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Adoption and Use of Precision Farming Technologies: Results of a 2003 Survey of Ohio Farmers

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Abstract/Description:
This report is based on a survey of a random sample of Ohio farmers conducted in March 2003. The objectives were to understand the adoption and use of precision farming and other production technologies. Comparison of 1999 and 2003 surveys suggest that adoption of precision farming components is progressing, but at a slow to moderate pace. About 32 percent of farmers have adopted one or more precision farming components. The average adopter makes use of 4.2 precision farming components. Larger farmers have adopted more rapidly, and are using a larger number of the PF components. Most farmers evaluate both individual PF components and the entire PF system positively.

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Precision farming technologies (PF) are increasingly important on Ohio farms. Although adoption is still at low levels for many precision farming technology components, precision farming service businesses continue to expand the range of services they offer. As farmers and their agribusiness partners expand their use of and skill with this technology, there will undoubtedly be an impact on agricultural productivity. Precision farming technologies are unique in that the impact on farm production and profitability results largely by providing data and information to assist farmers to make site-specific management decisions regarding fertilization, crop protection, drainage, variety selection and other inputs. By making more informed management decisions, farmers can perhaps increase yields, become more efficient and thereby lower costs, or make better machinery management decisions.

The research results reported here are based on statistical analysis of a survey mailed to a random sample of 2,500 Ohio farmers in March and April of 2003. The purpose of this survey research is to understand what PF system components Ohio farmers have adopted, how farmers use their PF system, the costs and benefits of the PF system, and management changes that have resulted from PF system adoption.

The Response rate for the sample was about 50 percent. There were about 1,000 respondents who were actively farming and who completed the survey. Gross sales for the sampled farmers averaged $179, 472 (table 1). This compares to the 1997 Census of Agriculture average for Ohio of $220,986, also computed for farms greater than $40,000 of sales. About 20 percent the sample had sales of $250,000 or more (versus 21.4% for the census). Operator age averaged 54.7 years (census average was 50.4 years); about 3.5 percent of the respondents were under 35 years of age, and 18 percent were over 65. The majority of farm operators had a high school degree; 13 percent had less than a high school education, and 37 percent had some college education or a college degree (9.6 percent had postgraduate education or degree). Finally, about 57 percent of the farmers worked full time on the farm (52% for the census), about 34 percent worked off farm year-around, and just over 9 percent worked seasonally off the farm.

Precision Farming Adoption

Precision farming (PF) is not a single technology, but rather is a suite of technologies that can be combined as a system. The farmer will choose those technology components that provide for the needs of the specific farm. Therefore, the precision farming systems employed by farmers may differ significantly. Likewise, the uses made of the PF system will vary with manager knowledge, preferences, and needs. Table 2 reports the adoption of various PF components by the sampled farmers. It also provides a comparison to adoption percentages reported in 1999 by a random sample of farmers.

The most frequently adopted PF practice was georeferenced grid soil sampling. More than 15 percent had adopted grid soil sampling in 2003, up from 8 percent in 1999. Such intensive soil sampling typically is used as the basis for variable rate (VRT) fertilizer applications. The next most frequently adopted PF practices, both in 2003 and 1999, were variable rate applications of lime and fertilizers. Fourteen percent of the farmers surveyed report VRT application of lime and phosphorus fertilizer, and more than 13 percent reported VRT of potassium fertilizer. Nitrogen fertilizers are less frequently applied at variable rate (7.7%), in part because the optimal rate of this nutrient is more a function of weather, planting date, and commodity price than is true for P, K and lime.

The adoption of combine yield monitors now stands at nearly 12 percent adoption, up from 6 percent in 1999. The combine yield monitor allows estimates to be made of harvested yield every few seconds as the combine moves across the field. A related technology, often adopted with the yield monitor, is the global positioning system. In 2003, about 7.6 percent of the farmers reported adoption of a global positioning system, up more than 5 percentage points since 1999.

Precision guidance is another noteworthy precision farming technology. Precision guidance uses a GPS system to provide information about the exact position of a tractor or combine so that navigation of that implement can either be assisted (e.g., a lightbar system that instructs the driver how to steer) or steering of the tractor is automated based on a predefined map (auto pilot systems). Such technologies can allow more precise application of seed, fertilizers, agrichemicals and other inputs, especially in conditions of poor visibility (e.g., night-time applications). Precision guidance was essentially unavailable in 1999, but now has been adopted by 5.2 percent of the reporting farmers.

It is also instructive to note the PF components that have been adopted least frequently. Variable rate application (and GPS or sensor-directed spot spraying) of herbicides and pesticides has been adopted relatively infrequently, and have had very low increases from their 1999 levels. This is likely due to two reasons. In the case of herbicides, the introduction of Round-up Ready® crops may have taken away the incentive to variably apply other weed control chemicals. Secondly, the state of knowledge of how to determine appropriate rates of herbicide and pesticide for variable application lags behind similar decision rules for fertilizer nutrients. Clearly, georeferenced scouting for weeds and pests might be a basis for such decisions. Scientists are also working on decision rules that relate herbicide application rates to soil types, organic matter levels, and other predictors of the most appropriate level of herbicide application. However, few PF service providers are offering this service currently.

The last row in table 2 shows the percentage of farmers who have adopted one or more precision farming components. In 2003, about 32 percent had adopted at least one component. This compares to 23.6 percent who had adopted at least one component in 1999. Twenty-five percent of adopting farmers had adopted only a single PF component (Table 3). About half of the adopting farmers were using 4 or more PF components. The average number of components adopted was 4.14.

Adoption rates for precision farming components varied significantly by several farm and farmer characteristics. Table 4 shows adoption rates for the 19 precision farming component technologies by farmers grouped into four sales class sizes. For most technologies there is a strong tendency for larger farms to adopt at a higher rate than smaller farms. For variable rate application of P, K and Lime, which usually is priced on a per acre basis, adoption rates are just over twice as large for the largest farms relative to the smallest sales group. However, for technologies such as yield monitor, GPS receiver, and precision guidance where a fixed investment is required, adoption is 10 to 15 times greater for the largest than for the smallest farms. There are some PF components that appear to be adopted at a higher rate for smaller than for larger farms. These include technologies of questionable economic value, particularly variable rate application of herbicides, pesticides and nitrogen fertilizers.

A similar pattern can be observed with operator education level (Table 5). Farmers with more formal education tend to adopt precision farming technologies at a higher rate. This is particularly true with components such as the yield monitor, GPS receiver, and precision guidance, all of which approach or exceed twice the adoption of lesser educated by more educated farmers. Likewise, adoption varies with age of the primary operator (Table 6). In this case, younger operators tend to adopt PF components at higher rates. Finally, level of adoption varies with operator off-farm employment (Table 7). Farmers who work full-time on the farm tend to adopt in PF at higher rates than those who work at full-time jobs away from the farm. However, those who work seasonally away from the farm have the highest rate of adopting at least one precision farming component.

Relative Benefits and Costs by PF Component

Farmers were also asked to indicate the value of each precision farming component. The relative benefits and costs associated with the use of each PF component are evaluated in Table 8. Farmers were asked to respond to the statement, "On my farm the benefits of (named PF component) clearly exceed its costs". The scale used was -2 (strongly disagree) to +2 (strongly agree). A higher mean response indicates greater net benefits; A mean response greater than zero suggests an average evaluation where benefits exceeding costs. Variable rate application of lime received the highest average net benefit ranking (0.88), suggesting that this is the most profitable single PF component. Variable rate seeding ranked second. Even though it has been adopted by only a small percentage of farmers (4.2%), those using this technology gave it high marks. VRT of phosphorus and potassium fertilizers ranked 3rd and 4th, followed by precision guidance. The yield monitor ranked ninth, with a mean of 0.64. Interestingly, all of the components had mean scores greater than zero, suggesting that the average user of this component felt that benefits exceeded costs.

Precision farming has often been called site-specific management. This recognizes the fact that precision farming typically creates value by allowing the farmer to manage individual parts of the field differently. However, it also suggests that the precision farming components that are profitable also will vary from farm to farm, depending on that particular farmer's needs and managerial strengths. It is also apparent that some PF components should be adopted in sets. For instance, the potential of the yield monitor cannot be fully captured unless the combine also is equipped with a global positioning system (GPS). Addition of GPS means that yield numbers can be georeferenced, stored in a geographical information system, and, later, yield maps and other forms of spatial analysis can be done. Hence, the GPS-yield monitor combination is necessary to derive the full information value from the yield monitor. In this research, we found that farmer evaluation of the precision farming system was greater when yield monitor and GPS were adopted in tandem. In 2003, about 11.6 percent of the farmers reported adoption of a yield monitor, but only 5.5 percent had adopted both GPS and yield monitor (Table 9). That is, less than half of the combines with yield monitor also have GPS capabilities. This is even more dramatic when one considers this by farm size (Table 9). For farms with less than $250,000 of annual sales, 6.4% have adopted a yield monitor, but less than one third of these have GPS as well. More than half of the combines with yield monitors on the largest farms have GPS, and thus have access to a greater ability to analyze the determinants of yield variability. In the lower panel of Table 9 are the average usefulness scores (as calculated in Table 8), but reported for yield monitors with and without joint adoption of GPS. The average evaluation score is significantly greater for those farmers with both yield monitor and GPS.

Benefits and Costs of Overall PF System

Farmers were asked "for your farm situation, are the total benefits of the complete precision farming system greater than the total costs of this system?" This question is intended to evaluate the usefulness of the entire precision farming system adopted by that farmer, perhaps including several of the components identified in previous tables. Table 10 summarizes the responses for the full sample and for farmers categorized by farm size, education level, age, and other factors. The scale of -2 to +2 was used to calculate average response, where -2 is "No, Costs are significantly greater than Benefits" and +2 is "Yes, Benefits are significantly greater than Costs". The average response for the sample is 0.41, indicating that for the average producer evaluation, benefits exceeded costs. Fifty-four percent of the sample suggested that benefits were greater than costs, and less than 21 percent felt costs exceeded benefits.

The bottom of table 10 provides results for evaluation of the overall PF system by farm size, education level and operator age. Although there is some suggestion that evaluation scores differ with farm and farmer characteristics, the differences in the mean evaluation scores were not statistically different at the 0.10 probability level.

Table 1. Sample descriptive statistics for selected farm characteristics.

Measure		Mean	Std. Dev.
Farm Size (acres)		499.8	577.7
Gross Sales ($)		179,472	219,048
Farms by Gross Sales Class ($)		Percent	
	$50,000 - 99,999	44.6	
	100,000 - 249,999	35.0	
	250,000 - 499,999	14.8	
	Over $500,000	5.5	
Operator Age (years)		54.7	11.7
Farms by Operator Age Class (yrs)		Percent	
	Less than 35	3.5	
	36-50	36.9	
	51-65	41.7	
	66 and over	17.9	
Operators by Formal Education level		Percent	
	Less than High School	13.0	
	High School Graduate	50.8	
	Some College	14.0	
	College Graduate	12.6	
	Post Graduate Education or Degree	9.6	
Farms by Percent of Land Controlled by Lease		Percent	
	0-25%	41.37	
	26-50%	16.79	
	51-75%	18.35	
	76-100%	23.5	
Operators Working off the Farm		Percent	
	None	56.8	
	Seasonally	9.4	
	Year Around	33.8	

Table 2. Percent of Ohio farmers who had adopted various precision farming components in March 1999 and 2003.

	Percent adopting	
	2003	1999
Georeferenced (i.e., map-based or location specific) grid soil sampling	15.3	8.1
Variable Rate Application of Phosphorus	14.1	7.3
Variable Rate (i.e., rate varied across field) Application of Lime	14.0	6.7
Variable Rate Application of Potassium	13.4	7.3
Yield Monitor	11.6	6.0
Boundary Mapping	9.8	4.3
Variable Rate Application of Nitrogen	7.7	6.3
Satellite GPS receiver	7.6	2.2
Georeferenced field scouting for weeds	6.0	2.3
Variable Rate Application of Herbicides	5.3	5.7
Precision Guidance (light-bar navigation or auto pilot system)	5.2	
Aerial or Satellite Field Photography	5.2	2.7
Georeferenced field scouting for insects, pests, or disease	4.9	2.0
Variable Rate Seeding	4.2	3.4
Variable Rate Application of other Nutrients	4.1	3.9
GPS or Sensor-Directed Spot Spraying of Herbicides	3.0	1.3
Variable Rate Application of Pesticides	2.8	2.9
GPS or Sensor-Directed Spot Spraying of Pesticides	0.9	
Percent who have adopted one or more of above	31.8	23.6

Table 3. Number of Precision Farming components adopted by precision farming adopters.

Number of components adopted	Percent
1	25.2
2	13.0
3	12.6
4	11.0
5	9.8
6	7.3
7	6.1
8	5.3
9 or more	9.8
Mean number of PF components adopted	4.14

Table 4. Percent of Ohio farmers who had adopted various precision farming components by farm sales class.

	Gross Farm Sales ($)			
Measure	$50,000 - 99,999	100,000 - 249,999	250,000 - 499,999	Over $500,000
	Adoption Percent			
Georeferenced soil sampling	9.49	15.38	21.93	37.78
Variable Rate Application of Phosphorus	12.97	11.15	17.24	28.89
Variable Rate Application of Lime	11.39	12.21	18.97	31.11
Variable Rate Application of Potassium	12.30	10.69	16.67	26.67
Yield Monitor	3.76	9.51	24.35	41.30
Boundary Mapping	5.00	9.58	16.38	25.58
Variable Rate Application of Nitrogen	9.87	5.75	6.09	8.89
Satellite GPS receiver	2.51	4.55	13.91	42.22
Georeferenced field scouting for weeds	7.28	4.20	4.35	14.29
Variable Rate Application of Herbicides	7.37	3.07	5.22	4.44
Precision Guidance	2.51	3.42	7.96	25.00
Aerial or Satellite Field Photography	4.06	5.30	6.19	9.09
Georeferenced field scouting for insects, pests, or disease	5.35	3.14	6.42	9.30
Variable Rate Seeding	5.71	2.65	4.39	4.44
Variable Rate Application of other Nutrients	4.43	2.68	4.42	8.89
GPS or Sensor-Directed Spot Spraying of Herbicides	4.43	1.52	3.51	2.22
Variable Rate Application of Pesticides	3.83	2.29	2.68	0.00
GPS or Sensor-Directed Spot Spraying of Pesticides	1.25	0.38	1.74	0.00
Percent who have adopted one or more of above	25.58	28.68	47.01	58.70

Table 5. Percent of Ohio farmers who had adopted various precision farming components by operator education level.

	Operators by Formal Education level	
Measure	High School or Less	Post High School
	Adoption Percent	
Georeferenced soil sampling	12.47	20.44
Variable Rate Application of Phosphorus	13.89	14.60
Variable Rate Application of Lime	13.01	16.00
Variable Rate Application of Potassium	13.62	13.19
Yield Monitor	9.13	15.52
Boundary Mapping	8.26	12.82
Variable Rate Application of Nitrogen	9.85	4.40
Satellite GPS receiver	5.30	11.59
Georeferenced field scouting for weeds	6.18	5.90
Variable Rate Application of Herbicides	6.45	3.66
Precision Guidance	3.65	7.55
Aerial or Satellite Field Photography	3.83	7.61
Georeferenced field scouting for insects, pests, or disease	4.98	4.48
Variable Rate Seeding	5.78	1.81
Variable Rate Application of other Nutrients	4.72	3.28
GPS or Sensor-Directed Spot Spraying of Herbicides	3.41	2.55
Variable Rate Application of Pesticides	3.45	1.84
GPS or Sensor-Directed Spot Spraying of Pesticides	1.27	0.36
Percent who have adopted one or more of above	29.92	35.94

Table 6. Percent of Ohio farmers who had adopted various precision farming components by operator age.

Measure	Age Class (Years) 35 or younger	36-50	51-65	over 65
	Adoption Percent			
Georeferenced soil sampling	26.92	16.00	15.11	11.67
Variable Rate Application of Phosphorus	25.93	13.67	15.02	10.74
Variable Rate Application of Lime	33.33	14.49	14.01	10.00
Variable Rate Application of Potassium	25.93	13.82	13.78	9.84
Yield Monitor	14.81	11.19	12.97	9.09
Boundary Mapping	11.11	12.59	8.36	8.20
Variable Rate Application of Nitrogen	14.81	8.70	7.10	5.83
Satellite GPS receiver	7.41	8.66	8.25	4.92
Georeferenced field scouting for weeds	7.41	4.80	6.37	7.44
Variable Rate Application of Herbicides	7.41	4.73	5.47	5.93
Precision Guidance	7.41	6.16	6.07	0.83
Aerial or Satellite Field Photography	3.70	6.86	4.81	3.28
Georeferenced field scouting for insects, pests, or disease	7.41	4.01	4.29	6.72
Variable Rate Seeding	3.70	3.97	4.82	3.33
Variable Rate Application of other Nutrients	0.00	4.74	4.15	4.20
GPS or Sensor-Directed Spot Spraying of Herbicides	3.70	3.25	1.91	5.08
Variable Rate Application of Pesticides	0.00	1.83	3.55	3.39
GPS or Sensor-Directed Spot Spraying of Pesticides	0.00	1.09	1.27	0.00
Percent who have adopted one or more of above	48.15	33.69	31.35	27.78

Table 7. Percent of Ohio farmers who had adopted various precision farming components by operator off-farm employment.

	Operators Working off the Farm		
Measure	None	Seasonally	Year Around
	Adoption Percent		
Georeferenced soil sampling	17.82	13.24	11.65
Variable Rate Application of Phosphorus	14.91	14.93	12.15
Variable Rate Application of Lime	15.16	19.12	10.48
Variable Rate Application of Potassium	13.73	16.18	11.69
Yield Monitor	14.91	11.76	5.98
Boundary Mapping	11.55	11.76	6.77
Variable Rate Application of Nitrogen	6.9	4.41	9.72
Satellite GPS receiver	10.73	5.97	3.19
Georeferenced field scouting for weeds	5.71	5.88	6.4
Variable Rate Application of Herbicides	4.71	7.35	5.24
Precision Guidance	6.88	5.88	2.41
Aerial or Satellite Field Photography	4.41	7.35	5.6
Georeferenced field scouting for insects, pests, or disease	5.3	1.49	5.22
Variable Rate Seeding	4.4	2.94	4.05
Variable Rate Application of other Nutrients	3.47	4.48	4.8
GPS or Sensor-Directed Spot Spraying of Herbicides	3.44	1.47	2.4
Variable Rate Application of Pesticides	2.49	3.03	3.2
GPS or Sensor-Directed Spot Spraying of Pesticides	1.22	0	0.8
Percent who have adopted one or more of above	33.97	37.68	27.78

Table 8. Farmer evaluation of the benefits and costs of individual precision farming components.

		On my farm, the benefits of this technology clearly exceed its costs.					
	Percent adopting	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Mean*
		---- Percent ----					
Variable Rate Application of Lime	14.02	34.04	39.36	13.83	6.38	6.38	0.88
Variable Rate Seeding	4.24	20	40	35	5	0	0.75
Variable Rate Application of Phosphorus	14.06	24.18	39.56	25.27	6.59	4.4	0.73
Variable Rate Application of Potassium	13.38	24.42	41.86	20.93	6.98	5.81	0.72
Precision Guidance	5.16	35.14	27.03	21.62	5.41	10.81	0.70
Variable Rate Application of Pesticides	2.81	23.08	30.77	38.46	7.69	0	0.69
GPS or Sensor-Directed Spot Spraying of Herbicides	3.04	12.5	50	31.25	6.24	0	0.69
Georeferenced field scouting for insects, pests, or disease	4.85	14.29	50	25	7.14	3.57	0.64
Yield Monitor	11.58	21.79	32.05	37.18	6.41	2.56	0.64
GPS or Sensor-Directed Spot Spraying of Pesticides	0.92	20	20	60	0	0	0.60
Georeferenced soil sampling	15.29	16.19	43.81	24.76	9.52	5.71	0.55
Variable Rate Application of Nitrogen	7.71	20.93	32.56	32.56	6.98	6.98	0.53
Satellite GPS receiver	7.63	24.53	26.42	33.96	7.55	7.55	0.53
Georeferenced field scouting for weeds	5.98	10.81	45.95	32.43	5.41	5.41	0.51
Variable Rate Application of other Nutrients	4.12	18.18	36.36	31.82	4.55	9.09	0.50
Variable Rate Application of Herbicides	5.33	24	20	40	12	4	0.48
Aerial or Satellite Field Photography	5.15	12.5	46.88	21.88	9.38	9.38	0.44
Boundary Mapping	9.78	9.09	36.36	40.91	9.09	4.55	0.36

* Mean evaluation is calculated with values of 2, 1, 0, -1 and -2 for *strongly agree, agree, neutral, disagree* and *strongly disagree*, respectively.

Table 9. Adoption of Computer Yield Monitors by various farm and farmer characteristics.

Measure	Yield Monitor		GPS		YM + GPS	
Full Sample	11.60		7.60		5.50	
Gross farm sales						
Less than $250,000	6.40	***	3.40	***	2.00	***
Over $250,000	29.19		21.90		16.70	
Evaluation of the usefulness of the yield monitor[a]						
Farmers without GPS	0.42	***				
Farmers with GPS	1.04					

* One, two or three asterisks indicate a difference of the means of the two groups that is significant at the 0.1, 0.05, and 0.01 probability levels, respectively.

a Mean evaluation is calculated with values of 2, 1, 0, -1 and -2 for *strongly agree, agree, neutral, disagree* and *strongly disagree,* respectively.

Table 10. Farmer evaluation of the benefits and costs for the overall precision farming system, by various farm characteristics.

	Benefits are significantly greater than Costs	Benefits are slightly greater than Costs	Benefits and Costs are about equal	Costs are slightly greater than Benefits	Costs are significantly greater than Benefits	Mean*
			Percent			
Full Sample	20.74	33.51	25.00	7.98	12.77	0.41
Gross farm sales						
$50,000 -2499,999	22.50	26.67	30.00	7.50	13.33	0.38
Over $250,000	18.75	43.75	15.63	9.38	12.50	0.47
Age of operator						
50 or Less	18.82	40.00	24.71	8.24	8.24	0.53
51 and over	22.00	29.00	26.00	8.00	15.00	0.35
Education level of operator						
High School or Less	17.76	31.78	30.84	7.48	12.15	0.36
Post High School	25.00	35.00	17.50	8.75	13.75	0.49

* Mean evaluation is calculated with values of 2, 1, 0, -1 and -2 for *benefits are significantly greater, benefits are slightly greater, benefits and costs are equal, costs are greater,* and *costs are significantly greater,* respectively