this technology (Lambert et al., 2015; Reuters, 2008).

Table 1. Adoption numbers and levels for each specific information gathering technology and variable rate application input for the 2013 Southern Cotton Farm Survey

	Number of Respondent Users	Adoption Level^z (%)
Information gathering-overall users^y	**740**	**40.9**
Yield monitor-with GPS	366	20.2
Georeferenced soil sampling-grid	403	22.3
Georeferenced soil sampling-zone	228	12.6
Aerial photos	213	11.8
Satellite images	113	6.2
Soil survey maps	239	13.2
Handheld GPS/PDA	148	8.2
COTMAN plant mapping	32	1.8
Electrical conductivity	83	4.6
Digitized mapping	40	2.2
Variable rate application-overall users^y	**459**	**25.3**
Nitrogen	172	9.5
Phosphorous	322	17.8
Potassium	332	18.3
Lime	339	18.7
Seed	76	4.2
Growth Regulator	80	4.4
Harvest Aid	37	2.0
Fungicide	20	1.1
Insecticide	34	1.9
Herbicide	37	2.0
Irrigation	27	1.5
Other	4	0.2

^{z} Adoption level by category equals the number of respondent users for that category divided by 1,811 responses.

^{y} Overall users are respondents who used any one or more of the information gathering (IG)/variable rate application (VRA) technologies.

The VRA adoption level (25.3%) was similar to yield monitor with GPS (20.2%) and georeferenced grid soil sampling (22.3%) because VRA typically is implemented based on spatial yield monitoring or soil sampling data (Fountas et al., 2005). Thus, VRA needs to be bundled with yield monitor or soil sampling. Table 1 shows that 18.7% of respondents used VRA for lime application and 18.3% for potassium, with phosphorus (17.8%) close behind, followed by nitrogen (9.5%), growth regulator (4.4%), and seed (4.2%). Fountas et al. (2005) reported 71% of responding grain farmers to the survey conducted in the U.S. eastern Corn Belt used VRA for lime, 59% for fertilizer, and 12% for seed. The difference between adoption levels for cotton and grain farmers might be explained by the bundling of yield monitoring with VRA and that the development of cotton yield monitors lagged behind the introduction of grain yield monitors (Lambert et al., 2015; Larson et al., 2005; Watcharaanantapong et al., 2014).

Timing Trends of PF Adoption Levels. Overall PFT adoption trends for the 14 states are presented for IG, GPSG, VRA, and ASC categories in Fig. 3, and for the specific PFT within each category in Figs. 4, 5, and 6. Annual growth and cumulative adoption levels are illustrated from 2000 through 2012 because the survey was conducted in early 2013. Adoption growth levels for the current year are represented in green as “newly observed,” and cumulative adoption levels for the current year are illustrated with an orange border as the previous year’s cumulative adoption level (“previous cumulative”) plus the newly observed adoption level.

The cumulative adoption levels (across years) for IG, GPSG, VRA, ASC categories (Fig. 3) and the specific PFT within each category (Figs. 4, 5, 6) generally fit the S curve (Griliches, 1957). By 2012, the cumulative adoption levels reached 39.7% for IG, 41.9% for GPSG, 22.0% for VRA, and 26.9% for ASC (Fig. 3). The adoption curves were flatter in the early dissemination period for IG, GPSG, and VRA. This result is consistent with the learning-by-doing hypothesis. Adoption of innovation technology requires time for trial and error before new users master the technology (Arrow, 1962; Luh and Stefanou, 1993). Farmers who have a high capacity for learning new software and analytical skills can master PFT more quickly and adopt earlier than those who do not (Griffin et al., 2004). Those respondents who adopted later or who had not yet adopted likely perceived barriers to adopting these technologies. About 49.1% (890) of respondents perceived PFT as too expensive and about 17% (311 respondents) indicated benefits associated with these technologies were uncertain.

All attributes of the S-curve were described (including origin, slope, and inflection) except the ceiling due to our limited years of data. The origin represents the year when the technology adoption started to spread (Griliches, 1957). Conventionally it is defined as the year when the cumulative adoption level reached 10%, although there is no unique way to define the time of development (Griliches, 1957). Using conventional criteria as the origin threshold, IG reached the threshold in 2000 (14.2%), GPSG in 2006 (11.9%), VRA in 2009 (11.9%), and ASC in 2009 (10.3%). The threshold year was earlier for IG than the other PFT because georeferenced soil sampling became available to cotton producers in the early 1990s before the other technologies became available (Torbett et al., 2007; Watcharaanantapong et al., 2014).

The slope of the cumulative adoption curve (S curve) is the annual growth adoption level of new PFT users. It represents the increased adoption level from the previous to current year. The inflection point on the S-curve occurs in the year when the maximum annual adoption growth occurs (Dixon, 1980; Marsh et al., 2000). The maximum annual growth year occurred in 2008 (4.0%) for IG, 2010 for GPSG (6.8%), and 2010 for VRA (4.4%). The earlier maximum growth year for IG was primarily driven by georeferenced grid soil sampling with peak growth of 2.8 % in 2008 and somewhat by handheld GPS/PDA with 1% that year (Fig. 4). The maximum annual growth year for VRA occurred in 2010 because the peak growth occurred in that year for all inputs—nitrogen (2.0%), phosphorus (3.3%), potassium (3.8%), and lime (3.2%) (Fig. 5). Both VRA and georeferenced zone soil sampling had the same maximum growth year (2010) primarily because VRA implementation is bundled with information from zone soil sampling (Fountas et al., 2005). In 2010, ASC had maximum (7.2%) annual adoption growth for planters (3.2%) and sprayers (5.9%). ASC is characterized as a new or developing VRA system (Grisso et al., 2011). This study, however, defined ASC as a major category of PFT, consistent with some literature (Larson et al., 2016; Velandia et al., 2013).

Figure 3. Temporal adoption level of precision farming technologies (PFT) for the 2013 Southern Cotton Farm Survey. Adoption level by category equals the number of respondent users for that technology category divided by 1,811 responses. Previous cumulative adoption level refers to cumulative percentage of respondent users for that technology category before the current year. Newly observed adoption level refers to percentage of respondent users for that category for the current year.

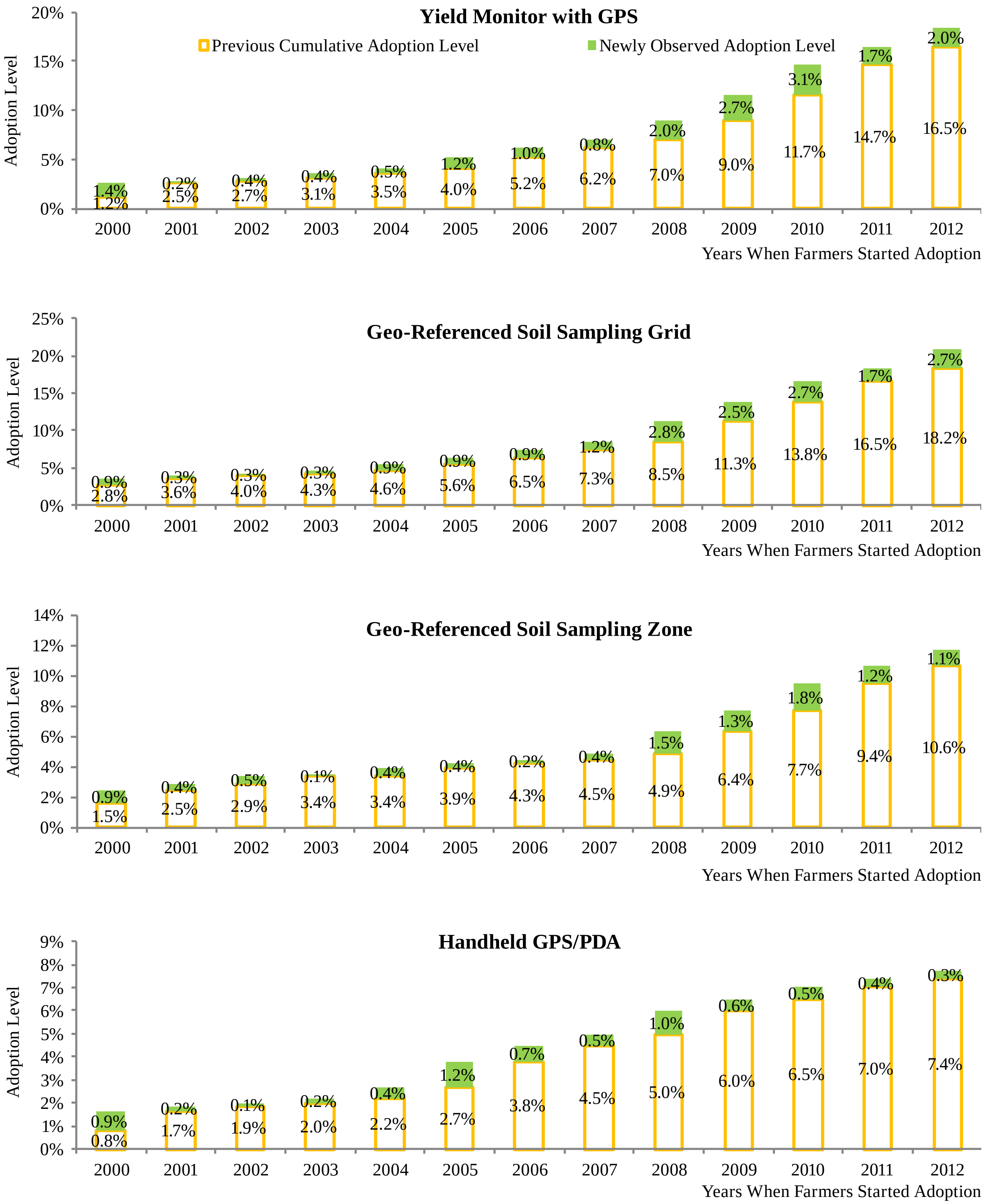

Figure 4. Adoption level of each specific information gathering (IG) technology for the 2013 Southern Cotton Farm Survey. Adoption level by category equals the number of respondent users for that technology category divided by 1,811 responses. Previous cumulative adoption level refers to cumulative percentage of respondent users for that technology category before the current year. Newly observed adoption level refers to percentage of respondent users for that category for the current year.

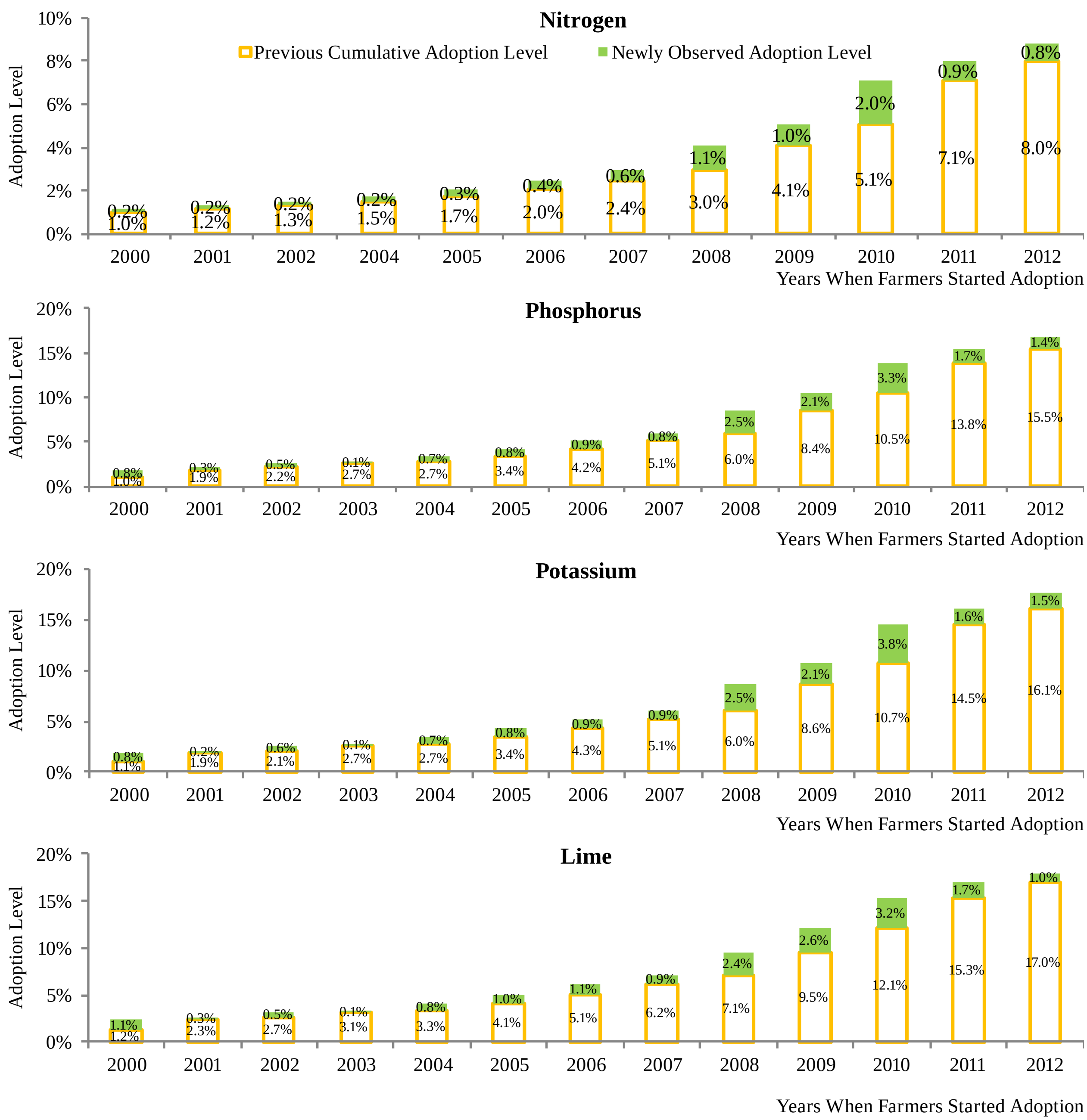

Figure 5. Adoption level of variable rate application (VRA) for each input for the 2013 Southern Cotton Farm Survey. Adoption level of each input equals the number of respondent users for that input used with VRA divided by 1,811 responses. Previous cumulative adoption level refers to cumulative percentage of respondent users for that input used with VRA before the current year. Newly observed adoption level refers to percentage of respondent users for that input used with VRA for the current year.

The maximum annual adoption growth is higher for GPSG (6.8%) than for VRA (4.4 %) or IG (4.0%). This can be explained by the following direct benefits to farmers that GPSG offers, compared with other PFT for information enrichment (Tey and Brindal, 2012). GPSG is used to locate positions for accurate application of input and harvest, reduction of overlaps, skips, and extended working time and fatigue, and an increase in machinery field capacity resulting in reduced costs (Shockley et al., 2010;Tey and Brindal, 2012). GPSG adoption is usually bundled with adoption of VRA or yield monitor (Schimmelfennig and Ebel, 2016). Schimmelfennig and Ebel (2016) found approximately half of farmers who reported adopting yield monitor also adopted GPSG and some of them adopted VRA as well. This PFT bundling also explains why the peak adoption growth year (2010) was the same for GPSG, VRA (Fig. 3), and yield monitor with GPS (Fig. 4).

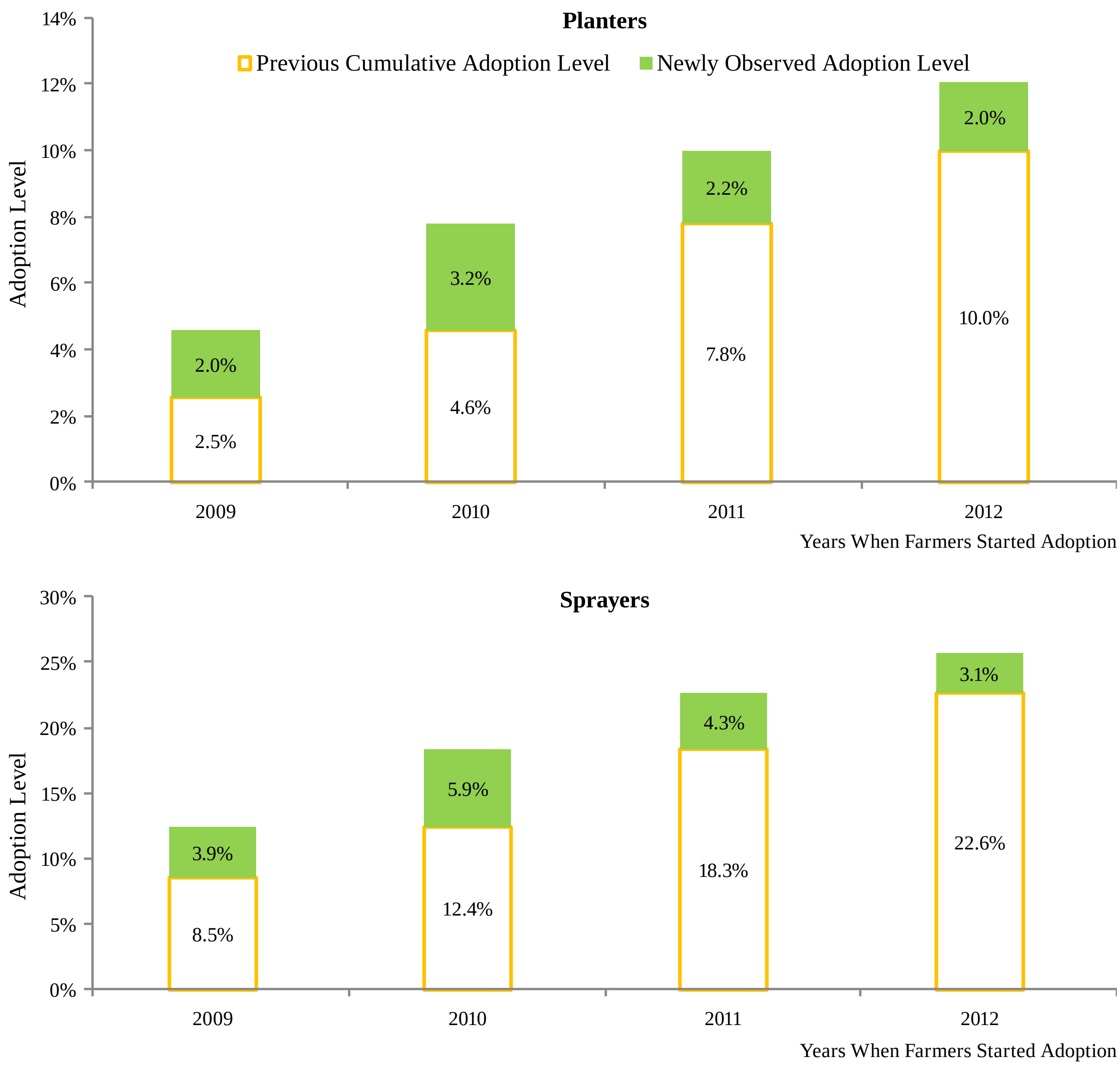

Figure 6. Adoption level of automatic section control (ASC) for planters and sprayers for the 2013 Southern Cotton Farm Survey. Adoption level by category equals the number of respondent users for that technology category divided by 1,811 responses. Previous cumulative adoption level refers to cumulative percentage of respondent users for that technology category before the current year. Newly observed adoption level refers to percentage of respondent users for that category for the current year.

Geographic Distributions of PF Adoption Levels. Adoption levels by USDA farm production region and state are presented in Table 2. Generally, of the 1,811 responding cotton farmers, the highest PFT adoption level occurred in the Corn Belt (91.7%), followed by the Mississippi Delta (80.7%) and the Northern and Southern Plains (75.4%). The lowest PFT adoption level was in the Southeast (65.2%). The numbers of reported PFT users were superimposed on the map of the surveyed counties to illustrate the spatial distribution of PFT use (Fig. 2). Counties where the most respondents reported using PFT (16-19 users) were in the Northern and Southern Plains and the Appalachian regions. In each farm region, a few counties had no cotton farmers reporting the use of PFT.

Table 2. Adoption numbers and levels of precision farming technology users by USDA farm production region and state for the 2013 Southern Cotton Farm Survey

	Number of Survey Responses	Precision Farming Technologies		Information Gathering		GPS Guidance		Variable Rate Application		Automatic Section Control	
		Number of Users[z]	Adoption Level[x] (%)	Number of Users	Adoption Level (%)	Number of Users	Adoption Level (%)	Number of Users	Adoption Level (%)	Number of Users	Adoption Level (%)
Corn Belt	48	44	91.7	27	56.3	42	87.5	24	50.0	16	33.3
MO	48	44	91.7	27	56.3	42	87.5	24	50.0	16	33.3
Mississippi Delta	228	184	80.7	129	56.6	163	71.5	97	42.5	67	29.4
AR	43	38	88.4	24	55.8	35	81.4	20	46.5	14	32.6
LA	72	61	84.7	47	65.3	57	79.2	33	45.8	18	25.0
MS	113	85	75.2	58	51.3	71	62.8	44	38.9	35	31.0
Northern & Southern Plains	659	497	75.4	186	28.2	467	70.9	59	9.0	166	25.2
KS	28	25	89.3	13	46.4	25	89.3	3	10.7	13	46.4
TX	598	448	74.9	162	27.1	418	69.9	50	8.4	141	23.6
OK	33	24	72.7	11	33.3	24	72.7	6	18.2	12	36.4
Appalachian	414	304	73.4	203	49.0	268	64.7	142	34.3	159	38.4
TN	117	96	82.1	67	57.3	89	76.1	57	48.7	61	52.1
NC	261	185	70.9	121	46.4	157	60.2	77	29.5	82	31.4
VA	36	23	63.9	15	41.7	22	61.1	8	22.2	16	44.4
Southeast	462	301	65.2	194	42.0	256	55.4	135	29.2	122	26.4
FL	28	24	85.7	16	57.1	19	67.9	13	46.4	5	17.9
GA	217	140	64.5	88	40.6	122	56.2	58	26.7	47	21.7
SC	88	57	64.8	41	46.6	48	54.5	35	39.8	27	30.7
AL	129	80	62.0	49	38.0	67	51.9	29	22.5	43	33.3
Overall	1,811	1,331	73	739	40.8	1,196	66.0	457	25.2	530	29.3

[z] Precision farming technology (PFT) users for the 2013 survey includes respondents who checked yes on whether they used PFT for cotton production, whether they used GPS guidance (GPSG), or whether they used variable rate applications (VRA), or respondents who indicated years or acres for which information gathering (IG) technologies or automatic section control (ASC) were used.

[y] Adoption level equals the number of respondent users divided by the number of survey responses in that state or farm production region.

Similar to the pattern of PFT adoption, GPSG had the highest adoption level in the Corn Belt (87.5%), followed by the Mississippi Delta (71.5%) and the Northern and Southern Plains (70.9%), with the lowest reported level (55.4%) in the Southeast. Of the four PFT categories, GPSG was the most widely adopted. This finding is consistent with previous studies that found GPSG usually bundled with IG, VRA, or ASC (Bakhtiari and Hematian, 2013; Schimmelfennig and Ebel, 2016). IG had the highest adoption level in the Mississippi Delta (56.6%), followed by the Corn Belt (56.3%) and the Appalachian region (49.0%). The highest VRA adoption level was reported in the Corn Belt (50.0%), followed by the Mississippi Delta (42.5%) and the Appalachian (34.3%) regions. The lower VRA adoption level, relative to IG and GPSG, resulted because VRA is bundled with yield monitor or soil sampling and not all farmers who use that latter technologies follow through with VRA. The highest ASC adoption level was found in the Appalachian region (38.4%), followed by the Corn Belt (33.3%) and the Mississippi Delta (29.4%) regions. The lower ASC adoption level, relative to GPSG and IG, was primarily due to later availability (2006 or 2007) (Fig. 3).

CONCLUSIONS

The objective of this study was to describe trends in the adoption of PFT by southern U.S. cotton producers and their geographic distribution. A mail survey of cotton producers was conducted in 2013 in 14 southern states to provide data on adoption of PFT including IG, GPSG, VRA, and ASC. The overall PFT adoption level was 73.5% for the 14 states. The adoption levels were 40.9% for IG, 67.0% for GPSG, 25.3% for VRA, and 29.3% for ASC. The VRA adoption level (25.3%) was similar to the level for yield monitor with GPS (20.2%) and georeferenced grid soil sampling (22.3%) because VRA uses information obtained from IG technologies, so the adoption of these technologies is bundled. The cumulative PF adoption levels across years generally fit the logistic function curve (Griliches, 1957) and were flatter in the early dissemination period for IG, GPSG, and VRA. The peak annual adoption growth level was 4.0% in 2008 for IG, 6.8% in 2010 for GPSG, 4.4% in 2010 VRA, and 7.2% in 2010 for ASC.

Geographically, cotton farmers in the Corn Belt had the highest PFT adoption level, followed by the Mississippi Delta and the Northern and Southern Plains regions. The lowest PFT adoption level was in the Southeast region. Of the four PFT categories, GPSG was the most widely adopted. It had the highest adoption level in the Corn Belt, followed by the Mississippi Delta and the Northern and Southern Plains regions. IG had the highest adoption level in the Mississippi Delta, followed by the Corn Belt and the Appalachian regions. The highest adoption levels were in the Corn Belt region for VRA and in the Appalachian region for ASC.

Information about PFT adoption trends is valuable to researchers, consultants, and farmers in learning how PFT was disseminated among southern cotton producers, helping them make more informed PFT adoption and production decisions. Geographic adoption patterns are valuable to farm input dealers or co-ops to help them target potential buyers of PFT equipment or services. Industry personnel and crop consultants could benefit from these findings, using them to develop effective outreach materials and provide more accurate information to help farmers develop more effective production strategies.

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