Future technologies

ADOPTION OF PRECISION AGRICULTURE TECHNOLOGY

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Acknowledgements

The authors wish to thank KFMA Economists who collected data from KFMA member farmers, Koren Roland with KMAR-105 for data processing, and Emily Carls for data entry from the precision agriculture technology instruments. The authors are indebted to Kevin Herbel for supporting our research.

Number words: 1907

Academic

The analysis and work in this paper are solely the effort of the authors.

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Abstract

Precision agriculture technologies have been available for adoption and utilization at the farm level for several decades. Some technologies have been readily adopted while others were adopted more slowly. An analysis of 621 Kansas Farm Management Association (KFMA) farmer members provided insights regarding adoption of technology. The likelihood that farms adopt specific technology given that other technology had been adopted are reported. Results indicate some technologies were more readily adopted than others. These results are useful to farmers considering investment in technology, retailers targeting potential technology adopters, and manufacturers in supply chain management.

Keywords: conditional probabilities, dis-adoption, obsolescence, profitability

Introduction

Adoption of precision agriculture has generated interest among researchers. Precision technologies have been available since the commercialization of global navigation satellite systems (GNSS) in 1994 yet adoption has been slow among some farmers. Olson and Elisabeth (2003) reported whole-farm impacts of precision agriculture adoption from Minnesota early in the infancy of these technologies. Their study attempted to evaluate technology impacts on profitability. They surveyed 212 farms and reported 28% used precision agriculture. They suggested that the sample size was not adequate to ascertain expected differences between adopters and non-adopters. Previous studies on technology adoption and profitability were disjointed, focusing on farm-level adoption in one study and *ex ante* profitability of technology in other studies. Besides Olson and Elisabeth (2003), no studies were found that jointly determined the profitability of technology adoption. However, a series of studies evaluated differing aspects of precision agriculture adoption. Schimmelpfennig and Ebel (2016) analyzed U.S. Department of Agriculture

(USDA) Agricultural Resource Management Survey (ARMS) data to report sequential adoption of variable rate technologies along with combine yield monitors with and without GNSS. Their study examined cost differences between technology adopters and non-adopters. Lambert et al. (2015) evaluated technology adoption on cotton producing farms across the United States. They concluded that farmers adopted technologies individually and bundled together. The longest running technology adoption study focuses on agricultural service providers rather than farmers since 1997 (Erickson et al. 2017).

Background and Literature Review

Profitability and sustainability benefits of precision agriculture are said to be 'site specific'. Given that the economics of technology are a function of not only the specific grower's fields but also the management ability of the grower, profitability assessments of specific technologies have been elusive (Griffin et al. 2018). Precision technologies have been categorized into two distinct groups for adoption analyses, i.e. embodied knowledge or information-intensive (Griffin et al., 2004). Embodied knowledge technologies such as automated guidance and automated section control have been more readily adopted than information intensive technologies such as yield monitors and grid soil sampling (Griffin et al. 2017).

Precision agriculture has been found to affect profitability by substituting information and knowledge for fertilizer, seeds and chemicals given soil and other conditions. Several researchers examined these savings from an environmental stewardship perspective and reduction of purchased inputs leading to better sustainability of resources (Bongiovanni and Lowenberg-DeBoer 2004; Dhoubhadel and Griffin 2018; Schimmelpfennig 2018; Torbett et al. 2007, Watson et al. 2005). Schimmelpfennig and Ebel (2016) examined distortions between technology adoption given lower input costs. They reported differences in farm size, operator education, and farm type were significant. There was also an inconsistency in the savings as variable rate technology in some instances could result in increased inputs usage. At least one study evaluated technical efficiency of technology adoption (McFadden and Rosburg 2018).

Lambert et al. (2015) used multiple indicator multiple causation models to examine utilization and adoption of 10 agricultural technologies. Their study differed from those discussed thus far in terms of methodology and focus on bundling rather than individual technologies. This study builds upon Griffin and Yeager (2018) by expanding on adoption statistics rather than duration analyses

Methods

Farm-level data were available from Kansas Farm Management Association (KFMA). The KFMA databank included detailed farm-level agronomic and financial information from the previous 40 years. In 2015, KFMA economists began collecting precision agriculture adoption information (Griffin et al. 2017). By December 2018, 621 KFMA farms reported having 'used' or 'never used' technology. Of the 621 farms reporting, 523 (84%) reported adopting at least one technology. Specific technologies examined included yield monitor, variable rate fertilizer and seeding, precision soil sampling, automated guidance, and automated section control.

Adoption of Precision Technology

Kansas farms have adopted precision technologies but at varying rates over time (Figure 1). Since commercialization, embodied-knowledge technologies such as GNSS-enabled guidance and section control have been readily adopted. In 2008, the number of farms using automated guidance surpassed the number of farms using manual control lightbar guidance. In roughly 2011, the utilization of lightbar guidance began to plateau due to automated guidance continuing to be adopted (Figure 1). Adoption of nearly all technologies evaluated began to level off in 2014, in conjunction with drastically lower net farm incomes associated with reduced commodity prices.

In the last decade, nearly all new combine harvesters came equipped with GNSS yield monitors; however, possession of technology does not imply utilization of farm data. Fewer than half of farms adopted yield monitors (Figure 1), which is consistent with national estimates from USDA ARMS.

Kansas farms make use of precision soil sampling such as grids and smart sampling. However, adoption rates for intensive soil sampling remained below 50% (Figure 1). Variable rate applications of fertilizer and seed were utilized by less than one-fourth of farms (Figure 1). These data were graphed in a bar plot to emphasize some technologies were readily adopted while others have more non-adopters than adopters (Figure 2)

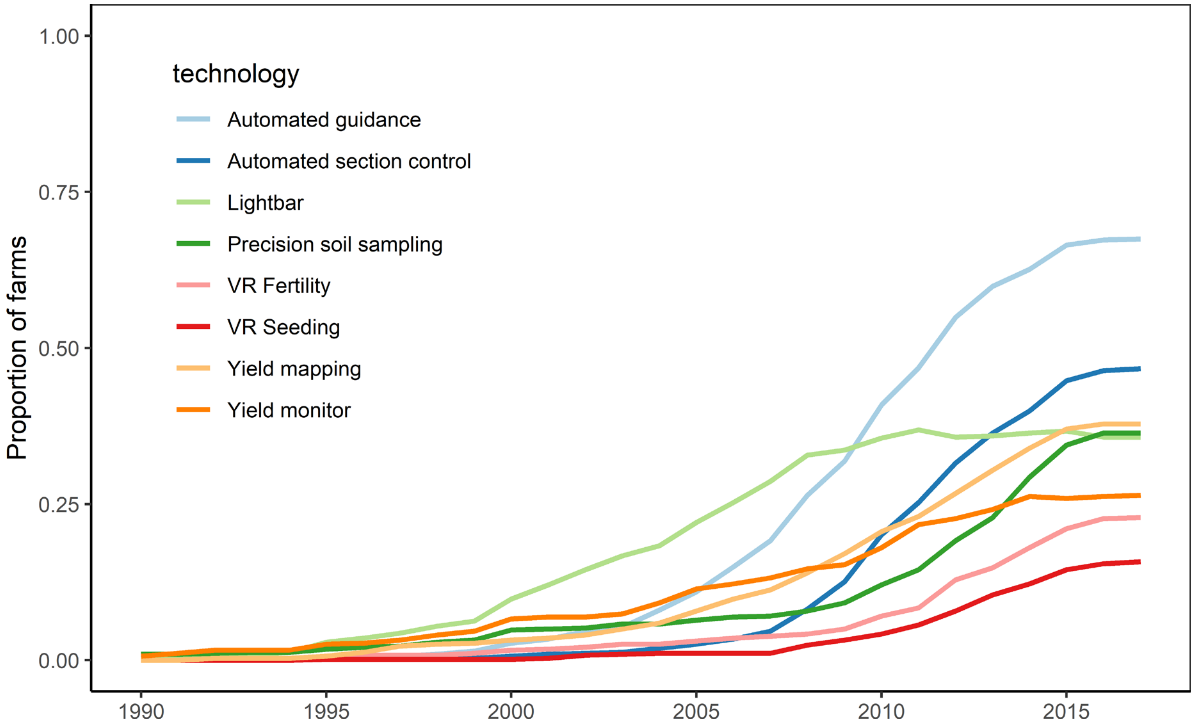

Figure 1. Percent of Kansas farms utilizing precision technologies over time

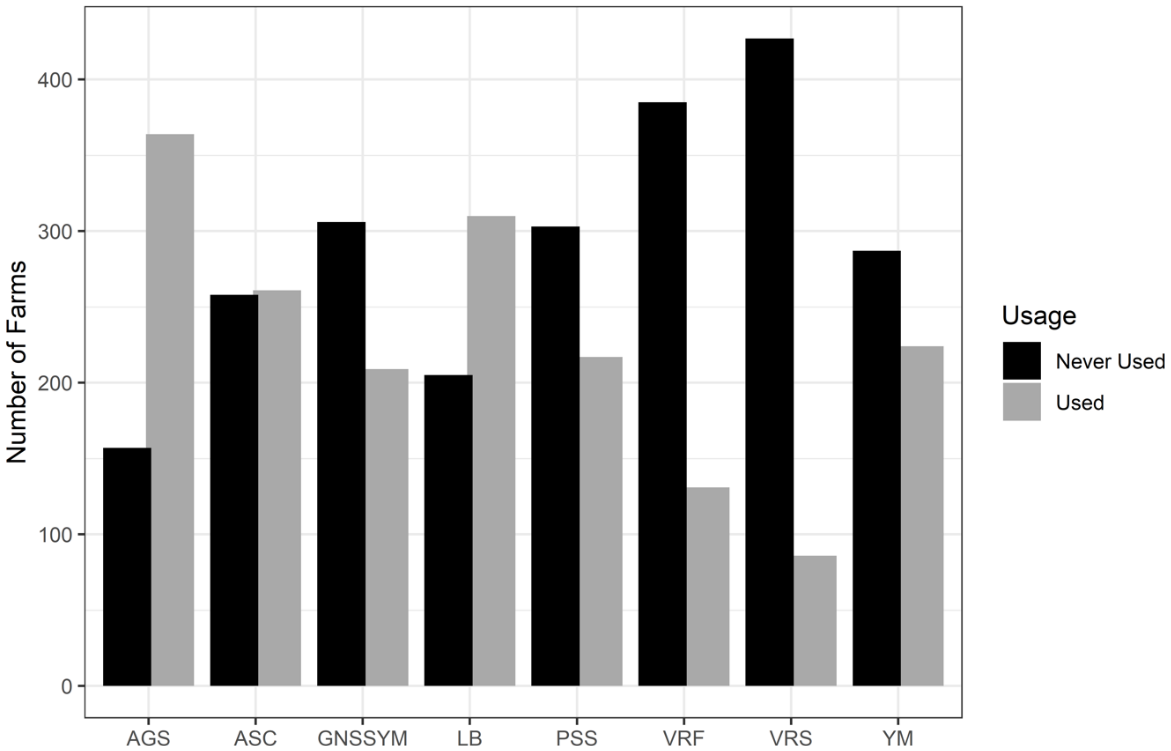

Figure 2. Number farms adopting or not adopting specific technologies

Of the 621 respondents, 425 (68%) farms adopted automated guidance. Almost 60% of farms have used lightbar guidance. Nearly half (47.8%) of Kansas farms utilize automated section control. Only 16.4% of Kansas farms using variable rate technology to apply seeds at site-specific rates. Historical yardsticks for both embodied-knowledge and information-intensive precision agriculture technology served as basis for comparison. Specifically, technologies were compared to automated guidance, yield monitors with GNSS, and variable rate fertility. Relative to automated guidance, 85% and 70% of farms adopted lightbar guidance and section control, respectively. The remaining information-intensive technologies were less than 60% of farms. Relative to yield mapping, 63% of farms used variable rate fertility and 42% adopted variable rate seeding.

The most frequently adopted number of technologies was three (Figure 3). Eighty farms have adopted exactly three of the eight technologies. Fifty-eight farms have adopted only one technology. More farms have adopted four or five technologies than either one or two technologies. Less than 20 farms have adopted all eight technologies.

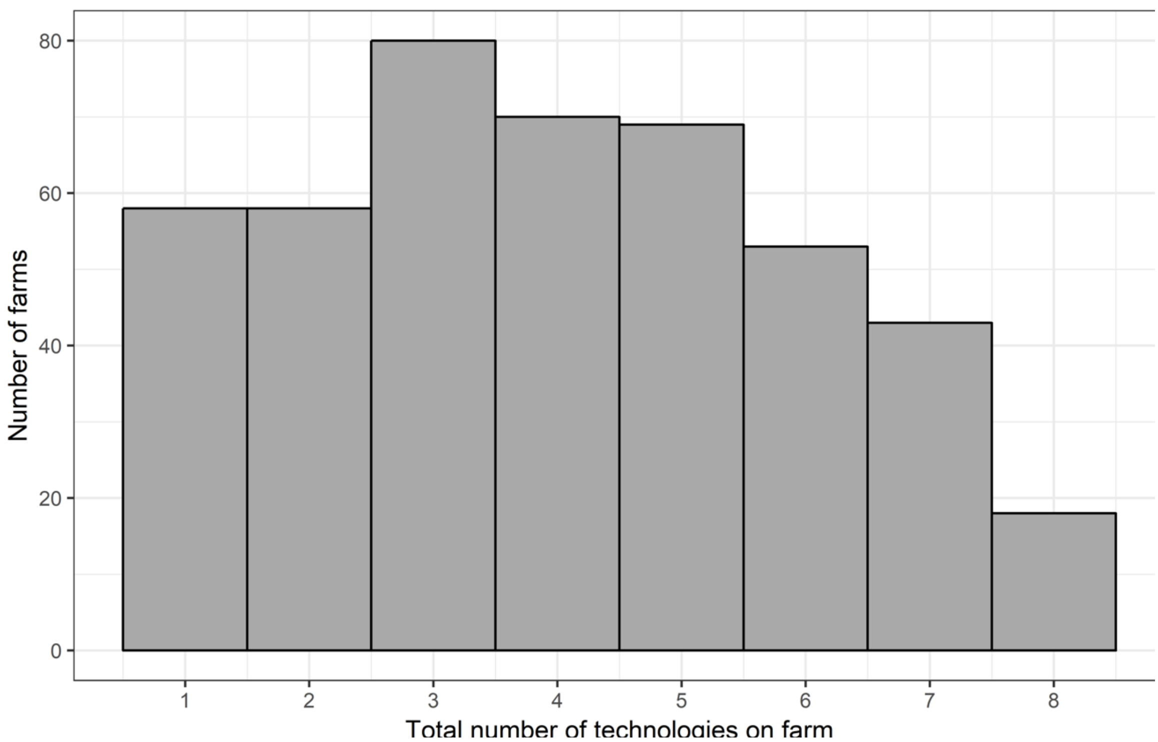

Figure 3. Number technologies used by farms adopting technology

Conditional Probabilities and Proportion of Farms

The KFMA data provides useful information on the likelihood of farms to engage in adoption of technology given that other technologies are being utilized. The proportions presented in Table 5 show a farm's probability of adopting one technology given that another technology was being used on the farm in the same year. These technologies include yield mapping (YMGNSS), yield monitor (YM), automated guidance (AGS), automated section control (ASC), lightbar (LB), precision soil sampling (PSS), variable rate application of fertilizer (VRF), and variable rate seeding (VRS).

The first column in Table 1 lists the technologies that are 'given', meaning that these are the technologies that are the basis for comparison. The top row lists the same technologies but indicate the level of utilization for that technology (along the top row) 'given' that the other technology (along the first column) was being used on that farm. The values along the diagonal are blank since statistics on a technology 'given' as the same technology does not provide useful information. For a farm that uses yield mapping (first row, YMGPS), the probability that the farm uses automated guidance (third column) was 94%. Farmers who use yield monitors are less likely to use section control and automated guidance than farmers who have GNSS on their combines (Table 1).

Farms that use variable rate application for fertilizer (7th row, VRF) have 86% likelihood of using precision soil sampling (6th column, PSS) while the probability of using variable rate seeding (8th column, VRS) is 41% (Table 1). In other words, farms that use variable rate application of fertilizer are more likely to use precision soil sampling than variable rate seeding. For farms that have yield mapping (YMGNSS), the probability of using variable rate seeding (VRS) is 35%, while the probability of having automated guidance (AGS) is 94%. Farms that have adopted yield mapping are therefore more likely to utilize automated guidance than variable rate seeding.

Table 1. Conditional probability adopted with respect to another technology, n=621

	YMGNSS	*YM*	*AGS*	*ASC*	*LB*	*PSS*	*VRF*	*VRS*
YMGNSS	-	0.54	0.94	0.82	0.7	0.66	0.46	0.35
YM	0.51	-	0.89	0.67	0.71	0.49	0.35	0.22
AGS	0.54	0.53	-	0.66	0.7	0.5	0.33	0.23
ASC	0.67	0.58	0.95	-	0.73	0.57	0.43	0.31
LB	0.47	0.5	0.82	0.6	-	0.48	0.31	0.18
PSS	0.64	0.5	0.86	0.67	0.7	-	0.53	0.29
VRF	0.73	0.59	0.91	0.82	0.73	0.86	-	0.41
VRS	0.82	0.56	0.97	0.9	0.63	0.71	0.62	-

Based on these conditional probabilities, some technologies are preferred to others for farms given that other technologies are being utilized by that farm. The proportion of farms adopting automated guidance (3rd column) was highest, ranging from 82% (for farms that had previously adopted lightbar) to 97% (for farms that had previously adopted variable rate seeding) (Table 1). As reported above, the adoption of automated technologies such as automated guidance on tractors and combine harvesters has much greater adoption than information-intensive technologies such as yield monitors, grid soil sampling, and traditional variable rate applications of fertilizer and seeds.

Since most KFMA farms utilize automated guidance while less than half utilize yield mapping or variable rate applications, it logically follows that the proportion of farms adopting automated guidance given any other technology would be the highest values across any technology. In addition, GNSS is required to make controller-driven variable rate applications and to collect site specific yield monitor data (i.e. yield mapping, GNSS yield monitor). Since GNSS is already being utilized on the farm, it reasonably stands that one of the major uses of GNSS would be for automated guidance.

As opposed to automated guidance, variable rate seeding (8th column) had much lower adoption rates, and lower proportions ranging from 18% (for farms that had adopted lightbar guidance) to 41% (for farms that had adopted variable rate fertilizer). If a farm successfully utilizes variable rate fertilizer then making use of variable rate seeding intuitively seems the natural next step in the adoption process.

Prescriptive fertilizer application recommendations necessitate site-specific soil fertility information. Three of the leading methods to obtain data sufficient for variable rate applications are on-the-go sensor based and map based from yield monitors (for nutrient replenishment based on grain nutrient removal) and precision soil sampling (for sufficiency, buildup, and maintenance) (Ess et al. 2001). In the absence of on-the-go sensors, farms utilizing variable rate fertility (7th row, VRF) are expected to either use yield mapping (73%) or precision soil sampling (86%). Since the highest proportions given variable rate fertility is for precision soil sampling, it can be concluded that farms rely mostly on chemical analysis of soil samples rather than yield data as a proxy for nutrient removal especially when applying phosphorus and potassium. However, this relationship may change during times of relatively low commodity prices when farms desire to avoid costs associated with intensive grid soil sampling and to replace nutrient removal rather than building fertility levels.

Discussion

Farm-level adoption rates in Kansas were comparable to those reported by USDA (Schimmelpfennig and Ebel, 2016). The statistics presented in this paper are consistent with estimates on yield mapping and automated guidance. Schimmelpfennig and Ebel reported that one-fourth and 29% of American corn farms had adopted yield mapping and automated guidance, respectively, by 2010; these metrics are nearly identical to estimates presented by this study for the same time period. The American corn farmer statistics for variable rate fertilizer were somewhat higher than those reported by this study at 19%. Overall, the detailed information on farmers' adoption of precision agriculture in Kansas were indicative of the national perspective of American corn farmers.

Conclusion

Automated technologies such as guidance and section control are expected to have much higher rates of adoption than data technologies like yield monitors. Differences in adoption rates are a function of the required human capital costs to utilize these different categories of technologies. Results indicate that even though lightbars were once considered embodied-knowledge technology, obsolete technology may be considered information-intensive given that the user must make use of the information. Farmers continue to adopt technology although recent commodity prices have slowed the rates.

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