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PRECISION AGRICULTURE TECHNOLOGY ADOPTION

IN U.S. CROP PRODUCTION

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Abstract

The objective of this research was to obtain updated estimates of the usage of precision agriculture technology on commercial scale U.S. crop farms. Over 800 U.S. farms with corn, soybean, wheat or cotton enterprises were surveyed to learn of their usage of the following key precision agriculture technologies; yield monitoring, guidance and auto-steer for tractors and harvesters, precision soil sampling and variable rate fertilizer application, variable rate seeding, use of drones or unmanned aerial vehicles (UMAV) and satellite/aerial imagery. Results indicated that these key precision agriculture technologies were more widely used among commercial scale U.S. crop farms than reported previously, ranging as high as 93 and 91 percent for auto-steer and yield monitors, respectively. Variable rate fertilizer application and variable rate seeding were being used by 73 and 60 percent of farms, respectively. Only drones/UMAV were being used by less than half of the farms surveyed. Sixty-nine percent of survey respondents reported that the biggest barrier to adoption of precision agriculture technology was cost suggesting that a majority of U.S. crop producers still find precision agriculture technology's value proposition at least somewhat problematic.

Keywords: Precision agriculture technology adoption, yield monitors, auto-steer, precision soil sampling, variable rate fertilizer, variable rate seeding

Introduction

Precision agriculture is based on the premise that through the application of technology farmers can reduce their productions costs, improve their productivity or both by applying the right amount of inputs in the right place at the right times (Robert, Rust and Larson, 1995). A great deal of research on precision agriculture focused on the economic benefits associated with technology adoption (Griffin et al., 2004; Shockley et al., 2011; Shockley et al., 2012; Smith et al., 2013; Schimmelpfennig, 2016, 2018; Schimmelpfennig and Ebel, 2016). Results were mixed with respect to the impact these precision technologies had on farm profits, although recent research concluded that precision agriculture use has a small (~2%), but positive, impact on net returns and operating profits (Schimmelpfennig, 2016). It is also important to note that improvements in financial returns associated with precision agriculture can arise from two different sources: reduced production costs or increased yield. While researchers generally focused on cost savings, there is growing interest in the potential yield benefits associated with more tailored input applications, especially as variable rate input applications become more common.

Precision agriculture technologies have evolved significantly over the last two decades as both manufacturers and software companies developed new products and improved older products. It was widely assumed that cost reductions and productivity increases accruing from of these technologies' application would lead to their widespread adoption by now. Many studies have evaluated the adoption of precision agriculture technologies, including several in recent years (Erickson and Widmar, 2016; Schimmelpfennig, 2016; Torrez et al., 2016; Zhou et al., 2017). Overall, these studies indicate precision agriculture technologies adoption rates have increased over the last two decades but the reality is that precision agriculture technology adoption in the U.S. has lagged behind expectations, with overall adoption rates rarely eclipsing 50% of farms or even 50% of planted acres. To put this in perspective, compare precision agriculture's adoption with that of genetically engineered crops in the United States, which over roughly the same period were widely adopted by producers and put into use on about 90% of corn and soybean acres (Mintert, 2016; Wechsler, 2017).

However, it is important to note that previous research has also consistently found that adoption rates vary with a variety of observable farmer and farm business characteristics. In particular, adoption rates are generally higher among larger farms (Fernandez-Cornejo et al., 2001; Schimmelpfennig, 2016). For example, according to the most recent USDA Agricultural Resource Management Survey (ARMS) for corn, conducted in 2010, only

12% of the smallest farms (less than 243 hectares) reported using at least one precision agriculture technology. Compare that with the largest farms in the same survey (over 1,538 hectares) who reported adoption rates of 80%, 84%, and 40% for GPS soil/yield mapping, guidance systems, and variable rate technology, respectively (Schimmelpfennig, 2016). As a result, evaluating adoption rates of all farmers might not adequately characterize precision agriculture technology adoption by the industry.

Additionally, even the most recently published adoption rate estimates for U.S. farmers are several years old, leaving open the possibility that adoption rates have changed markedly in recent years. Given that larger farms are more likely to adopt precision agriculture technologies, industry wide adoption rates likely provide an incomplete picture of precision agriculture technologies usage. This is particularly relevant in the U.S. since larger farms, especially for the major U.S crops of corn, soybeans, wheat, and cotton operate most of the acreage and provide the majority of production.

The purpose of this study is to provide an up-to-date assessment of the adoption of key precision agriculture technologies by the larger scale U.S. crop farms that produce the majority of U.S. corn, soybeans, wheat and cotton. Producers of these crops were selected because these four crops collectively accounted for approximately 70 percent of 2017 U.S. planted crop acreage and thereby provide an opportunity for improved understanding of how widespread usage of key precision agriculture technologies is today on the majority of U.S. crop acreage.

Precision agriculture technology is a broad term encompassing many different technologies, some of which are quite specialized and only applicable in a small range of applications. However, there are several key precision agriculture technologies suitable for use in the four principal crops of corn, soybeans, wheat and cotton dominating U.S. planted acreage that have been widely available for many years. Those technologies are yield monitoring, guidance and auto-steer for tractors and harvesters, precision soil sampling and variable rate fertilizer application and variable rate seeding. Additionally some newer precision agriculture technologies that appear to be gaining traction with producers, namely the use of drones or unmanned aerial vehicles (UMAV) and satellite/aerial imagery, were also of interest.

Methods

To learn about producers' adoption of these key precision agriculture technologies, a phone survey of U.S. farmers that produce corn, soybeans, wheat and cotton was conducted from early June to early July 2017. To conduct the survey a list of U.S. commercial crop producers was obtained from Farm Journal Publishing and the surveys were conducted via telephone. Respondents were asked a series of questions regarding their usage of yield monitoring, guidance and auto-steer, precision soil sampling, variable rate fertilizer application, variable rate seeding, usage of drones and UMAV's and satellite/aerial imagery. The survey sample was stratified to focus on farm operations that provide the majority of U.S. production of the four crops. As a result, only farms that had total planted crop acreage of 405 or more hectares were surveyed. This approach was employed to obtain a sample representative of commercial scale crop producers that provide the vast majority of U.S. crop production.

To ensure that the sample of farms was representative of U.S. agriculture, quotas were imposed when sampling. The first quota focused on operation size. The U.S. Department of Agriculture's (USDA) 2012 Census of Agriculture reported that there were nearly 173,500 farms with more than 405 hectares in the U.S. (USDA, 2014). Sampling a population of this size with a confidence level of 95 percent and a margin error of 5 percent required a sample size of at least 384 respondents. However, according to USDA, nearly half of the farms that operate 405 hectares or more operate less than 810 hectares, which is still not a very large farm in the U.S. today. To ensure that the sample was truly representative of U.S. farms that produce the majority of these four crops, the sample size was doubled and quotas established such that at least 400 responses were obtained from farms operating between 405 and 810 hectares and 400 responses from farms operating 810 hectares or more. To further ensure that the sample was broadly representative of U.S. crop producers, 25 percent of the sample was comprised of wheat (20.5%) and cotton (4.5%) farmers with the remainder of the sample comprised of farmers with corn or soybean enterprises. The enterprise quotas were derived from the distribution of corn, soybean, wheat and cotton acres reported by USDA in the 2012 Census of Agriculture (USDA, 2014). Ultimately, the survey yielded 837 usable responses.

Results

Results from the survey responses were interesting in that they indicated precision agriculture technology was being used on a higher percentage of commercial scale farming operations than reported in previous research. Figure 1 provides an overview of key results. Nearly all of survey respondents reported using auto-steer technology (91%) and yield monitors (93%). The next most popular technology among farmers in the survey was variable rate fertilizer application as 73 percent of respondents reported employing this technology. Sixty-six percent of those surveyed said they use precision soil sampling and 60 percent indicated they use variable rate seeding on their farms. Just over half (56%) of farms in the survey said they make use of satellite or aerial imagery on their farms. Unsurprisingly, one of the newest precision agriculture technologies, use of a drone or UMAV, was the least widely used technology as only 25 percent of respondents reported using this technology on their farm.

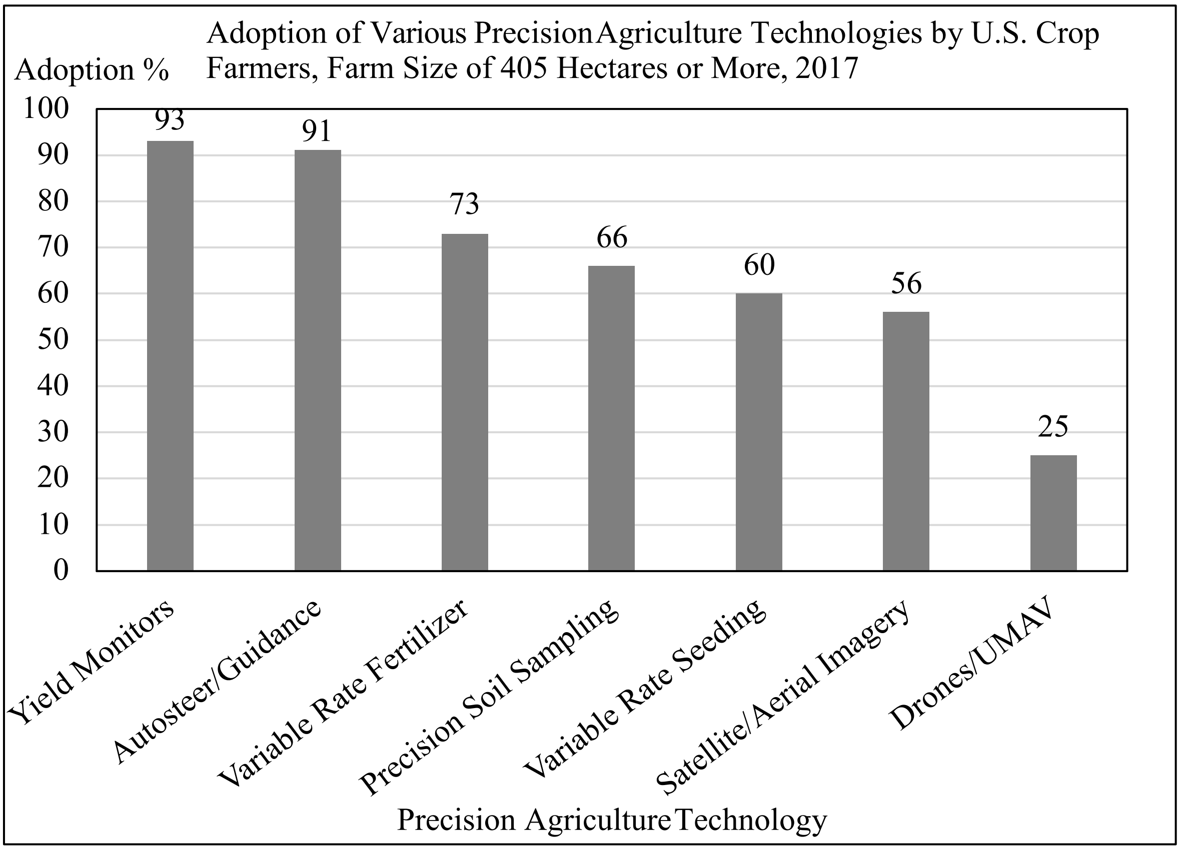

Figure 1. Adoption of Various Precision Agriculture Technologies by U.S. Crop Farmers, Farm Size of 405 Hectares or More, 2017.

To learn more about what might be holding back adoption of precision ag technologies, survey respondents were presented with several potential barriers to adopting precision ag technology and asked whether they agreed or disagreed that the factor was a barrier to their farm's adoption of precision ag technology. The most commonly identified barrier to adoption, by a wide margin, was cost as 69% of respondents agreed it was a barrier. Lack of confidence in recommendations, lack of service partner support, field topography, and lack of variability in soil productivity were all identified by approximately four out of ten (37% to 43%) respondents as barriers to technology adoption. Somewhat fewer producers, just 30% of respondents, felt that difficulty in making decisions based on precision ag technologies was a barrier.

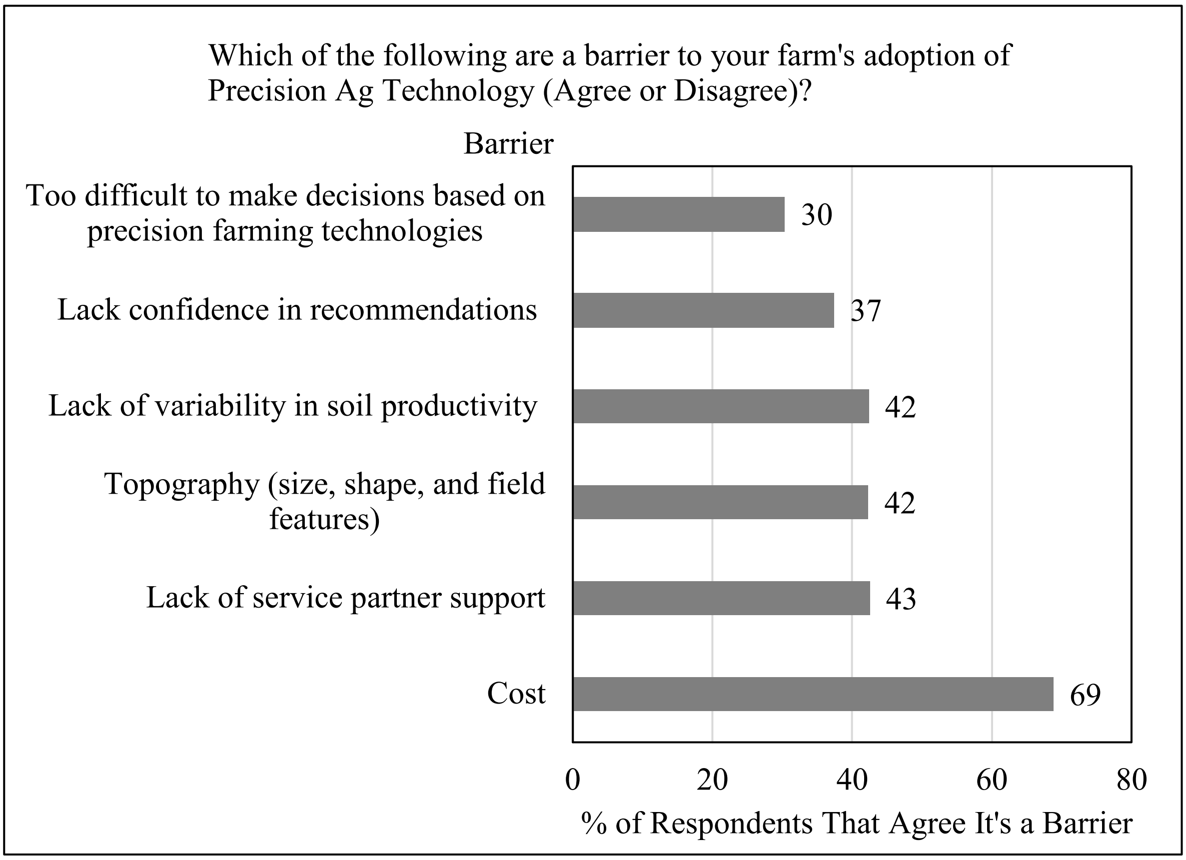

Figure 2. Barriers to Adoption of Precision Ag Technology by U.S. Crop Farmers, Farm Size of 405 Hectares or More, 2017.

Producers were also queried regarding their plans for the future with respect to investments in precision ag technology. Specifically, we asked producers to look ahead five years and estimate whether their annual investments in precision farming technologies and services would be more than, about the same, or less than in 2016 (the most recent full year when the survey was conducted in summer 2017)? Responses to this question revealed a good degree of optimism about the future of precision ag technology. Just over ninety percent of respondents said they expect to invest the same or even more per year than in 2016. Perhaps more revealing is the fact that nearly half (45%) of respondents said they expect to be investing more in precision technology each year than they invested recently.

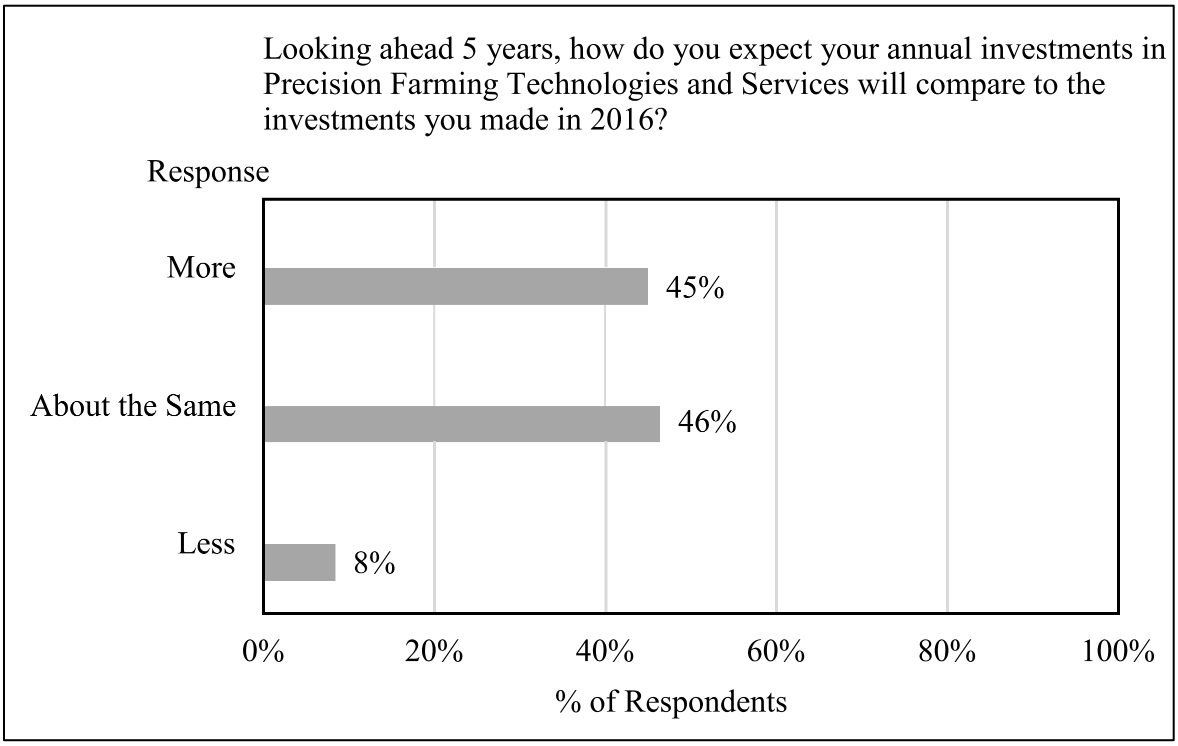

Figure 3. Expectations for Annual Investments in Precision Farming Technologies Five Years in the Future by U.S. Crop Farmers, Farm Size of 405 Hectares or More, 2017.

As with most technologies, there is a widely held expectation that precision ag technology will improve over time. Broadly speaking, prospective improvements in precision ag technology can come about from 1) better recommendations based upon data collected, which implies better models of crop and livestock production that are reliant on data being collected; or 2) improved data collection. Improved data collection could arise from engineering improvements that make possible more accurate data collection or, possibly, collection of new data that is not possible with current technology. We asked producers whether they thought most of the improvements would come about from improved data collection or from improved recommendations. Responses from producers were quite interesting. Nearly twice as many producers (64%) expect most of the improvements to come from better recommendations as opposed to improved data collection (32%).

Discussion

Prior to this study, the most recent comprehensive assessment of precision agriculture adoption rates was published by USDA's Economic Research Service (Schimmelpfennig, 2016). Although published in 2016, the data reported by Schimmelpfennig was actually collected long before the publication date. For example, the most recent adoption rate data included for corn and soybean producers were collected in 2010 and 2012, respectively and adoption rate data for cotton and spring wheat producers were even older. In contrast all of the data in this study were collected in mid-2017, meaning data were at least five years newer than in the USDA study. Additionally, the crop producers surveyed in Schimmelpfennig represented a somewhat different enterprise mix than that represented by the producers in this study. Specifically, Schimmelpfennig surveyed corn, soybean, cotton, peanut, rice and spring wheat producers whereas this study reported results obtained from corn, soybean, cotton and wheat producers. With those caveats in mind, it's still interesting to compare some of the results from the USDA study to those presented here.

Schimmelpfennig's results include a breakout for corn farms of their use of GPS soil/yield mapping, guidance systems, and variable rate technology by farm size. Results indicated that, as farm size increased, adoption rates increased. Adoption rates for these technologies on small farms of less than 243 hectares were very low, just 12 percent for all of the technologies. Adoption rates for farms ranging in size from 405 to 890 hectares were higher, but still relatively low. For example, use of guidance technology ranged among this group ranged from 33 to 66 percent and use of GPS soil/yield mapping ranged from 39 to 54 percent of farms. The USDA study indicated that it wasn't until the largest size category in the study was examined, farms over 1,538 hectares, that reported adoption rates climbed sharply, reaching 80 percent for GPS soil/yield mapping and 84 percent for guidance systems. Still, just 40 percent of these large farms reported that they were using variable rate technology.

There are several reasons that likely account for the higher adoption rates reported in this study, even when adjusted for farm size, compared to those in Schimmelpfennig. First, it appears that over time various precision agriculture technologies are simply being more widely adopted by U.S. producers. The evolving adoption rates could be a function of 1) improvements in the technology over time; 2) reduced cost as the technologies mature; and 3) improved understanding of how to implement the technologies in a crop production system providing higher yields, lower costs per acre or both. The last point is one that is potentially multi-faceted. One possibility is an improvement in crop production models that underlie some of the technologies, especially use of yield mapping and variable rate technology. But another possibility is the time and effort required on the part of producers to fully realize the benefits these technologies offer. Stated another way, it is possible that it has simply taken time for farm operators to actually learn how to take advantage of precision agriculture technologies. On a related point, the lack of specialization on many smaller farms that might be required to fully capture the benefits of precision agriculture technology could be one reason why precision agriculture technology adoption rates on smaller farms tends to lag behind that of larger farm operations.

Finally, there is an aspect of precision ag technology adoption that our survey was not able to address. Over time, some precision technologies have become standard on new equipment and, as a result, producers might not make an explicit decision to invest in the technology, yet it is still viewed as adopted by the farm since the farm operator has access to it. Although differentiating between precision technologies that come standard vs. technologies requiring an explicit investment decision might not seem important, in some cases there could be a difference between technologies “adopted” because they were standard equipment vs. those purchased to fulfill perceived needs. The difference could lead to a divergence between adoption rate and technology use. Adoption rate might indeed be higher than technology use for some technologies that simply come as standard on new equipment.

Conclusions

Adoption of precision agriculture technologies by U.S. crop producers has been slower than for other key production technologies such as GMO crops. However, results presented here indicate that, by 2017, key precision agriculture technologies were being widely used by U.S. commercial scale producers of corn, soybeans, cotton and wheat as over 90 percent of surveyed producers were using auto-steer/guidance technology and yield monitors and nearly three-quarters of producers surveyed were using variable rate fertilizer applications. Usage of precision soil sampling, at 66 percent, and variable rate seeding, at 60 percent of respondents was less popular, suggesting a sizable minority of commercial crop producers were still not convinced that these technologies would improve their farms’ profitability. Finally, just one-fourth of the farms in this survey indicated that they had adopted one of the newest precision agriculture technologies, use of drones/UMAV’s.

Reviewing the survey results, several points stand out. First, most producers did not seem to view using precision ag technology difficult when making farm level decisions since just 30% of respondents agreed this was a barrier. However, since nearly seven out of ten respondents identified cost as a major barrier to adoption, it indicates a large number of producers still find precision agriculture’s value proposition at least somewhat problematic. Nevertheless, producers remain optimistic that precision agriculture’s value proposition will improve enough to justify maintaining or actually increasing their investment in the future.

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