WORLDWIDE ADOPTION OF PRECISION AGRICULTURE TECHNOLOGY: THE 2010 UPDATE

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ABSTRACT

Precision agriculture technology has been on the market for nearly two decades; and the question remains regarding how and to what extent farmers are making the best use of the technology. Yield monitors, GPS-enabled guidance technology, farm-level mapping and GIS software, on-the-go variable rate applications, and other spatial technologies are being used by thousands of farmers worldwide. The USDA Agricultural Resource Management Survey (ARMS) and the annual CropLife/Purdue University Precision Ag Survey data are used to update U.S. precision agriculture adoption numbers while adoption estimates for the rest of the world are based on reports from an international network of collaborators. In addition to updating the adoption of precision technology, we discuss farmers' use of precision agricultural services from both a farmers' willingness-to-pay. This presentation is of interest to farmers considering adoption of precision technologies, the agricultural industry supplying products and services, agricultural researchers, and policy makers.

Keywords: adoption, technology, survey, yield monitors

INTRODUCTION

The adoption and profitability of precision agriculture technologies is understood to be site specific. In some areas of the world variable rate fertilizer application is highly profitable, while in other areas it rarely covers costs. Some farmers and agribusinesses focus on analysis and utilization of yield monitor data; others find guidance systems to be the most profitable subset of precision agriculture. The objective of this paper is to summarize the global adoption level of precision agriculture. These results can be used to guide scientists and practitioners regarding what has been learned and where to go from here. Adoption estimates are based on reports from an international network of collaborators and publicly available literature. United States precision agriculture adoption numbers are based on USDA Agricultural Resource Management Survey (ARMS) data and the Precision Agricultural Services Dealership Survey (Whipker and Akridge, 2009). Although not all adoption trends are continually tracked in a quantifiable manner, we rely upon local experts to provide the estimates reported here.

Yield Monitors

Site-specific yield data have been collected from crops including cereal grains, oilseeds, fiber, forage, biomass, fruits and vegetables. Yield monitors have been used by farmers and researchers for the gamut of crops; however most of data on adoption has focused on grains, oilseeds and cotton. In the United States 28% of corn and 22% of soybean areas were harvested in 2005 and 2002, respectively, with a yield monitor (Griffin 2009a). Griffin and Lowenberg-DeBoer (2005) and Lowenberg-DeBoer and Griffin (2009) provided world-wide estimates of yield monitor adoption, comparing the US, EU and Latin America by estimating the number of yield monitors per million arable hectares (Table 1). Germany is projected to have the highest density of yield monitors in the world (523 M ha^{-1}) followed by the United States (335 M ha^{-1}), Denmark (247 M ha^{-1}), Sweden (119 M ha^{-1}) and the United Kingdom (107 M ha^{-1}). It is estimated that more than 90% of yield monitors in Argentina are associated with a GPS, whereas in the US most are not (Table 2).

The commercialization of yield monitors has occurred at different times for each type of crop or harvester. The first widely commercialized yield monitors for the grain combine became available in 1992 (Griffin et al. 2004), over two years before GPS equipment was fully operational for civilian uses (United States Naval Observatory). The cotton yield monitor became commercially available in 1998, at a time when over 20% of US corn and soybean were harvested with yield monitors (Griffin 2009a). It was initially expected that the adoption of yield monitors would occur more quickly for higher valued crops that provide an opportunity to achieve greater net returns. Yield monitors are most often associated with grain harvesters because of the relatively higher adoption rates due to being commercialized several years before yield monitors for cotton (Vellidis et al. 2003), grapes (Bramley and Williams 2001), sugar beet (Konstantinovic et al. 2007), tomatoes (Pelletier and Upadhyaya 1999), fruits (Alchanatis et al. 2007; Ampatzidis et al. 2009), forages (Kumhala et al. 2005; Maguire et al. 2003; Wild et al. 2003; Wild and Auernhammer 1999), peanuts (Durrence et al. 1999; Vellidis et al. 2001), baling hay, wheat and barley (Maguire et al. 2007), surgarcane (Bongiovanni and Vicini, 2008; Bramley, R.G.V. and

Quabba, 2001; Roloff andFocht, 2006; Wendte et al., 2001), and other crops (Griffin et al. 2004). Although yield monitors for grains (corn and wheat) have been discussed in the literature more frequently than those for other crops (Griffin et al. 2004), producers of higher value crops are relatively faster at adopting them for production decisions. With the commercialization of yield monitors and GPS equipment, many georeferenced yield observations can be recorded relatively inexpensively.

Table 1. Number of yield monitors by country

Country	Estimated Number	Year of Estimate	Source (year) of Estimate	Yield monitors per million hectares
Americas:				
United States	30 000	2000	Daberkow et al. (2002)	335
Argentina	5000	2009	Bongiovanni (2010)	172
Brazil	500	2009	Molin (2010)	11
Chile	60	2009	Best (2010)	100
Uruguay	150	2009	Terra (2010)	100
Europe				
U.K.	400	2000	Stafford (2000)	107
Denmark	400	2000	Stafford (2000)	247
France	50	2000	Stafford (2000)	5
Germany	4250	2003	Wagner (2000)	523
Netherlands	6	2000	Stafford (2000)	27
Sweden	150	2000	Stafford (2000)	119
Belgium	6	2000	Stafford (2000)	17
Spain	5	2003	4ECPA participants (2003)	1
Portugal	4	2003	Conceicao (2003)	6
Other				
Australia	800	2000	Lowenberg-DeBoer (2003a)	42
South Africa	15	2000	Nell (2000)	3

Source: Adapted from Griffin and Lowenberg-DeBoer 2005

Table 2. Share of U.S. crops on which yield monitor technologies were used, 1996-2005, percent of planted acres [1/]

Yield monitor without GPS

	Oats	Soybean	Cotton	Barley	Sorghum	Peanuts	Durum wheat	Spring wheat	Winter wheat	Corn	Potatoes	Sunflower	Rice	Sugarbeet
1996		14					9	3	2					
1997		10					6	11	6	12				
1998		15	*				4	6	6	12				
1999		17	4			*			17	16	3	8		
2000		21	1				*	9	10	18			18	1
2001										19				
2002		22												
2003			2	13	100									
2004						2	16	14	10					
2005	3									28				

Yield monitor with GPS

	Oats	Soybean	Cotton	Barley	Sorghum	Peanuts	Durum wheat	Spring wheat	Winter wheat	Corn	Potatoes	Sunflower	Rice	Sugarbeet
1996		3					*	*	*					
1997		4					*	*	1	5				

1998		6	*		2		*	1	*	3				
1999		6	*						7	6	3	*		
2000			*					*	3	6			6	*
2001										7				
2002		8												
2003			2	4	11									
2004						*	7	4	2					
2005	*													

1/ These estimates are revised from previously published estimates based on updated weights from the ARMS.
* = less than 1 percent
Source: Agricultural Resource Management Survey, ERS/NASS, USDA
Adapted from Griffin (2009b) using USDA-ARMS data

Table 3. Use of yield monitor data for selected crops with and without GPS, 2002 – 2005

Crop	Soybean		Cotton		Barley		Durum wheat		Spring wheat		Winter wheat		Corn	
Year sampled	(2002)		(2003)		(2003)		(2004)		(2004)		(2004)		(2005)	
With GPS?	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No

Monitor crop moisture	68	86	*	*	68	67	100	52	60	63	60	85	91	83
Document yields	50	40	25	41	76	38	69	65	54	37	41	29	51	30
Conduct field experiments	42	23	37	*	32	5	*	13	53	9	14	9	46	28
Tile drainage	32	8	5	3	6	6	*	*	7	*	32	2	31	7
Negotiate new crop lease	9	1	1	3	5	*	53	*	21	*	*	1	5	2
Divide crop production	6	7	7	54	12	11	*	48	*	3	7	8	12	11
Irrigation	4	*	4	8	24	3	*	*	*	*	*	*	4	3
Other uses	7	13	1	19	15	8	53	*	6	20	*	7	7	5

* Less than 1 percent

Source: Agricultural Resource Management Survey, ERS/NASS, USDA
Adapted from Griffin (2009b) using USDA-ARMS data

Utilization of Yield Monitors

It is likely that most yield monitors in the rest of the world have GPS and are directly related to the relative value of capital to labor. Anecdotal evidence supports the idea that nearly all the yield monitors in Argentina are associated with a GPS. Farm managers in Argentina see no reason to have a yield monitor that is not capable of recording geo-referenced data; mainly because the combine harvester operator is not the farm decision maker who can make use of the information.

Beginning in 2002, eight questions related to how farmers use yield monitor data were asked on the ARMS survey. Soybean was the crop examined by the 2002 ARMS survey. In 2003, cotton, sorghum, and barley were examined. In 2004, spring wheat, winter wheat, and durum wheat were the focus of the ARMS survey. Corn was examined by the 2005 ARMS survey. Table 3 presents information for all crops.

The leading use of yield monitors by farmers has been to monitor crop moisture. Anecdotal evidence suggests that farmers use the moisture sensor to determine if the crop is ready to be harvested and/or in deciding on which drying or storage facility to send the particular crop. Although the moisture sensor on yield monitors was initially intended to accompany the mass flow sensor to correct for moisture when calculating yields, the moisture reading on its own has been the most commonly used data from the technology.

Documenting yields is the second most common use of yield monitors and the original intent of the technology. Although these data suggests that yield documentation has not been a primary use of the technology with landowners in negotiations or splitting crop shares, yield documentation in general remains to be the second greatest use. The remaining questions regarding uses of yield monitor data give more detail into how documenting yields have been used by farmers.

Yield monitors and other site-specific sensors have allowed farmers to collect many low-cost yield observations. Farmers have used this information to compare crop varieties, tillage treatments, and other inputs or systems. For the crops reported in this fact sheet, using yield monitors to conduct field experiments ranked as third or fourth greatest use. For cotton pickers equipped with GPS, conducting field experiments was the greatest use of the technology.

In areas of the U.S. that rely upon subterranean tile to drain soils, anecdotal evidence has suggested that yield monitors equipped with GPS have helped to quantify the yield reduction due to poor drainage and the potential benefit from drainage improvements. The quantification of yield and profit losses due to poor drainage can be a factor in making land improvements where the farmer owns or leases the land. The ARMS data supports the notion that farmers are using yield monitors with GPS to make tile drainage decisions especially for soybeans, winter wheat, and corn with over 30% of farms with a GPS yield monitor. Except for barley, making irrigation decisions based on yield monitor data has not been a common use of the technology, with less than 10% of farms stating that they have made irrigation decisions based on the technology.

With the exception of cotton, farmers have not used yield monitors in lease negotiations or splitting crop shares. Early in the use of yield monitors, it was expected that leasing arrangements would benefit from the technology; however, from this data and anecdotal evidence, farmland lease arrangements have not been greatly influenced by precision technology especially for negotiating the lease. Farmers producing cotton, durum wheat, and sorghum have made at least some use of the technology for splitting crop shares.

Precision Soil Sampling

In Brazil, Silva et al (2010) estimate that 30% of Sugar Mills in Sao Paulo use grid soil sampling techniques for 70% of the total area. In the United States, evidence suggests that an overall reduction in grid and zone soil sampling has occurred; however, in localized areas precision soil sampling methods are common and are associated with a reputable third-party precision agricultural expertise. More than half of U.S. service providers offered soil sampling with GPS, 59% offered grid soil sampling, one-fourth offered soil sampling by soil type (Whipker and Akridge, 2009).

GPS-enabled Navigation Technologies

An example of an embodied-knowledge technology used by both farmers and service providers is GPS-enabled navigation technologies. The best source of service provider data in the U.S. is from the CropLife/Purdue survey (Whipker and Akridge, 2009). The Precision Agricultural Services Dealership Survey Results has been published annually by Whipker and Akridge since 1996. Since 2005, they have reported the estimated market area using GPS guidance; or in other words how service providers perceived farmers using the technology. In 2009, they reported that 41% of market area used lightbar manual guidance, up steady from 22% in 2005. Automated guidance was used on 21% of market area in 2009, up steadily from 4% in 2005. At the service provider level, lightbar guidance had a very high adoption rate, reaching nearly 80% in just 10 years. Automated guidance was used by more than half of service providers in 2009, sharply increasing from 6% in 2004.

Anecdotal evidence suggests that lightbar guidance has a very quick payback on investment at under one year while automated guidance technologies have breakeven payback periods of three to seven years (Griffin, 2009). Griffin (2009) went on to evaluate the benefit of differential GPS correction to proxy for the farmers' willingness-to-pay for satellite subscription fees and found that on representative Midwestern farms that remained at the same acreage farmers would be willing to pay between $1,600 and $3,000 for an annual fee. When farm sizes were able to be increased to reflect increased in-field equipment efficiencies, farmers would be willing to pay between $1,300 and $12, 500 per year.

SUMMARY AND CONCLUSIONS

Worldwide, the adoption of spatial technologies has been slower and more localized than many analysts in the 1990s expected. Even though the conditions of large-scale farming operations tend to favor adoption of GPS guidance technologies, especially as the cost of technology and GPS differential correction declines. Compared to information-intensive technologies such as yield monitors and variable rate applications based on analyzed data, GPS guidance has been readily adopted. Precision agriculture technology automation of recordkeeping, employee supervision and quality control also has its greatest advantage in large scale operations.

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