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RESEARCH LETTER

Discovering farmers' views of on-farm precision experimentation

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Abstract

Precision agriculture technologies (PATs) have revolutionized agriculture production and provide many benefits to farmers. Among these benefits is the ability to conduct experiments using PATs and collaborate with researchers in a process known as on-farm precision experimentation (OFPE). OFPE is a citizen-science approach that fosters relationships and knowledge-sharing to address challenges of mutual interest. While the literature on precision agriculture is extensive, little research has addressed farmers' willingness to conduct OFPE with researchers. Interviews with 11 Illinois farmers revealed high adoption rates of PATs. Interest in collaborating with researchers to conduct OFPE was mixed, with farmers identifying clear channels of communication as the most important factor in their decision to collaborate. While additional study is needed among the larger farming community, these initial insights may contribute to the larger effort to encourage greater collaboration between researchers and farmers to find real-world solutions to agronomic, economic, and environmental challenges.

1 | INTRODUCTION

Precision agriculture technologies (PATs) have revolutionized the agriculture industry by improving efficiency and increasing profits through higher yields and lower input costs. PATs also make it easier and more convenient for farmers to conduct their own on-farm research and trials. Farmers can benefit from conducting on-farm precision experimentation (OFPE) by learning new practices and effectively employing site-specific management in their operations to help them balance economic pressures with environmental challenges. The benefits of OFPE are not just limited to farmers. For researchers, conducting OFPE can be beneficial because they engage directly with farmers to ensure that the topics being addressed are relevant to real-world production. OFPE can also foster relationships and knowledge-sharing between farmers and researchers to collaboratively address challenges of mutual interest (Krmenec & Stelford, 2022).

Despite these promoted benefits, PAT adoption rates have remained low throughout the United States. Farmers have yet to fully recognize the benefits of these technologies on their operations, including the ability to conduct their own on-farm research. Several studies have addressed the low adoption rates of PATs (e.g., Schimmelpfennig, 2016). However, one thing missing from the literature is a discussion of whether farmers are interested in conducting OFPE.

To contribute to the discourse about OFPE, an overall needs assessment of OFPE is needed. The needs assessment discussed herein explores topics such as motivating factors for farmers to conduct OFPE, their perceptions of the work done by university researchers on trial plots, and their interest in working with university researchers or extension agents to conduct OFPE. The first step of the needs assessment is to

Abbreviations: OFPE, on-farm precision experimentation; PATs, precision agriculture technologies; USDA, United States Department of Agriculture; VRT, variable rate technology.

gain initial insights from farmers. To accomplish this, interviews were conducted with 11 Illinois farmers, which revealed varying perspectives on PATs and OFPE.

1.1 | Literature review

Since their introduction, PATs have been widely analyzed, and the literature on PAT adoption is extensive. Because it is a more recent development, fewer studies have specifically addressed OFPE. However, conducting OFPE requires the use of PATs, and therefore these two bodies of literature are closely connected. The literature on PAT adoption can be broken into two groups: farmers' perceptions of PATs and the factors influencing a farmer's decision to adopt these technologies.

1.1.1 | Perceptions of precision agriculture technologies

Farmers perceive increased convenience from PATs such as autosteer and guidance, while variable rate technologies are more likely to reduce inputs and save costs (Batte & Arnholt, 2002). Furthermore, farmers believe that other significant benefits from using PATs include precise knowledge of soil nutrient and pH levels (Thompson et al., 2019). Enhanced monitoring of soil health and weather patterns can increase efficiency through the accurate application of inputs, and machinery can be managed more precisely and serviced when needed (Boehlje & Langemeier, 2022). Ofori and El-Gayar (2021) analyzed 45,000 posts on social media platforms such as Twitter, Reddit, and LinkedIn over a 10-year span, which showed that users were discussing topics such as data privacy and smart farming, yield gains/losses, and reducing climate change. However, a 2016 analysis of United States Department of Agriculture (USDA) data showed that only 30%–50% of corn and soybean acres were farmed using PATs, revealing the slow adoption rate of these technologies (Schimmelpfennig, 2016). Despite these low levels, there has been an increase in the adoption rates of some technologies (Boehlje & Langemeier, 2022).

A USDA Economic Research Service report outlined recent adoption trends for PATs important for conducting experiments, including yield monitors, autosteer, and variable rate technology (VRT) (McFadden et al., 2023). Autosteer and guidance systems have the highest adoption, being utilized on over 50% of soybean acres and nearly 60% of corn acres. Approximately 45% of corn and soybean acres utilize yield maps. VRT has been adopted on more than 35% of corn acres, but on only 25% of soybean acres. Additionally, almost 23% of corn acres and 13% of soybean acres utilize yield maps, guidance systems, and VRT together, demonstrating that these technologies are often adopted in conjunction with each other.

Core Ideas

- Precision agriculture technologies (PATs) allow farmers to engage in on-farm precision experimentation (OFPE).
- OFPE fosters farmer and researcher collaboration to help address agronomic challenges.
- This study provides initial insight into farmers' perceptions of and interest in OFPE.

1.1.2 | Factors affecting adoption decisions

Studies that have analyzed the factors affecting PAT adoption have placed these technologies into two categories. Embodied-knowledge technologies are defined as those that do not require a farmer to have specialized skills to use the technology (e.g., automated guidance), while information-intensive technologies generate substantial amounts of data that require interpretation (e.g., yield monitors or VRT) (Miller et al., 2019). Ofori et al. (2020) found that in general, embodied-knowledge technologies were adopted more quickly than information-intensive technologies, and younger farmers adopted technologies sooner than older farmers. Kolady et al. (2021) revealed that embodied-knowledge technologies (mainly autosteer and GPS guidance systems) had adoption rates above 50%. Among information-intensive technologies, only yield monitors had an adoption rate above 50%, while technologies such as satellite imagery and grid soil sampling were the least-adopted technologies. This study also supports the belief that farm size has a positive effect on the adoption of PATs.

Tey and Brindal (2022) found that a farmer's education, farm income, cropped farm size, access to consultants, use of computers, and perceived profitability from using these technologies all influence a farmer's decision to adopt PATs. Pierpaoli et al. (2013) analyzed drivers of adoption from an ex-post (after adoption) and ex-ante (before adoption) perspective. Ex-post, the most influential factors include farm size, desire to reduce costs/increase profits, a farmer's education level, and their familiarity with computers. Ex-ante, factors that affect farmers' decision to adopt include the presence of experts to help them learn the technology, a technology's ease of use, and a farmer's overall views of PATs (Pierpaoli et al., 2013).

Schimmelpfennig (2016) found that large operations in the United States are more likely to adopt PATs, with corn and soybean farms adopting them at higher rates than wheat, cotton, and rice operations. A survey of Midwestern corn farmers found that concerns regarding flooding can increase the likelihood of adoption by 13%, while concerns about soil erosion

can negatively affect the likelihood of adoption (Gardezi & Bronson, 2020). Owner-operators are less likely to use PATs, while farmers are more likely to use them if they rent the land they operate. Higher operational diversity (i.e., growing more than two crop enterprises a year, or raising livestock and growing crops) is also positively correlated with PAT use (Gardezi & Bronson, 2020). A study of US cotton farmers' adoption of autosteer technology found that farmers who indicated that PATs would be more important in the next 5 years were approximately 10% more likely to have adopted autosteer (D'Antoni et al., 2012).

A farmer's decision to adopt PATs may also be affected by data privacy concerns. Ellixson et al. (2019) argued that the vast amounts of money being invested into big data in agriculture demonstrates the value of farm-level data, and further noted that very few legal protections exist for farmers and data collected on farms. In a survey of Australian farmers, Wiseman et al. (2019) found that nearly 75% of the respondents did not know much about the terms and conditions associated with using these technologies, with half feeling uncomfortable about a technology provider having direct access to collected data. More than half of their respondents did not trust a technology provider to protect their privacy and not share data with a third party (Wiseman et al., 2019).

1.2 | Literature on OFPE

On-farm precision experimentation (OFPE) is a collaborative, demand-driven process that brings farmers and researchers together "around mutually beneficial experimentation" (Lacoste et al., 2022, p. 2). Farmers have long expressed their desire to be involved in the research process and contribute their knowledge and experience to experiments (Gerber, 1992). Many farmer-researcher organizations prioritize this collaboration, which is "citizen science" that "involve[s] the public in the research process to generate genuine scientific outcomes" (Fraisl et al., 2022, p. 1). One of the earliest organizations, the Practical Farmers of Iowa, was founded in 1985 and helps guide research on farming practices that are profitable and environmentally sound by conducting experiments in on-farm research plots controlled by the farmers (Thompson & Thompson, 1990). Additional groups, such as the Nebraska On-Farm Research Network and the Ohio State eFields program, also bridge the gap between farmers and researchers. These organizations work to implement field-scale research trials on farmers' fields to address issues that are of mutual interest to both groups such as identifying optimal production practices and identifying ways to achieve economic efficiency. On-farm research networks such as these "are among the most robust methods for promoting improved practices" (Ryan et al., 2018, p. 6).

Longchamps (2022) interviewed 10 farmers across New York State and found that all the farmers interviewed stated they are conducting some kind of OFPE, demonstrating that OFPE is important for these farmers to run their operations. Further results indicated these experiments required considerable time investments by a farmer, and farmers put much thought and consideration into their experiments (Longchamps, 2022). This study provides unique insights into the dynamic landscape of OFPE, but the literature addressing farmers' views of and willingness to engage in OFPE remains sparse.

2 | PROCEDURES

Phenomenological research "focuses on individual experiences, beliefs, and perceptions" (Guest et al., 2013, p. 8). This qualitative approach often focuses on a small number of in-depth interviews. Eighteen Illinois farmers were invited to participate in this phenomenological study, with 11 consenting to be interviewed in the summer of 2022 to explore their perceptions of OFPE (Illinois State University IRB 2022-130). This small sample size is consistent with recommendations including 3–15 participants (Creswell & Poth, 2018) or 5–25 participants (Polkinghorne, 1989), among others, for this type of research. These farmers represent a convenience sample, a non-probability form of sampling where the participants are readily and easily available (Taherdoost, 2016), and a frequent approach to qualitative research (Stratton, 2021). Three farmers were participants in the Data-Intensive Farm Management (DIFM) project, which is a multi-state network of farmers and university researchers that collaborate to implement on-farm field trials using PATs for the purpose of identifying site-specific best management practices through OFPE (Data-Intensive Farm Management Project, 2023). These interviews were conducted on Zoom. The other eight participants are farmers in Logan County, IL, and their interviews were conducted in person. Participants were asked a series of questions addressing demographics, their use of PATs, the benefits from using PATs, any concerns regarding internet access and data privacy, and their views on collaborating with researchers to conduct OFPE (Figure 1). Each interview took approximately 15 min to complete.

3 | FINDINGS AND DISCUSSION

3.1 | Findings

All participants produce corn and soybeans, with some also raising livestock or growing hay. Participants' operations ranged from as few as 300 acres to as many as 7500 acres.

1) How long have you been farming? Do you own or rent the ground? What types of crops do you grow?
2) How long have you used these technologies? What technologies do you use?
3) What benefits do you get from using precision agriculture technologies? Are there any negatives to using these technologies?
4) What comes to mind when you hear the term "on-farm precision experimentation?"
5) Have you done any "informal" experiments using precision technologies?
    a. If YES
        i. What was the goal of your experiment(s)?
        ii. How many acres did you dedicate to the experiment(s)?
        iii. How did you determine if the experiment(s) were effective?
        iv. Did you work with any researchers or crop consultants on the experiment(s)?
        v. What technology/technologies did you use to conduct the experiment(s)? Which technology/technologies were most effective and why?
    b. If NO
        i. Have you ever tried on-farm experimentation? If so, why did you not continue to conduct experiments?
        ii. What would encourage or motivate you to conduct on-farm experiments?
            1. Would the availability of a PA technology affect your decision to conduct experiments?
6) Do the precision technologies that you use require internet connection? Do you have a reliable internet connection to use these technologies?
7) Does access to internet affect your decision to use a precision technology? What about your decision to conduct OFPE?
8) In using a precision technology, would you be comfortable or willing to share data with a technology provider? If a provider had direct access to the data, would that cause any concerns on data privacy?
9) When you work with a university researcher/extension agent, how involved are you in the process? Do they keep you involved throughout the process?
10) What is your perception of university research trials on trial plots? Do you believe they have any relevance to your operations?
11) When the trials are completed, how do you get the results?
12) Would you be willing to work more closely with university researchers/extension agents to conduct OFPE?

FIGURE 1 Farmer interview script.

Nearly all participants use PATs to at least some degree. For example, one participant only uses a yield monitor, while another stated they were on the "cutting edge" of PAT use. Those that use PATs indicated several benefits of using these technologies, including the availability of data to make better decisions or to negotiate cash rent agreements, and saving money on input costs. One participant went as far to say PATs "changed [their] farm." Other than occasional setbacks, such as the time needed to learn how to use these technologies, all participants stated that the benefits outweighed those challenges.

Seven participants indicated they had conducted experiments in the past. Among this group, four had dedicated an entire field to an experiment and the remaining three used a smaller test plot or portion of a field. Variable rate nutrient and seeding application were the most common types of experiments reported. Aside from the three participants in the DIFM project, the remaining participants rarely work with a crop consultant or university researcher to conduct their experiments. This group identified clear, open, and consistent communication as the most important factor that would encourage them to collaborate with university researchers. Participants expressed varying opinions on the significance of university trial plot experiments, with four respondents paying little to no attention to university trial plots, three paying some attention to these experiments, and the remaining four paying very close attention to the experiments and seeking to implement the findings on their operations. Five participants would be willing to consider collaborating with researchers to conduct OFPE. For others, a lack of appropriate equipment, unwillingness to set acres aside for an experiment, and simply not being interested in OFPE were factors that would prevent them from collaboration.

Participants also expressed varying views on internet access and data privacy. Seven participants that use PATs indicated they had sufficient internet access to use those

technologies, but believed that having faster, more reliable internet in some parts of their operation would be necessary in improving the reliability and accuracy of these technologies. Regarding data privacy, eight participants were not aware of the terms and conditions associated with using their technologies but had little concern about the privacy of their data. However, two participants were extremely worried about who has access to data collected on their operations and what is done with their data.

3.2 | Discussion

Farmers' adoption of precision agriculture technologies (PATs), and the benefits farmers perceive from those technologies, is well established in the literature. On-farm precision experimentation (OFPE) can benefit both farmers and researchers; however, farmers' willingness to engage in OFPE has not been widely studied. OFPE enables researchers to expand their studies from trial plots to farmers' fields. The resulting collaborations between farmers and researchers can contribute to the wider conversation about management practices that can help farmers balance economic and environmental pressures. The interviews discussed in this study are an important first step in analyzing farmers' willingness to engage in OFPE and will serve as a pilot study for a survey to be designed and distributed to a larger and more diverse group of farmers. The results from this pilot study and survey will provide researchers with the tools to help them effectively collaborate with farmers to produce research findings that are of benefit to the wider agricultural community.

AUTHOR CONTRIBUTIONS

Reagen G. Tibbs: Conceptualization; data curation; formal analysis; investigation; writing—original draft; writing—review and editing. **Maria A. Boerngen**: Conceptualization; funding acquisition; methodology; project administration; supervision; writing—review and editing.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

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