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Regional Dynamics of Precision Agriculture Adoption and Knowledge Transfer: Insights from Georgia Extension Agents

G. Orton[1], C.-L. Lee[2]

Abstract

The Cooperative Extension System plays a vital role in disseminating innovative knowledge from the University to public decision makers. However, there is a lack of studies on the dynamics of knowledge transfer from Extension agents to farmers, especially in the Southeastern U.S. in relation to precision agriculture adoption. This study aims to examine the dynamics of farmers' engagement with Extension agents in the state of Georgia, particularly concerning the adoption of precision agriculture. This study conducted a survey of Agriculture and Natural Resource Extension agents in Georgia; 84 agents were surveyed. The findings indicated that more than half of the Extension agents reported that they had been approached by farmers about precision agriculture-related Extension services in the past two farming seasons. The statewide average precision agriculture adoption rate was 43.78%, but adoption rates varied by geographic region, with the southern part of Georgia reporting a higher adoption rate than the northern part of the state. The findings offer insight into the information-seeking relationship between change agents and farmers in a precision agriculture context by focusing on the perspective of Extension agents, laying the groundwork for future research to explore the complementary viewpoint from targeted current and potential precision agriculture adopters.

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1. Ginger Orton, Assistant Professor, University of Georgia, 180 E. Green St., Athens, GA, 30602, ginger.orton25@uga.edu, https://orcid.org/0009-0005-4582-7700
2. Chin-Ling Lee, Assistant Professor, University of Georgia, 405 College Station Rd., Athens, GA, 30602, cllee@uga.edu, https://orcid.org/0000-0001-7752-6113

Introduction and Problem Statement

The Cooperative Extension System (CES) plays a vital role in disseminating innovative research from land-grant universities to the public, particularly agricultural producers for whom the institution was founded. Through outreach, Extension seeks to make innovative knowledge relevant, beneficial, and actionable to the public (National Institute of Food and Agriculture, 2025). Across the last 20 years, precision agriculture (PA) technology has increased in salience across scientific and industry domains. While multiple definitions of PA exist, we draw from DeBoer and Erickson's (2019) definition which states, "Precision agriculture is a management strategy that uses electronic information and other technologies to gather, process, and analyze spatial and temporal data for the purpose of guiding targeted actions that improve efficiency, productivity, and sustainability of agricultural operations" (p. 1553). PA technologies can generally be grouped into three categories: tools for collecting data (such as soil and yield monitors, sensors, or drones), tools for supporting decision-making (such as mapping software), and tools for adjusting inputs (such as variable-rate application systems) (Thompson et al., 2018). Together, they support the precise application of inputs such as water, fertilizer, and herbicides and provide economic and environmental benefits, thus benefiting both the farmer and society at large, as opposed to traditional whole-field applications (Getahun et al., 2024; Sanyaolu & Sadowski, 2024; Šarauskis et al., 2022). The economic savings of precise application are particularly important in a time of increasing input costs (Athearn, 2025).

Knowledge transfer from Extension agents to farmers is a two-way, symbiotic relationship essential for effective dissemination of beneficial innovations. Without meaningful interactions between the two, Extension's mission cannot be fulfilled, and farmers may not receive insight that can improve their operations. Extension agents have historically been trusted and sought by farmers across topics (Camillone et al., 2020; Heaney-Mustafa et al., 2018; Orem et al., 2024), however, only a small pool of research has investigated the dynamics between American farmers and Extension agents in the context of PA (Lee et al., 2023; Looney et al., 2022). Specifically, research has called for a more granular examination of engagement and adoption surrounding PA in an American context (Júnior et al., 2024). As an example, the most recent 2022 United States Department of Agriculture (USDA) Census broadly measured adoption as whether farmers use PA, but it did not investigate which practices farmers use (USDA, 2025). A deep dive into regional PA adoption patterns and the dynamics between farmers and Extension agents can contribute to improving engagement and overall adoption of PA.

Theoretical Framework

To frame this investigation, constructs from two theories were used: Rogers' (2003) Diffusion of Innovation (DOI) and Katz et al. (1973) Uses and Gratifications. Together, these theories help describe the way individuals, in this case farmers, seek information about novel technologies.

Rogers' (2003) DOI theory explores how innovations like PA diffuse through society and highlights the role of change agents in this process. Change agents, such as Extension agents,

influence the adoption of innovations within social system groups, like farmers. Agents accelerate how the technology's applications and benefits spread among potential adopters.

However, change agents are only effective when those receiving knowledge seek and receive meaningful information from the agent. These interactions are represented in Katz et al.'s (1973) uses and gratifications theory, which helps explain how and why individuals, such as farmers, engage with information sources, such as Extension agents. Information seekers play an active role in choosing their knowledge sources and seek information to fulfill their needs. As Extension agents are a primary information source for farmers, it is essential that Extension agents be prepared to meet farmers' information needs, including understanding the benefits of PA and farmers' adoption motivations to best leverage these concepts when engaging with farmers.

Purpose

This study sought to understand the dynamics of farmers' engagement with Extension agents in the state of Georgia, particularly concerning the PA knowledge transfer channels. The objectives of this study were to investigate the role of Extension agents in facilitating PA adoption by describing (a) the current state of farmers' engagement with Extension agents about PA information delivery methods, and (b) Georgia's regional PA adoption. These findings provide an updated and alternative description of PA adoption and information seeking in Georgia, which can improve targeted outreach determined to increase both meaningful engagement between farmers and Extension agents and adoption of PA.

Methods

To address the study's objectives, we conducted a census-style survey following Dillman et al's (2014) tailored design method. The instrument consisted of 13 questions that addressed the competencies required for PA knowledge transfer and the usage of existing communication channels. The data presented in this article were analyzed from a set of questions related to the usage of existing communication channels, aiming to address the research questions of this study. The target population included 127 Agriculture and Natural Resources (ANR) Extension agents affiliated with the University of Georgia Cooperative Extension. These individuals were selected because their work involved PA or direct interaction with farmers who either currently use or have the potential to adopt PA technologies. Recruitment was supported by the administrative teams of UGA Extension's four districts.

The instrument asked agents a series of questions to describe their clientele's information seeking frequency and production context related to PA. The item development was informed by information-seeking constructs in two theories: Uses and Gratification (Katz et al., 1973) and Diffusion of Innovation (Rogers, 2003) as well as the core components of the Extension mission to provide information dissemination to farmers. Additionally, the survey instrument underwent iterative rounds of expert review by a University of Georgia ANR specialist and an

Extension faculty member to assess content clarity and face validity. Information seeking was measured using a categorical question asking, “Thinking back to the past two planting and harvest seasons, how frequently have producers come to you with precision agriculture questions, discussions, or challenges?” with the options of never, once 3-5 times, 5-10 times, more than 10 times. The question focused on just the past two planting and harvest seasons to provide a consistent timeframe for each respondent in a relatively easy to recall span. Respondents were also asked to enter a numeric percentage of organic and conventional clientele as well as the percentage of clientele who currently use PA (0% to 100%). Additionally, we asked them to rank the top five commodity groups they directly work with as well as the percentages of each type of Extension clientele (e.g., crop farmers, homeowners, etc.). These last three questions were included to provide more context to the information-seeking landscape. The types of PA adopted in their regions were measured qualitatively by asking them to list examples. Given the qualitative nature of the data and the diversity in terminology used by respondents, we used a thematic analysis approach to identify the types of PA organically from the data while referencing common PA technology in the literature.

Surveys were administered both in print and electronically. In two Extension districts, questionnaires were distributed in person during ANR Extension Agent Update meetings. The remaining two districts utilized an online version due to the absence of scheduled meetings during the data collection window. Data were gathered in February 2025. A total of 87 agents completed the survey, yielding a response rate of 69%. After excluding three incomplete submissions, the final dataset included 84 valid responses (N = 127; n = 84), with a satisfactory response rate of 66% (Fincham, 2008). The majority of respondents were male (n = 55; 65%) with a mean age of 41.21 years (SD = 13.35), ranging from 22 to 70 years. The participants reported an average of 10.67 years of experience in Extension roles (SD = 10.9), ranging from 0.5 to 48 years.

Data analysis was conducted using SPSS version 29 and Excel. To analyze the qualitative responses, we used an inductive coding approach to create categories that could comprehensively capture the practices mentioned. The codebook underwent two rounds of revisions until it was established as reliable, meaning both authors categorized all mentioned practices similarly under each code.

Findings

The first research objective sought to describe how frequently Extension agents were contacted about PA. Participants selected how many farmers contacted them regarding PA from the options shown in Table 1.

Table 1

Frequency of Farmers Seeking PA Information During the Last Two Planting and Harvesting Seasons (n = 79)

Frequency Option	*f*	%
None	23	29.1
1 or 2 producers	20	25.3
3-5 producers	19	24.1
6-10 producers	9	11.4
More than 10 producers	8	10.1

The second research objective was to describe the current state of PA technologies were implemented in each agent's region, as well as the percentage of farmers using PA in each county. Fifty participants (59.5%) were able to list examples of PA. Table 2 reports the frequency of practices mentioned by participants.

Table 2

Frequency of Applied Technologies in Georgia (n = 50)

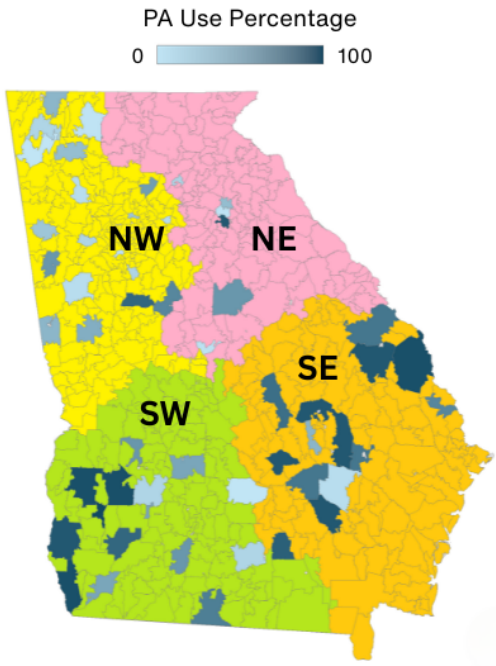
Technology	*f*	%
GPS	22	46
Auto-navigate	16	32
Sensors – moisture	14	28
Data collection & monitoring	14	28
Drone – general	13	26
VRT	12	24
Equipment	11	22
Irrigation	10	20
Mapping	9	18
Yield monitors	5	10
Drone – spray	5	10
GIS	2	4
Sensors – general	2	4

Note. Participants could list multiple technologies; therefore, the total number of technologies exceeds the number of respondents.

Respondents were also asked to report the perceived percentage of farmers in their district who were currently using PA. An average adoption rate of 43.78% was reported (Min = 0% adoption, Max = 100% adoption). The most frequently reported percentage of adoption was 10%, which represented 9 participants (10.7%), followed by 7 (8.3%) participants who reported 90% of their constituents used precision agriculture. Figure 1 maps the percentage density of PA adoption by county in Georgia.

Figure 1

PA Adoption Percentage Mapped by County in Georgia with Regional Distinction



Note. NW = northwest region, NE = northeast region, SW = southwest region, SE = southeast region; Regions based on CES classification in Georgia; All data were mapped by zip code, which may span county lines typically used by CES to define regions in Georgia

The agent's clientele was examined in terms of frequencies of organic and conventional production, the most present commodities, and the type of clientele. Most production was conventional (85%), with 15% classified as organic production. Table 3 represents the mean rankings of the most present commodities in respondents' districts.

Table 3

Extension Agent's Clientele Commodity Categorizations (n = 82)

	N	*M*	*SD*
Peanuts	39	1.90	1.14
Nursery	23	2.17	1.34
Cotton	40	2.30	1.24
Vegetables	36	2.42	1.38
Poultry	13	2.77	1.83
Hay	58	2.78	1.46
Fruit	39	2.87	1.44
Beef	49	2.98	1.55
Tobacco	3	3.00	2.00
Corn	36	3.08	1.18
Aquaculture	3	3.33	2.08
Horses	11	3.45	1.51
Soybeans	13	3.62	1.61
Sheep	8	3.88	1.46
Christmas Trees	6	4.00	.89
Grains	5	4.20	.45
Hogs	2	4.50	.71
Dairy	3	4.67	.58

Note. Categories are sorted from the lowest mean to the highest mean, because the mean score represents a rank, with 1 being the highest, most frequent rank, and 5 being the least frequent ranking, indicating a lower frequency.

The Extension agents identified all seven client categories as targets for their services, with crop growers being the most prevalent. Seventy-two respondents reported that, on average, 40.37% of their clients were crop growers, followed by homeowners (i.e., those seeking services related to maintaining, improving, or managing their home and landscape) with a percentage of 23.7%. Table 4 listed the most common constituent classifications of Extension agents' clientele.

Table 4

The Most Common Constituent Classifications of Extension Agents' Clientele (n = 82)

Classification	*N*	*M*	*SD*
Crop Growers	72	40.37	31.66
Livestock Producers	74	18.58	16.38
Foresters	56	6.27	6.43
Homeowners	76	23.70	20.51
Hobby Gardeners	70	10.94	12.15
Small Businesses	61	7.97	11.21
Educators	62	6.11	7.83

Note. Mean represents the average percentage of each classification reported.

Conclusions, Discussion, and Recommendations

The DOI framework emphasizes the role of change agents in the adoption process through their information exchange relationship (Rogers, 2003). Extension agents are prime candidates to foster PA adoption, and more than half of the ANR Extension agents (*n* = 56, *N* = 79, 70.9%) responded that they had been approached by at least one farmer about PA-related Extension services in the last two farming seasons. The uses and gratifications theory helps explain why individuals seek and engage with certain information sources (Katz et al., 1973), and our findings suggest farmers are choosing to engage with Extension agents about PA to meet their information needs. Because of this existing relationship, Extension agents must be provided with continued support to ensure they are prepared with the relevant knowledge and skills to meet farmers' information needs (Luck et al., 2015). Farmers need support and assistance to adopt the PA technologies, and Extension agents are uniquely positioned to provide this support (Lee et al., 2021). Additionally, Extension agents must be prepared to meet farmers' information needs when farmers seek PA-related information and be ready to support PA integration. Areas of high adoption density in the southern part of the state could also be promising places to start and may serve as hubs to drive adoption expansion in neighboring counties with large-scale production and hence increased propensity to adopt. Extension agents will need to collaborate with farmers and Extension agents beyond their counties to increase both adoption and meaningful knowledge transfer from the CES to the farmer.

The constituent classification results revealed that Georgia Extension agents work with diverse groups, primarily homeowners, livestock producers, crop growers, and hobby gardeners. This finding should be maintained when executing professional development and resource allocation. Although PA is increasing in salience for some constituent groups (e.g., crop growers, foresters, livestock producers), research also shows these groups tend to seek information from private consultants and agribusiness dealers (Erickson & Lowenberg-DeBoer, 2024), which illuminates the need for both capacity-building among Extension agents and an increased awareness among producers of the potential for agents to meet their PA needs. The findings highlight the importance of ensuring Extension agents are equipped with foundational PA knowledge to respond to the demand from this group of clientele effectively.

To further describe the potential observability of adoption (Rogers, 2003), we also sought to understand the current PA adoption rates in Georgia. Of the 84 respondents, 50 (59.5%) listed one or more examples of PA being used in their district. When asked which practices were being used, almost half of our respondents (*n* = 24, 48%) listed GPS or GIS technology, followed in frequency by auto-navigate technology (*n* = 16, 32%) and moisture sensors and data collection and monitoring (each with *n* = 14, 28%). Drones, VRT, equipment such as planters, and irrigation were each mentioned more than 10 times. It should be noted that the USDA Census only broadly measures PA use as yes/no, but has not yet measured the types of practices used, and no other studies have investigated Georgia's PA use on the county level. Therefore, the documentation of which practices are being used in Georgia provides novel insight into adoption. However, the variability and limited specificity in Extension agents'

responses regarding PA technologies suggest a potential gap in their familiarity with commonly defined categories in the literature and those used by industry providers (Erickson & Lowenberg-DeBoer, 2024). Many responses from Extension agents were broad or lacked detail, which underscores the need for targeted educational efforts to enhance Extension agents' knowledge of PA tools and terminology.

Across the state, an average adoption rate of 43.78% was reported. However, when looking at the county level, patterns emerge. The southern half of the state had higher levels of reported adoption than the northern half, which aligns with findings from the 2022 USDA Census (USDA, 2025). This finding is further supported by the fact that most of the large-scale peanut and cotton production takes place in the southern half of the state (USDA, 2025), aligning with studies finding high-density commodities adopt PA technologies more rapidly (Schimmelpfennig & Lowenberg-DeBoer, 2020), likely because their benefits are more visible to farmers (Rogers, 2003), encouraging adoption. Our findings do differ from the 7% PA use rate reported in the 2022 USDA Census, which may suggest Extension agents perceive there is more adoption due to the nature of their clientele who may be early adopters or have high information seeking behavior. Additionally, while PA can be used on both organic and conventional operations, most agents reported they worked with conventional clientele. The 2022 USDA Census reported the number of organic farms in Georgia had steeply declined by 19% from 2017 to 2022, with only 105 certified organic farms reported (<1%) (USDA, 2025). Our data showed Extension agents perceived a higher rate of organic production (15%), demonstrating organic farmers may be more engaged with Extension and therefore perceived as higher in number.

This study offers insight into the change agents and information-seeking relationship by focusing on the perspective of the Extension agent, laying the groundwork for future research. Notably, our instrument could have benefited from additional quantitative items to increase its reliability and better capture the role Extension agents play in the knowledge transfer process. While our qualitative measurement of which PA technologies are being used is a place to start, future inquiry should extend these findings to understand which technologies agents are confident in and which would benefit from further training. We also recommend that future research should build upon this foundation to explore the complementary viewpoint by measuring information-seeking behavior and motivations using a farmer sample to provide a more comprehensive understanding of adoption challenges and information dissemination process. Additional qualitative inquiry into the nature of the interactions from each viewpoint would also contribute meaningful insight.

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References

Athearn, K. (2025). Farm input costs rise and commodity crop prices fall. *University of Florida Institute of Food and Agricultural Sciences*. https://blogs.ifas.ufl.edu/nfrecsv/2025/05/14/farm-input-costs-rise-and-commodity-crop-prices-fall/

Camillone, N., Duiker, S., Bruns, M. A., Onyibe, J., & Omotayo, A. (2020). Context, challenges, and prospects for agricultural Extension in Nigeria. *Journal of International Agricultural & Extension Education*, *27*(4), 144–156. https://newprairiepress.org/jiaee/vol27/iss4/9/

Dillman, D. A., Smyth, J. D., & Christian, L. M. (2014*). Internet, phone, mail, and mixed-mode surveys : The tailored design method* (4th ed.). John Wiley & Sons Inc.

Erickson, B., & Lowenberg-DeBoer, J. (2024). 2024 precision agriculture dealership survey. *Croplife Magazine & Purdue University*. https://ag.purdue.edu/idaas/_media/croplife-purdue-precision-dealer-report-2024-1.pdf

Fincham, J. E. (2008). Response rates and responsiveness for surveys, standards, and the journal. *American Journal of Pharmaceutical Education*, *72*(2), 43. https://doi.org/10.5688/aj720243

Getahun, S., Kefale, H., & Gelaye, Y. (2024). Application of precision agriculture technologies for sustainable crop production and environmental sustainability: A systematic review. *The Scientific World Journal*, *2024*, 2126734. https://doi.org/10.1155/2024/2126734

Heaney-Mustafa, S., Sofo, F., Afzal, M., Anwar, Z., Fatima, B., & Hasan, F. U. (2018). Bridging farmer and researcher: Extension through the eyes of agents in rural Pakistan. *Journal of International Agricultural and Extension Education*, *25*(3), 111–124. https://doi.org/10.5191/jiaee.2018.25308

Júnior, M. R. B., de Almeida Moreira, B. R., dos Santos Carreira, V., de Brito Filho, A. L., Trentin, C., de Souza, F. L. P., Tedesco, D., Setiyono, T., Flores, J. P., Ampatzidis, Y., da Silva, R. P., & Shiratsuchi, L. S. (2024). Precision agriculture in the United States: A comprehensive meta-review inspiring further research, innovation, and adoption. *Computers and Electronics in Agriculture*, *221*, 108993. https://doi.org/10.1016/j.compag.2024.108993

Katz, E., Blumler, J. G., & Gurevitch, M. (1973). Uses and gratifications research. *The Public Opinion Quarterly*, *37*(4), 509-523. https://doi.org/10.1086/268109

Lee, C.-L., Strong, R., Briers, G., Murphrey, T., Rajan, N., & Rampold, S. (2023). A correlational study of two U.S. State Extension professionals' behavioral intentions to improve sustainable food chains through precision-farming practices. *Foods*, *12*, 2208. https://doi.org/10.3390/foods12112208

Lee, C.-L., Strong, R., & Dooley, K. E. (2021). Analyzing precision agriculture adoption across the globe: A systematic review of scholarship from 1999–2020. *Sustainability*, *13*(18), 1–15. https://doi.org/10.3390/su131810295

Looney, L., Montgomery, P., Edwards, M. C., Arnall, B., & Raun, W. R. (2022). Producers' adoption behaviors for precision agriculture (PA) technologies to improve nitrogen use efficiency: Diffusion of Innovations theory as an explanatory lens. *Advancements in Agricultural Development*, *3*(3), 40–50. https://doi.org/10.37433/aad.v3i3.205

Lowenberg-DeBoer, J., & Erickson, B. (2019). Setting the record straight on precision agriculture adoption. *Agronomy Journal*, *111*(4), 1552–1569. https://doi.org/10.2134%2Fagronj2018.12.0779

Luck, J. D., Fulton, J. P., & Rees, J. M. (2015). Hands-on precision agriculture data management workshops for producers and industry professionals: Development and assessment. *The Journal of Extension*, *53*(4). https://doi.org/10.34068/joe.53.04.04

National Institute of Food and Agriculture. (2025). Cooperative extension system. *United States Department of Agriculture*. https://www.nifa.usda.gov/about-nifa/what-we-do

Orem, M., Leggette, H., Parrella, J. A.; Lu, P., Palmer, K., Foster, J., Neely, H., & Noland, R. (2024). Harvesting trust: Exploring credible information sources about soil health practices for U.S. wheat farmers. *Journal of Applied Communications*, *108*(4). https://doi.org/10.4148/1051-0834.2553

Rogers, E. M. (2003). *Diffusion of innovations* (5th ed.). Free Press.

Sanyaolu, M., & Sadowski, A. (2024). The role of precision agriculture technologies in enhancing sustainable agriculture. *Sustainability*, *16*(15), 6668. https://doi.org/10.3390/su16156668

Šarauskis, E., Kazlauskas, M., Naujokienė, V., Bručienė, I., Steponavičius, D., Romaneckas, K., & Jasinskas, A. (2022). Variable rate seeding in precision agriculture: recent advances and future perspectives. *Agriculture*, *12*(2), 305. https://doi.org/10.3390/agriculture12020305

Schimmelpfennig, D., & Lowenberg-DeBoer, J. (2020). Farm types and precision agriculture adoption: Crops, regions, soil variability, and farm size. *Global Institute for Agri-Tech Economics Working Paper*, 01–20. https://doi.org/10.2139/ssrn.3689311

Thompson, N. M., Bir, C., Widmar, D. A., & Mintert, J. R. (2019). Farmer perceptions of precision agriculture technology benefits. *Journal of Agricultural and Applied Economics*, *51*(1), 142-163. https://doi.org/10.1017/aae.2018.27

United States Department of Agriculture. (2025). Census of agriculture. *National Agricultural Statistics Service*. https://www.nass.usda.gov/AgCensus/