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2010 Ohio Farming Practices Survey:

Adoption and Use of Precision Farming Technology in Ohio

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Abstract
The study updates past observations of farmers' precision farming practices and their use of precision farming information in the state. Data on farming practices were collected to determine the level of adoption of precision farming technology in Ohio, to better understand farmers' use of precision farming information and data, and to assess farmers' perceptions of the costs and benefits of their precision farming system. Results identify opportunities for further advancement of precision farming technology and aid research and extension programs in meeting the educational and informational needs of famers using precision farming technology.

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Introduction

U.S. farmers have rapidly adopted precision farming technology since the first tools were introduced in the 1990s. Several studies have investigated the adoption trends of precision farming technology (see, for example, Daberkow and McBride 2003; Fountas et al. 2005; Griffin et al. 2004; Khanna 2001; Batte and Arnholt 2003; Woods-DeWitt 2008; Arnholt, Batte, and Prochaska 2001; Batte et al. 2003). The studies suggest that adoption of precision farming technologies is influenced by multiple factors including socioeconomic characteristics (Khanna 2001; Woods-DeWitt 2008), farming experience and education (Hite, Hudson, and Intarapapong 2002; Reichardt and Jürgens 2009; Reichardt et al. 2009; Kitchen et al. 2002; Batte and Arnholt 2003), profitability (Woods-DeWitt 2008; Lambert et al. 2004; Batte 2000), access to information (Daberkow and McBride 2003; Fountas et al. 2005), and attitudes and perceptions towards precision farming technology (Adrian, Norwood, and Mask 2005). Other factors influencing adoption decisions include the need for additional managerial abilities required to effectively use precision farming technologies for decision making. Because precision farming is intrinsically information and data intensive, the complexity of farmers' information management processes and the need for specific information management skills increases substantially (Nash et al. 2009; Steinberger, Rothmund, and Auernhammer 2009). Lack of information technology skills and limited access to advanced precision farming training and services therefore may restrict the effective use of precision farming technologies (Kitchen et al. 2002; Fountas et al. 2005; Reichardt et al. 2009).

We build upon this previous research by designing this study to:

(1) determine the current level of adoption of precision farming technologies of a representative sample of Ohio farmers,
(2) identify farmers' current use of precision farming information and data, and
(3) assess farmers' perceptions of the costs and benefits of their precision farming systems.

Data and methods

The analysis is based on a mail survey administered in winter 2010. Questionnaire design and administration followed best survey practices (Dillman, Smyth, and Christian 2009). The surveys were mailed to a randomly selected sample of 3,000 farmers in Ohio. An announcement letter explaining the purpose of the survey was mailed on February 11, 2010. The first survey package was mailed on February 16, 2010 which included a letter, questionnaire, and a pre-paid return envelope. About ten days later, a postcard was mailed to thank respondents for participation and remind non-respondents to fill out the survey. On March 11, 2010, a replacement package was mailed to all non-respondents containing cover letter, questionnaire, and a pre-paid return envelope. All respondents who returned a completed questionnaire were entered into a drawing of 30 gasoline cards valued at $10 each.

The addresses were purchased from a commercial vendor who compiled the list from multiple sources, including official farm payments lists. The sample was restricted to farmers generating more than $50,000 in annual gross farm sales and stratified across farm sales categories to guarantee sufficient representation of larger farms. Sample addresses were drawn from all 88 Ohio counties.

Of the 3,000 surveys mailed, six were undeliverable and returned by the U.S. postal service. Forty-six surveys were returned by respondents who no longer participate in farming activities. Seventy-two respondents reported gross farm sales of less than $50,000 and were excluded from further analysis. A total of 1,401 surveys were returned of which 1,163 had sufficient data to enter our analysis. The effective response rate was 40.4% (Table 1).

Table 1: Survey responses

Item	Number
# Surveys sent	3,000
# Surveys undeliverable	6
# Refusals	99
# Surveys sent to 'non-farmers'[a]	46
# Surveys incomplete and/or excluded	139
# Surveys completed	1,163
Effective response rate	40.4%

Note: [a] – Figure includes those that are no longer farming or are deceased

A weighting procedure based on farm sales categories was applied in the calculation of all statistics to return estimates to a sample representative of Ohio farmers. Table 2 lists the sample stratification and applied weight factors for each category. For example, a weight factor of 2.871 applied to the smallest categories of farms with sales between $50,000 and $99,999 implies that each sample observation in this category was counted as 2.871 farms to offset the fact that farms in this group were under-represented in the responses.

Table 2: Sample stratification and weights

	Gross Farm Sales Categories				
	$50,000 to $99,999	$100,000 to $449,999	$500,000 to $999,999	$1,000,000 or more	All farms
# Ohio farms[a]	5,565	8,957	1,997	1,090	17,609
# Surveys sent	776	1,500	724	–[b]	3,000
# Surveys completed	128	505	279	251	1,163
Sample weight	2.871	1.171	0.473	0.287	

Notes: [a] – Figures from the 2007 USDA Census of Agriculture (NASS 2009). [b] – 724 surveys were sent to farms with gross farm sales of $500,000 or more

Table 3 presents a summary of key demographic variables of the weighted sample and a comparison with the 2007 Census of Agriculture (NASS 2009) for the same sales categories ($50,000 and above). Although the sample averages display some deviation from the figures reported by the Census of Agriculture, none of these deviations are considered severe enough to warrant further weighing of the sample. The average size of the surveyed farms was 705 acres which was slightly lower than the

Ohio average of 806 acres. The average age of respondents was slightly higher compared to the Ohio average, 58.6 years on average versus 54.0 years reported by the Census of Agriculture. Compared to the state average, survey respondents featured a smaller percentage of younger farmers (aged less than 35) and female farmers. The percentage of farmers aged 65 and over was higher than the Ohio average. Survey respondents compared well with the average educational background of Ohio farmers. The survey featured about the same number of crops farmers and a slightly higher number of farms that raised livestock compared to the state average. A higher number of farms had internet access (76.9%) than the state average (70.0%). Reported incidences of farmers working off-farm (part- or full-time) was lower (31.1%) than the Census of Agriculture reports for the state (44.4%).

Table 3: Weighted sample and Ohio average by selected characteristics

Variable	Weighted Sample	2007 Ohio Average[a]
	Mean (Standard deviation)	*Mean*
Farm size (acres)	705.0 (732.28)	806.1
Age (years)	58.6 (11.48)	54.0
	Percent	*Percent*
Age less than 35	2.8	6.0
Age 65 and over	29.4	19.6
High School degree and some college	70.9	67.2[b]
College degree or more	26.2	24.5[b]
Female	2.0	3.1
Internet access	76.9	70.0
Grows crops	96.5	95.9[c]
Raises livestock	49.3	43.5[d]
Works off-farm	31.1	44.4

Notes: [a] – Figures from the 2007 USDA Census of Agriculture (NASS 2009). [b] – U.S. average, figure from 2007 USDA Economic Research Service Agricultural Resource Management Survey. [c] – Percent of Ohio farms with cropland. [d] – Percent of Ohio farms reporting sales of any animals or animal products

Results

Precision farming is not a single technology but rather a suite of technologies to be combined as a system. Decisions about the adoption of precision farming components reflect the individual needs of specific farms. In addition, the use of precision farming technology and information will be influenced by one's farm characteristic and farming experience, knowledge, preferences, and managerial needs. The following sections present descriptive statistics and summarize the familiarity of farmers with precision farming practices. The adoption and use of individual precision farming technologies are presented next. Finally, farmers' perceptions of the benefits and costs of precision farming technologies are presented.

Sample descriptive statistics

Selected key descriptive statistics of the surveyed farmers are presented in Table 4. The average farm size was 705 acres. The largest group of farmers, about half of the respondents (50.9%), reported farm sales between $100,000 and $499,999. With few exceptions, respondents reported to grow crops (96.5%) and about half (49.5%) also reported to raise livestock. The majority of respondents (63.6%) reported a debt-to-asset ratio of less than 20% for their farm business. About a third (31.1%) was working off-farm at least part time. Operator age averaged 58.6 years. The largest group, 50.6% of surveyed farmers, was between 51 and 64 years old. The majority of respondents (73.8%) had a high school degree or some college education and 26.2% had a college degree. Two percent of the surveyed farmers were females. Internet access was available to 76.9% of farmers, with high-speed internet available to 57.9%.

Table 4 also highlights differences between adopters and non-adopters of precision farming technology. About 38.7% of surveyed farmers have adopted at least one precision farming component while the majority (61.3%) had not adopted precision farming for their farm. The survey confirmed distinct differences between adopters and non-adopters. Farmers who adopted precision farming technology reported a larger farm size by acres (1,094 acres versus 456 acres of non-adopters) and higher farm sales, as indicated by a 33.6% share of farms with sales of $500,000 or more for adopters versus 7.4% for non-adopters. Adopters were also less likely to raise livestock (36.5% versus 57.7% of non-adopters). Among the adopters was a higher share of farmers age 50 years or younger (32.8% versus 16.4%) and a lower share of operators age 65 and older (17.2% versus 32.6%). Finally, adopters were more likely to report a college degree than non-adopters (32.7% versus 22.1%).

Table 4: Sample descriptive statistics

Item	All farms	Adopters[a]	Non-adopters
	Percent or Mean (Standard deviation)		
Full sample	100	38.7	61.3
Farm size (acres)	705.01 (732.277)	1,093.71 (916.020)	455.72 (428.542)
Gross farm sales			
$50,000-$99,000	31.6	14.7	42.3
$100,000-$499,999	50.9	51.7	50.3
$500,000-$999,999	11.3	20.0	5.9
$1,000,0000	6.2	13.6	1.5
Grows crops	96.5	99.0	94.9
Raises livestock	49.5	36.5	57.7
Debt-to-asset-ratio			
0-20%	63.6	58.1	67.1
21-40%	22.5	27.4	19.4
41-70%	11.9	12.7	11.4
71-100%	1.3	1.5	1.2
>100%	0.7	0.3	0.9
Work off-farm	31.1	30.7	31.3
Age	58.6 (11.49)	55.2 (11.37)	60.8 (11.03)
Less than 35	2.8	5.3	1.2
36-50	20.0	27.5	15.2
51-64	50.6	49.5	51
65 and over	26.6	17.2	32.6
Educational background			
High school or some college	73.8	67.1	77.9
College degree or more	26.2	32.7	22.1
Female	2.0	1.1	2.5
Internet access	76.9	71.2	80.2

Note: [a] – Adopters signify those farmers who have adopted at least one precision farming component technology.

Familiarity with precision farming practices

About 3.6% of the surveyed farmers reported to plan adopting precision farming within the next three years, while 23.5% had no plans to adopt (Table 5). About 34% of the surveyed farmers reported to be unfamiliar with precision farming technology. Farm size as measured by farm sales, age, education, and enterprise type were all found to influence famers' familiarity with precision faming. More than half of farmers reporting sales between $50,000 and $99,999 were unfamiliar with precision farming but less than ten percent of farmers reporting sales of $1,000,000 or more indicated that they were unfamiliar with precision faming. Likewise, adoption rates increased with farm sales, from 18.0% in the category of farms with sales of less than $100,000 to 84.7% for farms with sales of $1,000,000 or more. Of famers aged 35 and younger, 75.0% had adopted precision farming and only 9.4% reported to be unfamiliar with it. On the other hand, of famers age 65 and older, only about a quarter had adopted precision farming technology and almost half (47.9%) were unfamiliar with precision farming technology. Farmers with a college degree were more likely to be adopters (48.5% versus 35.4% for famers without a college degree) and less likely to be unfamiliar with precision farming (21.1% versus 38.6%). Finally, operators who also raised livestock were less likely to have adopted precision farming (28.5% versus 39.8%) and were more likely to be unfamiliar with precision farming (40.3% versus 33.2%) compared to operators who grew crops only.

Table 5: Familiarity with precision farming by selected farm business characteristics

	"How familiar are you with precision farming practices?"			
	Adopted	Plan to adopt within the next three years	Don't plan to adopt	Not familiar
	Percent			
All farms	38.8	3.6	23.5	34.1
Gross farm sales				
$50,000 to $99,999	18.0	1.6	27.2	53.1
$100,000 to $449,999	39.4	5.4	25.7	29.4
$500,000 to $999,999	68.2	3.0	13.6	15.2
$1,000,000 or more	84.7	1.4	4.2	9.7
Age of operator				
35 and under	75.0	0.0	15.6	9.4
36-50	53.7	3.9	17.7	24.7
51-64	38.2	4.3	25.3	32.2
65 and over	24.9	2.6	24.6	47.9
Education level of operator				
High School and some college	35.4	3.3	22.7	38.6
College degree and more	48.5	4.6	25.7	21.1
Grows crops	39.8	3.7	23.3	33.2
Raises livestock	28.5	4.0	27.1	40.3

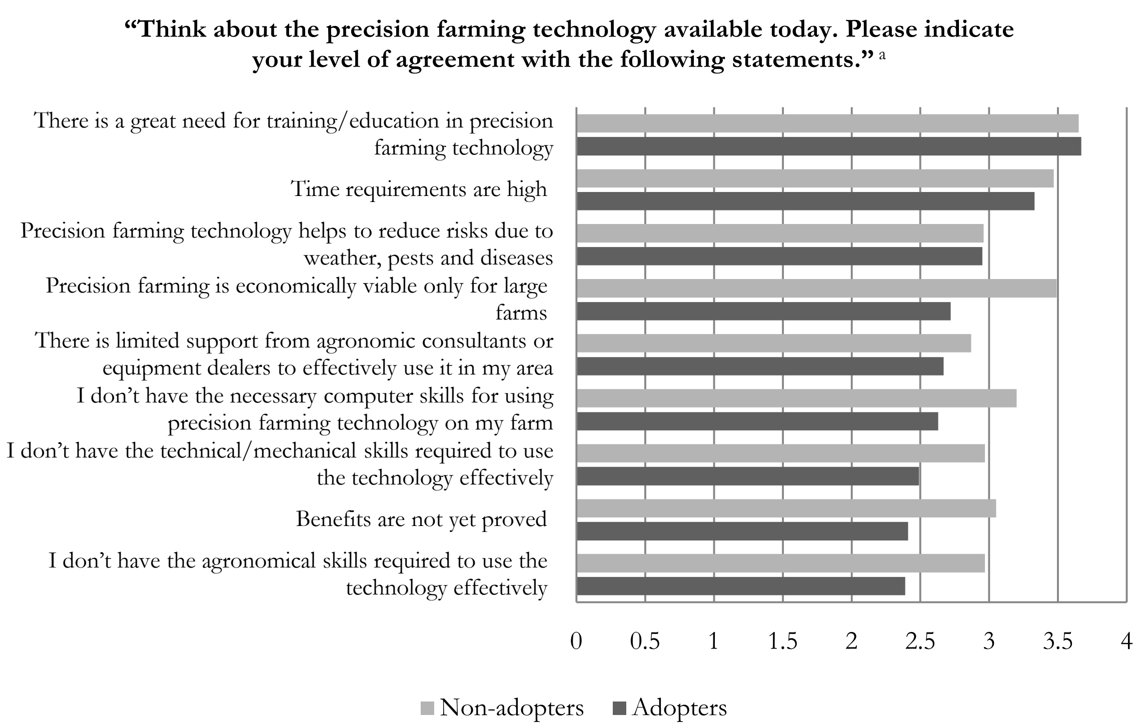
Note: [a] – Respondents were asked "How familiar are you with precision farming practices?" Possible answers were: "I am currently using precision farming technology on my farm", "I know about precision farming and I plan to adopt precision farming technology within the next three years", "I know about precision farming but I do not plan to adopt it in the next three years", and "I am not familiar with precision farming".

To further inquire about farmers' adoption decisions, the survey asked respondents additional questions including their perceptions of today's precision farming technology, preferred resources for precision farming information, and motivation for adoption of precision farming technology.

Perceptions of precision farming technology

About two-thirds of the surveyed farmers agreed or strongly agreed that there is a great need for training and education in precision farming and almost half agreed or strongly agreed that precision farming has high time requirements (Figure 1). Farmers also agreed or strongly agreed (30.2%) that precision farming technology helps to reduce risks due to weather, pests and diseases. Farmers' responses to these statements were fairly similar regardless of adoption status and didn't differ statistically. However, opinions on other statements were more distinctly based on adoption status. For example, non-adopters felt stronger than adopters that precision farming was economically viable only for large farms and that the benefits of precision farming are not yet proven. Non-adopters were more skeptical about their agronomical skills, technical/mechanical skills, and computer skills to implement and use precision farming effectively on their operation than adopters.

Figure 1: Respondents' perceptions of current precision farming technology

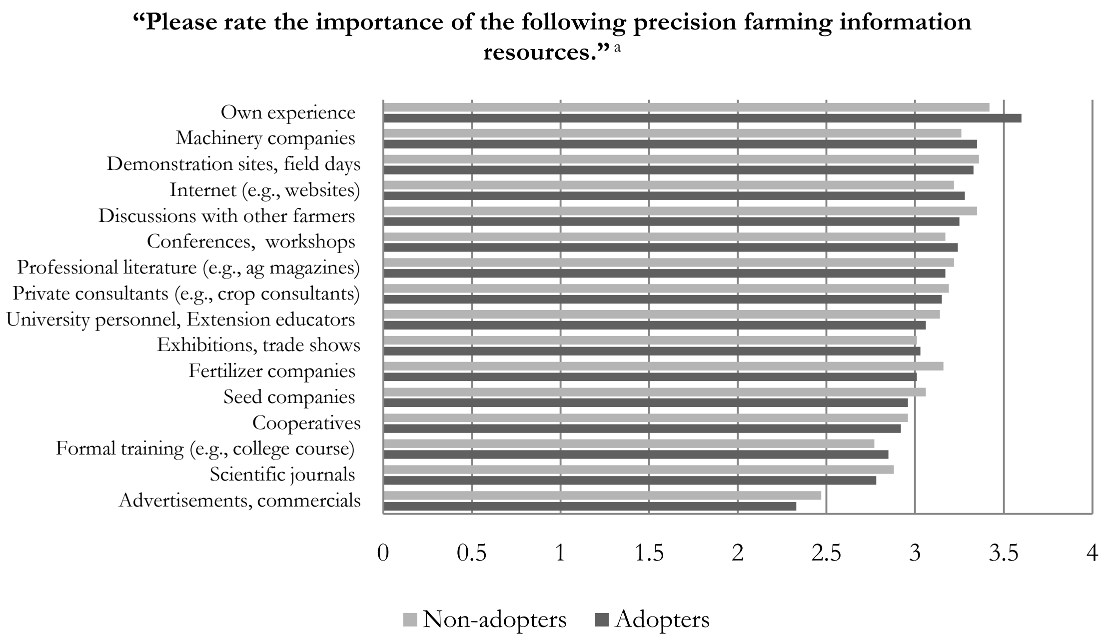


Note: [a] – Respondents were asked: "Think about the precision farming technology available today. Please indicate your level of agreement with the following statements." Items were measured on a five-point Likert scale, 1=strongly disagree, 2=disagree, 3=neutral, 4=agree, 5=strongly agree. Excludes respondents that reported to be unfamiliar with precision framing technology.

Sources for precision farming information

Asked about important information sources for precision farming technology, respondents' top five resources were their own experience, demonstrations sites and field days, equipment manufacturers, discussions with other farmers, and the internet (Figure 2). The least important information sources were seed companies, cooperatives, scientific journals, formal training, and advertisements. Differences in importance of information sources between adopters and non-adopters were statistically not significant.

Figure 2: Respondents' information resources for precision farming technology

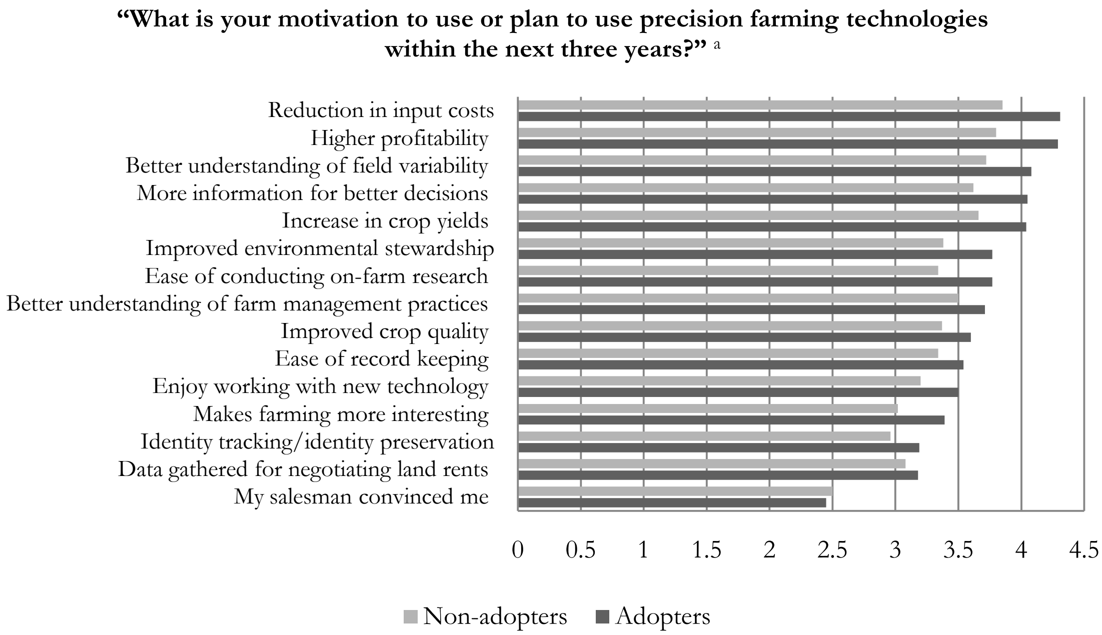


Note: [a] – Respondents were asked: "Please rate the importance of the following precision farming information resources." Items were measured on a four-point Likert scale, 1=not important, 2=somewhat unimportant, 3=somewhat important, 4=important. Excludes respondents that reported to be unfamiliar with precision framing technology.

Motivation for adoption of precision farming technology

The majority of respondents (87.3%) reported to agree or strongly agree that reducing input costs is the most important incentives to adopting precision farming technologies followed by increasing profitability (84.9% agree or strongly agree), and better understanding field variability (78.2% agree or strongly agree) (Figure 3). Other important motivators were the goal to increase crop yields (77.3% agree or strongly agree) and to gather better information for decision making (78.6% agree or strongly agree). Adopters gave most motivational statements higher evaluation marks than non-adopters. The differences were not always statistically significant.

Figure 3: Respondents' motivation for adopting precision farming technology



Note: [a] – Respondents were asked: "What is your motivation to use or plan to use precision farming technologies within the next three years?" Items were measured on a five-point Likert scale, 1=strongly disagree, 2=disagree, 3=neutral, 4=agree, 5=strongly agree. Excludes respondents that reported to be unfamiliar with precision framing technology.

Adoption and use of precision farming technology

Adoption rates for precision farming systems varied significantly based on selected individual precision farming components but also by farm and farmer characteristics. On average, respondents had 5.5 individual components adopted as part of their precision farming system (Table 6).

Table 6: Total number of precision farming components adopted

Number of components adopted	Percent
1	13.4
2	14.4
3	8.7
4	9.1
5	8.6
6	12.0
7	7.6
8	6.5
9	4.8
10	3.4
11	2.2
12 or more	9.4
Mean (Standard deviation)	5.5 (3.69)

Table 7 shows the adoption of precision farming components for the entire sample and by farmers grouped into farm sales categories. Precision farming technologies were adopted at a statistically significant higher rate by operators of larger farms compared to smaller farms.

GPS technology

The most basic precision farming technology, a portable or fixed mounted GPS device, was also the most frequently adopted precision farming technology with a 30.2% adoption rate. Compared to smaller farms, larger farms were exceeding the adoption rates of these devices by about eight times. 78.5% of farms with sales of $1,000,000 or more were using a GPS device compared to 10.2% of farms with farm sales between $50,000 and $99,999. Machine mounted devices were used by 94.4% of all adopters of GPS technology while portable devices were used by 12.3% of adopters (Table 8). Table 8 lists the most frequently reported manufacturers of GPS devices.

Precision guidance technology

The second most frequently adopted precision farming technology was precision guidance. This technology was adopted by 27.4% of respondents. Again, adoption rates varied substantially with farm size. While less than 10% of farms with sales between $50,000 and $99,999 were using this technology, adoption by farmers with sales of $1,000,000 or more was at 77.7%. The typical farmer reported having adopted precision guidance in 2005. Precision guidance utilizes a GPS system to provide manual steering assistance for a tractor, combine, or other implement by a lightbar system, to allow for assisted-steering, or to allow for automated steering. Farmers who adopted precision guidance reported to use this technology on almost 90% of their acreage. The most popular applications were spraying (85.0%), planting (59.2%), fertilizing (56.4%), tillage (39.6%) and harvesting (32.2%). Manual steering assisted by a lightbar was the most popular precision guidance technology reported by 65.1% of precision guidance adopters. 45.0% of adopters reported an assisted-steering system while 7.2% reported an auto-steering guidance system. The most popular manufacturers for these systems are listed in Table 9.

Yield monitor technology

Yield monitor technology was the third most popular precision farming technology. 25.3% of all surveyed farmers used a yield monitor. With 79.7%, the adoption rates by operators of large farms were exceeding the adoption rate of small farmers (7.0%) by about eleven times. The majority of adopters (64.7%) were using a yield monitor system linked to a GPS system. The typical farmer reported that they had adopted this technology in 2003 and were using it on 94.4% of all their acreage. Yield monitor data was most frequently used to observe during harvest (95.9% agreed or strongly agreed), to develop yield maps (63.5% agreed or strongly agreed), and to develop field management zones (34.7% agreed or strongly agreed). Table 10 lists the most popular manufacturers for yield monitor systems reported in the survey.

Geo-referenced soil mapping technology

Geo-referenced soil mapping was used by 22.7% of all farmers. Adoption rates range from 8.6% for small farmers to 55.8% for the largest farmers. Respondents reported that they adopted this technology most likely in 2004 and were using it on 71.2% of all acreage. The most common soil sampling technology was grid sampling. 75.3% of all adopters, or 17.8% of all farmers, used this technology. Zone sampling (i.e., sampling by management zones) was practiced by 19.3% of adopters, or 4.5% of all farmers. About 20.5% of adopters also reported to use soil conductivity surveying, e.g., Veris or EM38 field mapping, on their fields. Geo-referenced soil sampling data was most frequently used to develop soil fertility maps (88.8% agreed or strongly agreed), to support variable rate fertilizer applications (81.2% agreed or strongly agreed), and to develop field management zones (56.6% agreed or strongly agreed).

Variable rate application for fertilizer technology

The fifth most commonly adopted precision farming technology was variable rate application for fertilizer. Large farms were again leading the adoption, but the difference to smaller farms was less pronounced, exceeding adoption rates by about six times. Respondents reported that they had adopted this technology most likely in 2004 and were using it on 71.5% of all fields. Variable rate application was most popular for application of potassium (19.4%), lime (19.1%), and phosphorus (18.8%). Variable rate application for nitrogen was less popular with 5.7% of all farmers adopting. However, 35.6% of adopters of variable rate application technology reported that they were considering variable rate nitrogen applications within the next three years.

Other precision farming technologies

Boundary mapping was used by 15.6% of all farmers and aerial/satellite field imaging was adopted by 9.8% of all farmers.

Precision farming components that were adopted less frequently included variable rate application for seeds (9.0%), herbicides (8.0%), and pesticides (7.6%). Similarly, low adoption rates were reported for map-based field scouting for weeds (8.8%), insects (8.2%), and crop diseases (7.8%).

Emerging precision farming technologies

The survey also inquired about farmers' perceptions of several emerging precision farming technologies. The results are summarized in Table 11. 84.7% of respondents reported that technology for precision seed placement was somewhat important or important for their farm. Online sensors to guide variable rate application for nitrogen and other crop inputs were somewhat important or important for 78.7%. 73.6% of respondents also rated the development of precision farming technology designed specifically for smaller farms as somewhat important or important. 75.5% reported that the availability of more integrated software to better manage precision farming data were somewhat important or important.

Table 7: Adoption of precision farming components by farm sales category

Item	All farms	Gross farm sales: $50,000 to $99,999	$100,000 to $449,999	$500,000 to $999,999	$1,000,000 or more
			Percent		
GPS technology	30.2	10.2	30.5	58.1	78.5
Precision guidance	27.4	9.4	26.1	55.9	77.7
Yield monitor	25.3	7.0	22.6	59.1	79.7
Geo-referenced soil sampling	22.7	8.6	22.8	43.4	55.8
Variable rate application for fertilizer					
Potassium	19.4	8.6	18.6	36.9	49.0
Lime	19.1	7.8	18.0	38.0	50.6
Phosphorus	18.8	9.4	17.8	34.8	45.8
Nitrogen	5.7	3.1	5.1	10.4	15.1
Livestock manure	1.9	0.8	1.8	3.9	5.2
Boundary mapping	15.6	6.3	15.4	27.6	43.0
Aerial/satellite field imaging	9.8	4.7	9.5	19.4	20.7
Variable rate application for other farm inputs					
Seeds	9.0	4.7	8.3	15.4	25.5
Herbicides	8.0	4.7	7.9	13.6	15.9
Pesticides	7.6	3.9	7.7	12.9	15.1
Map-based field scouting					
Weeds	8.8	3.9	9.3	15.1	18.7
Insects	8.2	3.9	8.5	14.0	16.7
Crop diseases	7.8	3.9	7.9	14.0	15.5
Farmers adopting one or more of the above	38.7	18.0	39.4	68.2	84.7

Table 8: Adoption of GPS technology by type, use, and manufacturers

Item	*Percent (adopters only[a])*
Type	
Portable/handheld GPS	12.3 %
Machine mounted GPS	94.4%
Manufacturers	
All GPS (top 8)	
Trimble	28.8%
John Deere	25.1%
Ag Leader Technology	15.6%
Raven Precision	9.2%
Outback Guidance	7.1%
TeeJet Technologies	5.0%
Case IH Advanced Farming Systems	2.6%
Garmin	1.6%
Portable/handheld GPS (top 8)	
Trimble	19.1%
Ag Leader Technology	19.1%
John Deere	17.0%
Raven Precision	9.6%
TeeJet Technologies	5.3%
Garmin	5.3%
Farm Works	5.3%
Case IH Advanced Farming Systems	5.3%
Machine mounted GPS (top 8)	
Trimble	31.0%
John Deere	26.6%
Ag Leader Technology	16.1%
Raven Precision	8.2%
Outback Guidance	6.3%
TeeJet Technologies	3.8%
Case IH Advanced Farming Systems	3.5%
Garmin	1.3%

Note: [a] – Adopters signify those farmers who have adopted at least one precision farming component technology.

Table 9: Adoption of precision guidance technology by type, use, and manufacturers

Item	*Percent (adopters only[a])*
Type	
Manual steer assisted by a lightbar	65.1 %
Auto-steer without auto-turn	45.0%
Auto-steer and auto-turn	7.2%
Application	
Spraying	85.0%
Planting	59.2%
Fertilizing	56.4%
Tillage	39.6%
Harvesting	32.2%
Manufacturer	
Manual steer assisted by a lightbar (top 8)	
Trimble	33.8%
Raven Precision	16.6%
Outback Guidance	14.0%
Ag Leader Technology	12.1%
TeeJet Technologies	12.1%
John Deere	7.0%
Case IH Advanced Farming Systems	2.5%
Farm Works	1.3%
Steer assisted guidance (top 6)	
John Deere	48.2%
Trimble	30.9%
Ag Leader Technology	10.1%
Raven Precision	5.0%
Outback Guidance	3.6%
Case IH Advanced Farming Systems	1.4%
Automated guidance (top 4)	
John Deere	75.0%
Trimble	10.0%
Case IH Advanced Farming Systems	5.0%
Raven Precision	5.0%

Note: [a] – Adopters signify those farmers who have adopted at least one precision farming component technology.

Table 10: Adoption of yield monitor data by manufacturers

Manufacturers (top 5)	*Percent (adopters only[a])*
John Deere	48.0%
Ag Leader Technology	28.3%
Case IH Advanced Farming Systems	15.7%
AGCO Advanced Technology Solutions	3.5%
Trimble	3.1%

Note: [a] – Adopters signify those farmers who have adopted at least one precision farming component technology.

Table 11: Importance of emerging precision farming technologies and practices

Item	*Mean (Standard deviation)*
Technology for precision placement of seeds	3.23 (0.823)
Online sensors on machinery that automatically detect and apply nitrogen and other crop inputs at a variable rate	3.01 (0.840)
Precision farming technology designed specifically for smaller farms	2.96 (0.852)
More integrated software to better manage precision farming data	2.90 (0.864)
Precision guidance technology for implements	2.68 (0.908)
Ultra-precise tillage technology	2.55 (0.880)
Nano-sensor implants in fields that help detect, report and apply water, fertilizer and pesticides (i.e., "Smart Fields")	2.39 (0.925)
Tracking technology to improve grazing livestock distribution (e.g., ID tags for cattle)	1.96 (0.930)
Robot-controlled machinery	1.74 (0.828)

Note: Respondents were asked: "Think about future precision technology for your farm. Please rate the importance of the following emerging technologies." Items were measured on a four-point Likert scale, 1=not important, 2=somewhat unimportant, 3=somewhat important, 4=important.

Benefits and costs of precision farming technology

Benefits and costs of the overall precision farming system

Respondents were asked "for your farm situation, are the total benefits of the entire precision farming system greater than the total costs of this system?" The intention of this question was to evaluate the usefulness of the entire adopted precision farming system. Our assumption was that the profitability of individual precision farming components varies from farm to farm, depending on individual needs and managerial strengths. Also, some components are more likely to be adopted in sets to take full advantage of the benefits of those technologies. These factors are likely to impact the reported evaluation scores. Table 12 summarizes the responses for the overall precision farming system for all respondents and for respondents categorized by farm sales category, age, education level, and enterprise type.

The average evaluation score was 2.09 indicating that for the average operator evaluation, benefits of the adopted precision farming system exceeded costs. 28.0% of adopters reported that the benefits of their precision farming system were significantly greater than costs while 47.7% suggested that benefits were slightly greater than costs. Only 8.6% of farmers felt that costs were slightly or significantly greater than benefits. Operators of larger farms tended to report more positive evaluations scores than operators of smaller farms. For example, 85.9% of farmers with sales of $1,000,000 and more suggested that benefits were significantly or slightly greater than costs versus 75.0% for farmers with sales between $50,000 and $99,999. Differences were statistically not significant. Similarly, differences for responses categorized by operators' age, education level, and enterprise type were statistically not different.

Table 12: Benefits and costs of the entire precision farming system

	"For your farm situation, are the total benefits of the entire precision farming system greater than the total costs of this system?"					
	Benefits significantly greater (1)	Benefits slightly greater (2)	About equal (3)	Costs slightly greater (4)	Costs significantly greater (5)	
	Percent					*Mean*
All adopters	28.0	47.7	15.7	4.6	4.0	2.09
Gross farm sales						
$50,000 to $99,999	20.0	55.0	20.0	5.0	0.0	2.10
$100,000 to $449,999	22.6	47.4	18.9	4.7	6.3	2.25
$500,000 to $999,999	35.3	48.4	9.8	3.8	2.7	1.90
$1,000,000 or more	45.4	40.5	8.3	4.9	1.0	1.78
Age of operator						
35 and under	31.9	65.5	2.6	0.0	0.0	1.71
36-50	25.2	50.9	14.5	3.1	6.3	2.15
51-64	31.2	43.2	16.6	4.8	4.3	2.08
65 and over	21.3	50.9	20.2	7.2	0.4	2.15
Education level of operator						
High School and some college	27.0	46.8	18.2	4.5	3.5	2.11
College degree and more	29.3	49.8	11.1	4.9	4.9	2.06
Grows crops	28.1	47.3	16.0	4.6	4.0	2.09
Raises livestock	30.5	47.6	12.5	6.5	2.9	2.04

Note: Items were measured on a five-point Likert scale, 1= benefits are significantly greater than costs, 2= benefits are slightly greater than costs, 3= benefits and costs about equal, 4= costs are slightly greater than benefits, 5=costs are significantly greater than benefits.

Benefits and costs of individual precision farming components

Respondents were also prompted to indicate the perceived value of each precision farming component by asking "Overall, how would you rate the costs versus benefits of this technology?" Summary results of the benefits and costs of individual precision farming components are presented in Table 13. Variable rate application for fertilizer technology, adopted by about 20% of farmers, received the most positive evaluation with a score of 1.63. For the average farmer this is the most profitable individual precision farming component. 53.8% of respondents suggested that the benefits of variable rate application for fertilizer were significantly greater than costs, while 35.7% suggested that benefits were slightly greater. Only 4.5% of surveyed farmers felt that costs were greater than benefits for this technology. Geo-referenced soil sampling technology ranked second in positive evaluations with a mean evaluation score of 1.72. Adopted by 22.7% of farmers, respondents suggested that the benefits of geo-referenced soil sampling were significantly or slightly greater than costs for 51.1% and 34.9%, respectively. Precision guidance technology, adopted by 27.4% of respondents, ranked third with 40.7% of farmers suggesting that benefits were exceeding costs significantly. 34.5% reported that benefits were slightly greater than costs. The mean evaluation score for this technology was 1.87. Yield monitor technology ranked forth with 69.6% of respondents indicating that the benefits of this technology were exceeding costs. The mean evaluation score was 2.12. Map-based field scouting technologies and variable rate technologies for other crop inputs were ranked fifth and sixth. The average evaluation score for these technologies was 3.15 and 3.17, respectively, indicating that the average farmer felt that benefits and costs of these technologies were about equal. Note that these technologies were adopted by less than ten percent of respondents. Boundary mapping technology and aerial/satellite field imaging technology were ranked the least profitable precision farming technologies with mean scores of 3.26 and 3.35. These scores indicate that the average respondents felt that benefits and costs were about equal. Overall, the results suggest that for the average operator, any of these individual technologies were profitable or at least neutral in their benefits and costs.

Table 13: Benefits and costs of individual precision farming components

		"Overall, how would you rate the costs versus benefits of this technology?"					
	Adopted (all farms)	Benefits significantly greater (1)	Benefits slightly greater (2)	About equal (3)	Costs slightly greater (4)	Costs significantly greater (5)	
				Percent			*Mean*
VRT for fertilizer	19.9	53.8	35.7	6.0	2.4	2.1	1.63
Geo-referenced soil sampling	22.7	51.1	34.9	8.5	1.9	3.6	1.72
Precision guidance	27.4	40.7	39.5	13.2	5.0	1.5	1.87
Yield monitor	25.3	32.5	37.1	19.9	7.0	3.6	2.12
Map-based field scouting							
Weeds	8.8	2.6	12.8	51.4	28.4	4.8	3.20
Insects	8.2	3.3	13.9	50.8	27.5	4.4	3.16
Crop diseases	7.8	3.2	14.8	57.2	19.3	5.5	3.09
VRT for other crop inputs							
Seeds	9.0	4.2	9.1	46.8	34.0	5.8	3.28
Herbicides	8.0	3.1	14.4	51.4	24.9	6.2	3.17
Pesticides	7.6	2.9	14.8	58.4	19.6	4.2	3.07
Aerial/satellite field imaging	9.8	3.7	11.7	45.9	32.3	6.4	3.26
Boundary mapping	15.6	2.6	8.6	47.4	33.6	7.8	3.35

Note: Items were measured on a five-point Likert scale, 1= benefits are significantly greater than costs, 2= benefits are slightly greater than costs, 3= benefits and costs about equal, 4= costs are slightly greater than benefits, 5=costs are significantly greater than benefits.

Conclusion

This analysis of a recently collected representative sample of Ohio farmers provides an update of the most recent trends in the adoption of precision farming technology in the state. The study suggests that about 38.7% of all surveyed farmers have adopted at least one precision farming component and 3.6% plan to adopt precision farming technology within the next three years. Almost a quarter of farmers reported that they don't have plans to adopt precision farming within the next three years. 34.1% of respondents reported that they are not familiar at all with precision farming suggesting a need for more extensive educational and informational programming in the state. The survey confirmed distinct differences between adopters and non-adopters. In particular, operators of larger farms were shown to adopt precision farming technology at much higher rates than operators of smaller farms, confirming a trend identified in earlier studies. The most important individual precision farming components for producers in Ohio were GPS technology, precision guidance, and yield monitor technology. In the average producer evaluation, benefits of the adopted precision farming system were exceeding costs suggesting that precision farming was considered profitable by the average adopter.

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