Factors Influencing the Adoption of Precision Agricultural Technologies by Kansas farmers

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Executive Summary

Proper technology utilization is expected to improve farm productivity and profitability. The factors that influence technology adoption are important to know so that marketing strategies and policies can be implemented to improve adoption rates and increase farm productivity. Adoption of Precision Agriculture (PA) technology has recently grown at an incrementally faster pace compared to when PA were introduced. Adoption rates vary among PA technologies by farm size and operators age. An empirical adoption model was developed to understand why farmers have or have not adopted PA technologies. The results of the model show that farm size positively affects the adoption of PA technologies, farmer age decreased the probability of adoption, cropping efficiency on average had little effect, and risk aversion on average had a negative impact on PA technology adoption. Likewise, the predicted adoption probabilities for the PA technologies are presented. There preliminary results were based on a sample size of 453 farms.

Introduction

Precision agriculture (PA) technologies require a substantial investment of capital and time, but may offer cost savings and higher yield through more exact input management (Schimmelpfennig, USDA ERS 2016). Adoption rates vary substantially across PA technologies, and farm size has been a leading factor. The largest farms in our dataset, with over 2,800 acres, presented the highest adoption rates.

The technologies presented in this report are: Automated Guidance (AG), Lightbar (LB), Automated Section Control (ASC), Precision Soil Sampling (PSS), Yield Monitor (YM), Yield monitor with GPS (YM with GPS), Variable Rate Fertility (VRF), and Variable Rated Seed (VRS). The first six technologies can be used independently of each other. Guidance technologies provides the benefit of more accurate field operations, and reduce worker fatigue while extending the work day (Griffin, Lambert and Lowenberg-DeBoer 2005). PSS and YM technologies are being used by farms, suppliers of agricultural inputs, and custom service providers for farm production management recommendations and decisions. VRF is the only one of the eight technologies that is generally adopted in combination with other precision agriculture technologies due to dependency on site-specific information. VRF is considered to be complementary to soil and yield mapping and may lead to different cost savings when used with different types of mapping (Schimmelpfennig, USDA ERS 2016).

The adoption of new technology is related to operator characteristics, farm characteristics, farm profitability, and uncertainty of benefits (Tey and Mark 2012). Fenn and Raskino observed that when a new technology is released, almost all follow a similar trend and developed the Gartner's Hype Cycle, starting with the technology trigger, peak of inflated expectations, trough of disillusionment, slope of enlightenment and finally plateau of productivity. The decision to adopt a new technology from the farmer's perspective can be interpreted using the Gartner's Hype Cycle introduced in 1995. The Hype Cycles can help farm managers with the decision of whether or not to invest in a technology. If a technology is adopted too soon, the farmer may suffer unnecessarily through the painful and expensive lessons related with deploying an immature technology. If the adoption is delayed too long, the farmer could face a greater risk of being left behind and lose the benefits associated with the technology (Fenn and Raskino 2011).

Two types of opportunity for a farmer arise from incorporating the Hype Cycle in decision making. The first type of opportunity comes from optimizing the timing of adoption to obtain the maximum financial value possible. The second type of opportunity lies in joining the energy of the Hype Cycle in the broader marketplace by taking strategic advantage of the needs and actions of other players. Avoiding the traps that others fall into is one element of this. If the decision maker can outcompete their peers, even some of the time, by avoiding the pitfalls of adopting too early or giving up too soon, and avoiding the lost opportunity costs of adopting too late or hanging on too long, they will likely come out ahead. The adoption of one technology limits the availability of resources to adopt another new or complementary technology. If the decision maker can anticipate the tendencies of suppliers, investors, competitors, and skilled individuals at each stage of the Hype Cycle, they will be able to find the best deals, the best talent, the best publicity, and many other opportunities to advance their own adoption efforts. Perhaps, it is not so bad to wait until the right time, when prices and policies are more favorable and an "enlightened" understanding of the technology is possible. (Fenn and Raskino 2011)

The objective of this research was to identify factors that impact the adoption of precision agriculture technology by Kansas farmers, and describe what are the characteristics of technology adopters versus non adopters.

Data and Methods

Beginning in the fall of 2015, Kansas Farm Management Association (KFMA) members were surveyed regarding t heir adoption of precision agricultural technologies. The KFMA databank includes detailed farm-level agronomic and financial information from 1973 to 2015. By November 2016, 453 farms reported their respective adoption and utilization of PA technologies including the year of adoption and abandonment (if no longer currently in use). Of the 453 responses, 83% responded to having adopted at least one precision technology. However, when the PA survey data was merged with the KFMA databank and sorted for farms having observations each year since 1993, there was a loss of observations due to some farms not meeting the inclusion criteria.

The farmer's decision to adopt or not adopt a technology is modeled given a set of variables affecting the adoption of PA technologies using a Logit regression. To estimate the probability of adopting a PA technology, the following factors were analyzed: farm size, operator age, cropping efficiency, risk aversion, and time. Farm size is a continuous variable for the number of total acres operated. The operator's age is the age of the "primary" operator. Cropping efficiency is the ratio of total gross value of crops to total crop production cost, and is considered a good predictor of the operator experience (Goodwin and Mishra 2004). In the KFMA data set the total value of crops represents the total value of production from cropland, including the landlord's share, crop insurance proceeds, and government payments. Moreover, the total crop production costs are equal to total crop expense plus opportunity cost charge on listed property, motor vehicles, machinery and equipment, and buildings minus unpaid family and operator labor minus interest paid minus cash farm rent minus opportunity cost charge on net worth minus machine work income (Langemeier 2010). In addition, risk aversion is the ratio of crop insurance to total crop production cost, the notion being that higher the share of crop insurance in total crop production cost, the higher the farmer's risk aversion (Adhikari, Ashok and Sachin 2009). The time variable is a measure of the diffusion factor of a PA technology, as every year passes, technologies and know-how improve, the time variable captures all these interactions that are not available in the data set, difficult to measure, or otherwise unobservable. The time variable is involved in the innovation-decision process, the length of individual response, from first knowledge of a technological innovation to forming an attitude towards the innovation and implementing and evaluating the innovation's impact (Rogers 2003).

Results

Larger acreage farms are more likely to adopt PA technologies, ceteris paribus. In all cases an increase in the operator's age decreased the probability of adopting PA technologies. The effect of cropping efficiency differed across the PA technologies. Only for the Precision Soil Sampling (PSS) technology, cropping efficiency was statistically significant and negative. This may be because less efficient farms desire to improve productivity by intensive soil sampling while the most efficient farms do not expect a marginal benefit from this technology. Moreover, risk aversion effect on probability of adoption was different across PA technologies. For Automated Guidance (AG), risk aversion did not influence the likelihood of adoption, however the effect on Lightbar(LB) technology is positive and statistically significant. Risk taking operators probably are more likely to adopt information-intensive technology such as YM with GPS, PSS, and VRF, and are willing to invest capital and time to master these technologies. The variable time as a diffusion factor has a positive and statistically significant effect on adoption rate of PA technologies (see Appendix Table 1).

Variable Rate Technologies (VRT) are often acquired together with yield and soil mapping. The adoption of variable rate technologies can be conditioned given the adoption of other PA technologies and controlled by the adoption factors such as farm size, operator age, cropping efficiency, risk aversion and time. The concurrent adoption of AG, PSS, and YM with GPS has a positive and significant effect on the likelihood of VRT adoption, as opposed to LB technology (that had a negative effect). Automated section control has a negative effect on VRF and a positive effect on VRS (see Appendix Table 2).

Farm Size

Farm size has been considered a leading factor for the adoption of PA technology in both Kansas and across the United States. In 2015, automated guidance was the technology with the highest adoption rate in Kansas, and farm size is a highly influential factor (see Appendix Table 1). On average, Kansas farms with more than 2,800 acres are more likely to adopt PA technologies. The automated guidance and Lightbar navigation technologies adoption rates differed from one another by farm size. Lightbar had a lower adoption rate than automated guidance. As farm acreage increases the adoption rate of LB tends to decrease, probably offset by the increased adoption of automated guidance (see Griffin et al., 2016 for discussion of PA obsolescence). Yield monitor technologies were also highly appreciated in larger farms with a high share for YM with GPS. Automated section control has nearly 75% adoption rate for farms greater than 2,800 acres. In spite of the benefits, variable rate technologies, considered as cost saving, have a lower adoption rate than navigation technologies (Schimmelpfennig, USDA ERS 2016). Adoption results for VRT differ from the other technologies, but with higher share in larger farm size (Figure 1).

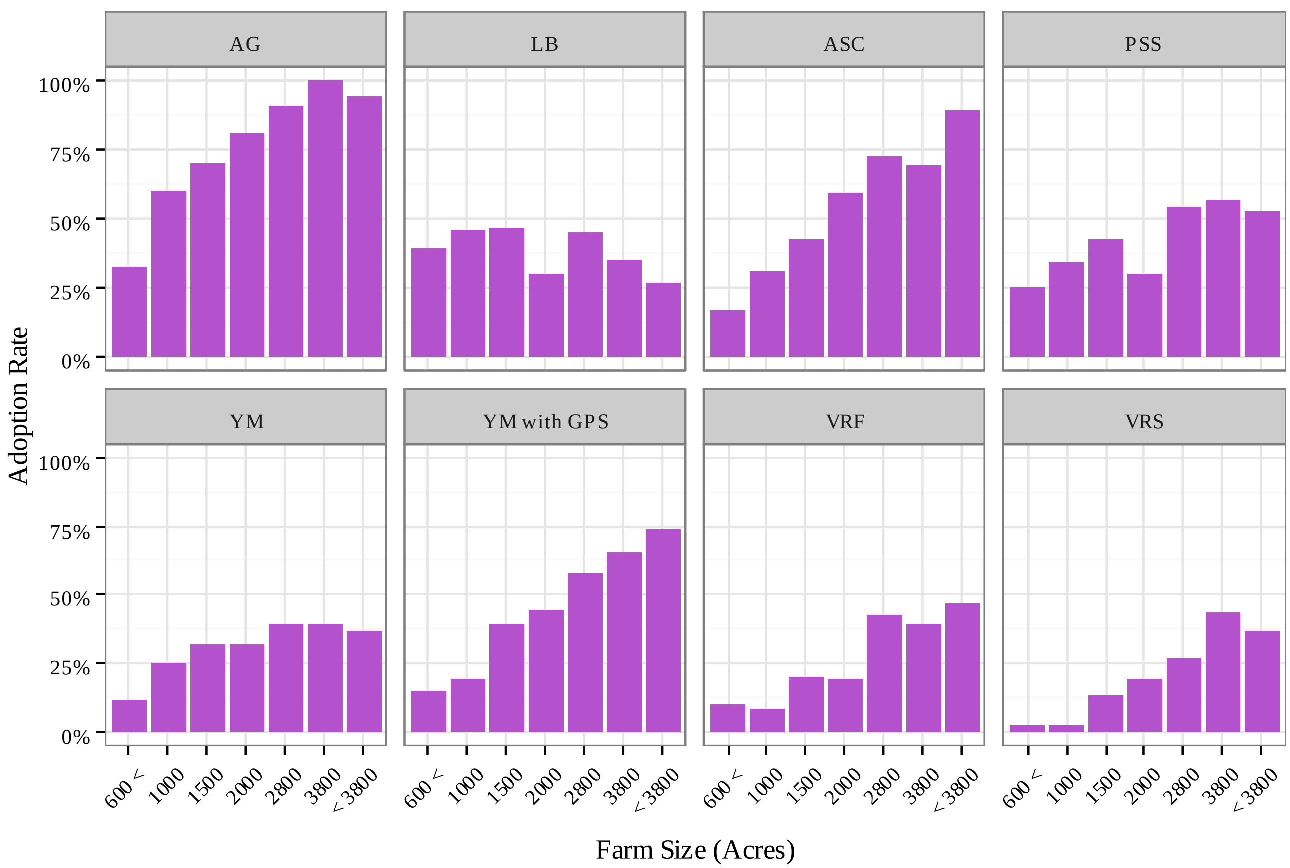

Figure 1. Adoption rate of PA Technology in 2015 by farm size

Operator's Age

The operator's age has a negative effect on PA adoption rates. Younger operators have higher adoption rates, however this effect is more pronounced in YM with GPS, ASC, PSS, AG and less in VRF, VRS, YM and LB (see Appendix Table 1). In fact, with LB and YM, adoption is only marginally higher with younger operators – the distribution of adoption is quite evenly spread across age groups. This is understandable, given that both YM and LB are older, albeit potentially obsolete technologies (Griffin, et al. 2016), with a longer history of familiarity across farmers of differing ages. On average, operators less than 60 years old have higher adoption rates than their older counterparts (Figure 2).

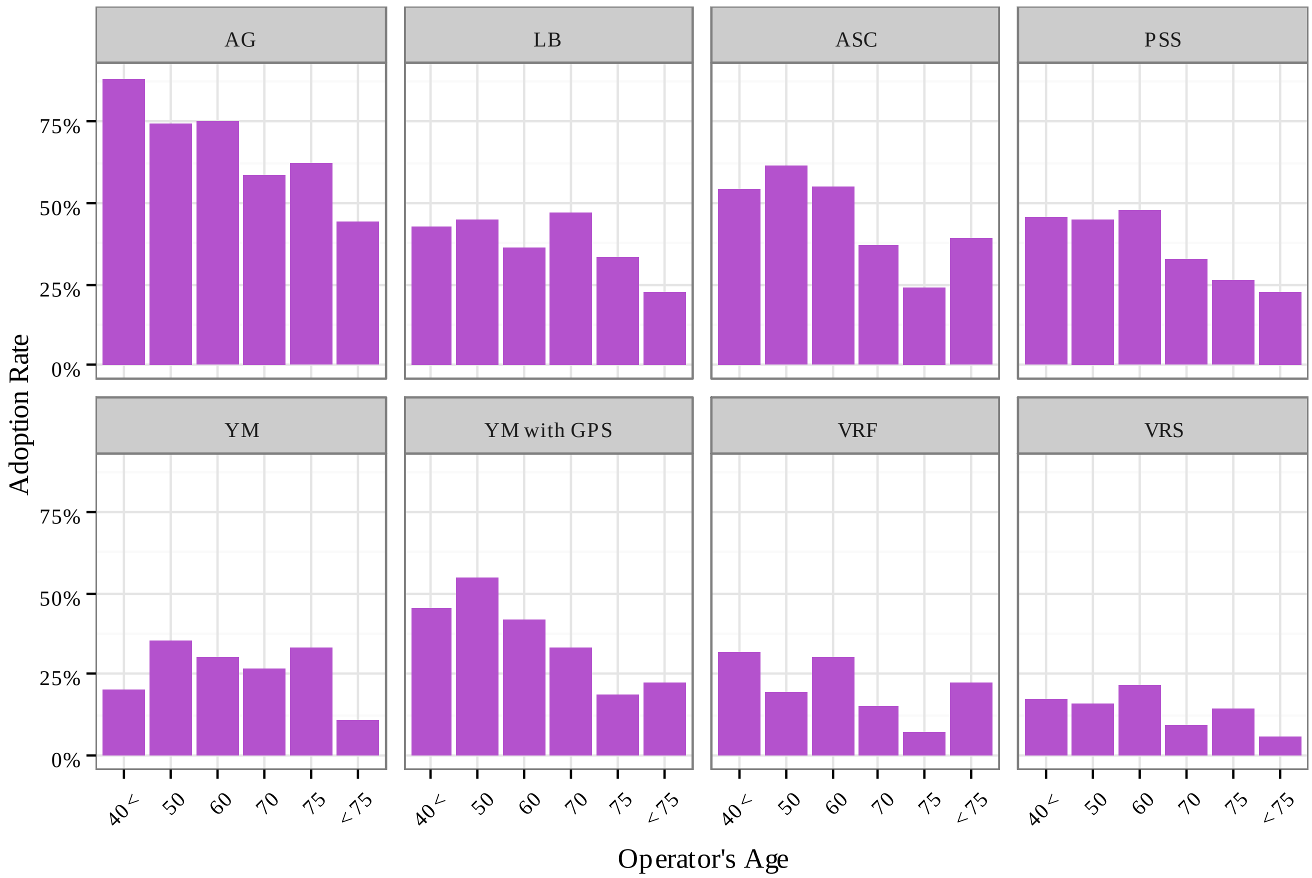

Figure 2. Adoption rate of PA Technology in 2015 by Operator's Age

Time

Finally, empirical evidences have shown that the probability of adopting PA technologies is affected by different factors explained in the adoption-decision model. Moreover, knowledge of how adoption likelihoods change over time assists agricultural businesses in marketing these products. The probability of adopting PA technologies was computed for the sample means with the following values: farmer's age of 52.5 years, cropping efficiency of 1.67 and risk aversion of 0.03, evaluated for farm size of 1,000, 1,500, 2,500 and 5,000 acres, from the year 2015 to 2020. It is expected that by 2020 90% of farms are likely to have adopted AG and ASC. Adoption rates are expected to be higher for YM with GPS than without GPS. The likelihood of adopting PSS is about 75% for farms with more than 5,000 acres and about 65% for smaller farms. For smaller farms with less than 2,500 acres the likelihood of adopting VRF or VRS is approximately 50% and 40%, respectively, by 2020. Conversely, for farms with more than 5,000 acres the probability of adopting VRF or VRS was expected to be 75% (Figure 3).

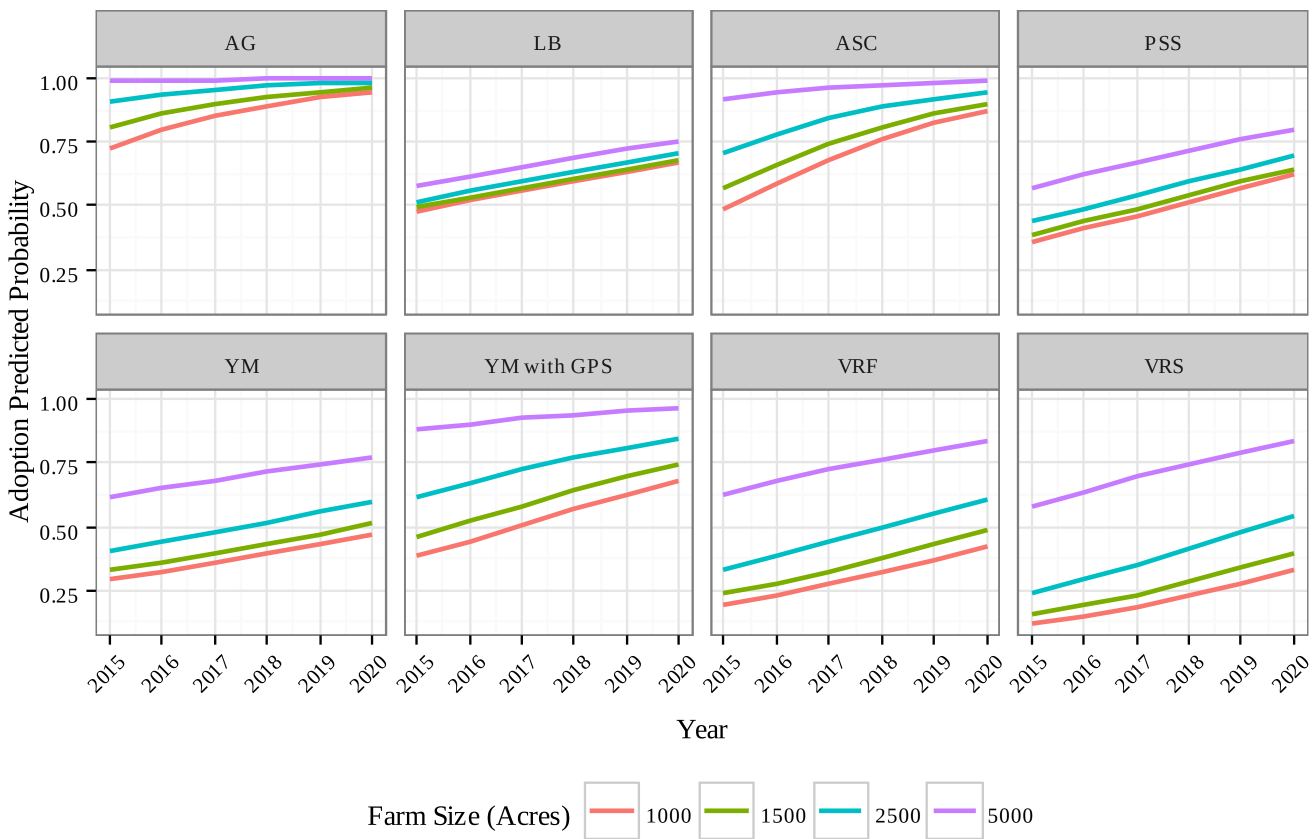

Figure 3. Adoption Predicted Probability by Farm Size 2010 – 2020

Conclusions

The Adoption-Decision Model indicated that similar factors influence the adoption of the PA technologies considered: Automated Guidance (AG), Lightbar (LB), Automated Section Control (ASC), Precision Soil Sampling (PSS), Yield monitors (YM), and Variable Rate Technologies (VRT). Larger acreage farms presented higher rates of adoption of most PA technologies, indicating possible economies of scale. The adoption of PA technologies was inversely related to the age of the primary operator. Experienced farmers with intimate knowledge of their operation may assess that some of these technologies do not add additional benefits within their planning horizon. The time variable played an important diffusion factor to explain increases in the adoption of PA technologies. However, further research is needed to measure the impact of PA technology on farm profitably and to develop guides to assist decision makers. These guides utilize farm characteristics as a benchmark against peer farm performance and determine optimal time to adopt these technologies to take advantage of the Gartner's Hype Cycle.

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Appendix

Table 1. Logit Regression Estimates of Adoption-Decision Model in PA technologies

Variable	AG[1]	LB	ASC	PSS	YM	YM with GPS	VRF	VRS
Log likelihood	-2048.75	-2937.78	-1475.93	-1883.15	-2172.33	-1863.77	-1240.36	-806.63
Sample Size	6,676	6,676	6,676	6,676	6,676	6,676	6,676	6,676
Prob > chi2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pseudo R2	0.42	0.13	0.37	0.18	0.13	0.26	0.20	0.24
Intercept	-753.37***	-317.02***	-793.35***	-431.5***	-308.91***	-495.19***	-445.32***	-526.36***
Farm Size (Acres)	0.0009***	0.0001***	0.0006***	0.0002***	0.0003***	0.0006***	0.0005***	0.0006***
Operator's Age	-0.0360***	-0.0142***	-0.0435***	-0.0373***	-0.0184***	-0.0478***	-0.0292***	-0.0247***
Cropping Eff.	-0.0844	0.0124	-0.1095	-0.1603**	-0.0307	-0.0493	0.1247	0.0071
Risk Aversion	-0.38	3.11***	0.38	-6.88***	-0.01	-3.96***	-12.45***	-3.16
Time	0.37***	0.16***	0.39***	0.21***	0.15***	0.25***	0.22***	0.26***

Note: Single, double, and triple asterisks (*, **, ***) indicate statistical significance at the 10%, 5%, and 1% level.

Table 2. Logit Regression Estimates of Adoption-Decision Model for Variable Rate Technologies

Variable	VRF	VRS
Log likelihood	-813.44	-576.48
Sample Size	6,676	6,676
Prob > chi2	0.00	0.00
Pseudo R2	0.47	0.46
Intercept	-87.47**	-46.19
AG[+]	1.41***	1.86***
LB[+]	-0.44***	-0.56***
ASC[+]	-0.30*	0.58***
PSS[+]	3.31***	1.48***
YM[+]	0.25	0.21
YM with GPS[+]	0.74***	1.74***
Acres	0.0004***	0.0004***
Age	-0.0024	0.0040
Cropping Eff.	0.42***	0.15
Risk Aversion	-11.66***	1.91
Year	0.04**	0.02

Note: Single, double, and triple asterisks (*, **, ***) indicate statistical significance at the 10%, 5%, and 1% level.

[1] AG: Automated Guidance, LB: Lightbar, ASC: Automated Section Control, PSS: Precision Soil Sampling, YM: Yield Monitor, YM with GPS: Yield monitor with GPS, VRF: Variable Rate Fertility, and VRS: Variable Rated Seed.

[+] Binary variable indicating whether or not the technology had been adopted.