ADVANCING PRECISION AGRICULTURE EDUCATION IN SUB-SAHARAN AFRICA: EXPLORING FACTORS FOR SUCCESS AND OBSTACLES

F.J. Adekoya, B.V. Bamidele, T.E. Adefare
Integrated Aerial Precision, Lagos, Nigeria
femi@iaprecision.com, +2348136163231

ABSTRACT

Precision Agriculture (PA) is a critical tool for addressing food security challenges, yet its adoption in Sub-Saharan Africa (SSA) remains low. This study examines the role of education in advancing PA adoption, focusing on barriers and opportunities for integrating PA into the agricultural curriculum in SSA, with Nigerian institutions as a case study. A mixed-methods approach was employed, involving 227 respondents comprising faculty, undergraduate, and postgraduate students from tertiary institutions. Quantitative surveys assessed awareness, familiarity, and factors influencing PA adoption, while qualitative interviews explored curriculum integration and potential solutions.

Findings reveal a significant gap in PA education, with 57.71% of respondents reporting no exposure to PA-related courses. Familiarity with basic tools such as GPS and drones was moderate, while advanced technologies like robotics and telemetry were largely unfamiliar. Key barriers include limited curriculum integration, inadequate digital infrastructure, and insufficient faculty expertise.

The study underscores the importance of updating agricultural curricula to incorporate PA concepts, enhancing digital infrastructure for practical learning, and providing faculty development programs through workshops and certifications. These reforms are essential to equip future agricultural professionals with the skills needed to adopt and implement PA, thereby fostering a skilled workforce capable of leveraging advanced technologies for sustainable agriculture. This research highlights the transformative potential of education in overcoming barriers to PA adoption, contributing to enhanced agricultural productivity and food security in SSA.

Keywords: Precision Agriculture, Sub-Saharan Africa, Agricultural Education, Technology Adoption.

INTRODUCTION

Globally, food production is projected to increase by 50% by 2050 to meet the needs of the rapidly growing population (FAO, 2020). Achieving this demand is unlikely without advanced technologies to improve food security, as traditional methods alone may fall short. Precision Agriculture (PA) has emerged as a vital approach to meet these challenges, focusing on efficiency, sustainability, and productivity. It relies on advanced technologies, including Geographic Information Systems (GIS), remote sensing, drone technology, and data analytics, to improve crop production while minimizing environmental impact (Gebbers & Adamchuk, 2010).

While Precision Agriculture (PA) is gaining momentum in developed countries due to advancements in technology and infrastructure (Fountas et al., 2020; Roberts et al., 2021), Sub-Saharan Africa (SSA) has been slower to adopt these innovations due to barriers such as limited digital infrastructure, high costs, and a lack of technical expertise (Mabaya et al., 2022; Tsan et al., 2019).

The education sector plays a crucial role in accelerating PA adoption by equipping farmers, agronomists, and extension workers with the skills necessary to implement these advanced technologies. With a growing population and the urgent need for food security, particularly in Sub-Saharan Africa (SSA), PA presents significant potential for improving agricultural productivity in the region. However, the successful adoption and implementation of PA largely depends on the level of education, awareness, and skill proficiency of the agricultural workforce (Tsan et al., 2019)

Precision agriculture education when incorporated into the Education curricula could increase the adoption of data-driven technologies and enhance the quality of agricultural education in Sub-Saharan Africa (SSA). However, for SSA where agriculture is a key livelihood and food security is a priority, this incorporation would mean that students enter the workforce well-prepared to contribute to resilient, productive agricultural systems.

This study aims to access the level of knowledge about precision agriculture in the education system in Sub-Saharan Africa, using university faculty, undergraduate, and postgraduate students in Nigeria as a case study to examine the familiarity with PA tools and technologies, and the factors and barriers influencing their willingness to adopt PA or become an expert in PA tools and the extent of PA integration in the academic curriculum.

MATERIAL AND METHODOLOGY

This study which was conducted in Nigeria adopted a mixed-method approach to retrieve data from penultimate year students, final-year students, postgraduate students, and lecturers of the Faculty of Agriculture across tertiary institutions in Nigeria. Quantitative data were gathered through a structured questionnaire, while qualitative data was collected using an in-depth interview.

The questionnaire was structured to gather information from respondents regarding their socio-economic characteristics, awareness and familiarity with Precision agriculture tools, and factors influencing their willingness to adopt PA or become an expert in PA tools. In addition, the qualitative interview contained questions regarding the integration of PA into educational curriculum as well as recommendations to the government and educational institutions. The study employed a purposive sampling method to collect data from 227 respondents across six geopolitical zones and analyzed using STATA. The analytical approaches used were descriptive statistics such as percentage and frequencies to examine the socio-economic characteristics, likert scale to measure level of familiarity with precision tools and willingness to adopt precision agriculture tools was analyzed using linear regression. The qualitative responses were then analyzed using thematic analysis.

RESULT AND DISCUSSION

Variables	Categories	Frequency	Percentage
Sex	Female	85	**37.44**
	Male	142	**62.56**
Age	18-30	142	**62.55**
	31-50	79	**34.80**
	51-65	6	**2.6**
	Min	18	
	Max	62	
Category of the Respondents	Finalist	62	27.31
	Lecturer/staff	42	18.50
	Penultimate year	28	12.33
	Post graduate Student	95	41.85
Taught or taken any course in Precision Agriculture	No	131	**57.71**
	Yes	96	**42.29**

Table 1.0 : Demographic characteristics of respondents

The discussion shows that most respondents are male (62.55%). This agrees with (Luka et al., 2023; Omotosho et al., 2020) who conducted a survey and found higher male participation in agricultural-related careers. A greater proportion of the respondents (62.55%) fall within the age bracket of 18-30. This is similar to the findings of (Luka et al., 2023) who found the mean age of agricultural students in Bauchi state to be 27 years indicating that their mean age is between 18 -30 years.

Based on the proportion of respondents who had been taught or taken any course relating to Precision Agriculture, most of the respondents (57.71%) had never taught or taken any course relating to PA. This likely implies that the majority of the agricultural students in Nigeria have not been exposed to the concept of precision agriculture via their institutions. This agrees with the findings of Adepoju et al., 2022 and Nyaga et al., 2021 who found in their studies that a significant gap exists in the learning and teaching of precision agriculture in tertiary institutions in Nigeria as many students have not been exposed to courses relating to PA.

Table 2.0: Level of familiarity with precision agriculture tools

PA Tool	Extremely Familiar	Moderately Familiar	Not Familiar At All
Variable Rate Application	9 (3.96)	85 (37.44)	116 (51.10)
GPS/GNSS	9(3.96)	98(43.17)	85(37.44)
Yield and Soil Moisture Sensor	6 (2.64)	78(34.36)	120(52.86)
Drones	6(2.64)	98(43.17)	86(37.89)
GPS Tracker	9 (3.96)	92 (40.53)	80 (35.24)
Digital Fencing	6 (2.64)	81 (35.68)	121 (53.13)
Field Sensor	5 (2.26)	85 (37.44)	113 (49.78)

Data Analytics	7 (3.08)	105 (46.26)	86 (37.88)
Digital Soil maps	6 (2.64)	80 (35.24)	119 (52.42)
Telemetry Systems and Automation Tech	6 (2.64)	48 (21.15)	165 (72.69)
Machine Vision Tech for livestock	4 (1.76)	53 (23.35)	159 (70.04)
Automated Feeding System for Livestock	7 (3.08)	96 (42.29)	89 (39.21)
Robotic Milking Systems	4 (1.76)	7 (33.04)	131 (57.71)
Electronic Identification for Livestock	6 (2.64)	79 (34.80)	12.5 (55.07)

Frequency/ Percentage

Table 2.0: Level of familiarity with precision agriculture tools

The survey reveals that the respondents are familiar with basic tools such as GPS, Drones, and Data Analytics in Precision Agriculture and less familiar with advanced tools like Robotic Milking systems, Telemetry systems, and automation technology

Willingness to adopt precision agriculture tools

Performance expectancy (PE): For every one-unit increase in Performance Expectancy, the behavioral intention to adopt PA increases by approximately 0.752 units. This strong positive relationship suggests that respondents believe that adopting PA will significantly enhance their performance, making this factor crucial in influencing their willingness to engage with PA technologies. This finding is similar to the result of Eweoya et al., 2021, who conducted a survey and found that performance expectancy is the most significant factor that influences the adoption of e-agriculture in Nigeria. In addition, Lee et al. (2023) highlights that performance expectancy significantly predicts professionals' intention to adopt precision agriculture technologies. This emphasizes the importance of demonstrating clear and tangible benefits of such technologies to potential users.

Effort Expectancy (EE): the coefficient of 0.214 indicates that EE positively influences adoption, though its effect is smaller compared to PE. This suggests that when PA technologies are perceived as easier to use, the students and lecturers are more likely to consider adoption ($p < .01$) or become experts in PA technology. This agrees with Al-zboon et al., 2022, that effort expectancy is positive and significant to the attitude of science and mathematics teachers towards integrating ICT in their teaching activities.

Social influence: The result shows that SI, with a coefficient of 0.048, is not statistically significant ($p = .292$), implying that social factors—such as recommendations from others—do not have a strong impact on adoption intentions for Precision agriculture technology. This agrees with Tey and Brindal (2012), that while social factors like recommendations can play a role, they are typically weaker predictors of technology adoption in precision agriculture compared to economic and technical factors, such as perceived financial benefits, ease of use, and productivity improvements.

Facilitating Conditions: The coefficient of 0.248 for FC is significant, indicating that when supportive resources or infrastructure are available, the likelihood of adoption or tendency to become an expert by the respondents, increases ($p < .01$). This is similar to the findings of Reichardt and Jurgens, (2009). In their research, Reichardt and Jürgens found that access to supportive infrastructure, such as technical resources and financial support, significantly enhances the adoption of precision agriculture technologies. Their findings highlight that when farmers have the necessary resources and infrastructure, they are more likely to adopt precision farming practices and improve their expertise over time.

Perceived Challenges: Having a negative coefficient of -0.217, PC significantly reduces the willingness to adopt or become an expert in PA. This suggests that the more challenges (e.g., high costs, technical difficulties) individuals perceive, the less inclined they are to adopt PA ($p < .01$). This agrees with Paustian, M., & Theuvsen, L. 2017. In their study, Paustian and Theuvsen found that perceived challenges (e.g., high initial costs, complexity of use) were significant barriers to adopting precision agriculture technologies. Their analysis suggests that as perceived difficulties increase, farmers are less likely to adopt these technologies, highlighting a negative association between perceived challenges and adoption intentions.

Predictor Variables	Coefficient	Standard Error	T value	P value
Performance Expectancy average	0.752***	0.048	15.69	0.0000
Effort Expectancy average	0.214***	0.051	4.18	0.000
Social Influence average	0.048	0.046	1.06	0.292
Facilitating Condition average	0.248***	0.033	7.61	0.0000
Perceived Challenges average	-0.217***	0.041	-0.526	0.0000
Constant	-0.995	0.277	-0.360	0.0000
Mean dep Variable 484.495				
R- squared 1.000				
F-test 3460540.518				

Summary of the Qualitative Interview

Results of the qualitative interview show the perceived benefits of precision agriculture as it enhances speed and accuracy in farming, reduces the workload of the farmers and assists in farm-data collection. The Finalists and Postgraduate students cited drone technology, GPS, and sensors as the technology they are most familiar with. The respondents gave high cost and gap in knowledge as the major barriers in the adoption of the PA tools. The respondents further noted that the integration of PA into their educational curriculum was very low. In terms of the respondent's willingness to adopt or become experts in Precision Agriculture, the respondents noted that the provision of education and training to the younger generation will attract students to agriculture. As stated by one of the respondents "I have a passion for training farmers. If I gain more knowledge, I will be able to train others" shows a willingness to enhance their knowledge and educate others too on precision agriculture.

CONCLUSION AND RECOMMENDATIONS

This study underscores the critical role of education in advancing Precision Agriculture (PA) adoption in Sub-Saharan Africa, with Nigeria as a case study. The findings reveal a significant gap in PA education, as many agricultural students lack exposure to PA concepts and tools due to insufficient curriculum integration. Despite these challenges, there is growing awareness among students and faculty about PA's potential to transform farming practices and enhance food security. The study highlights performance expectancy, effort expectancy, and facilitating conditions as key drivers of PA adoption, while perceived challenges deter progress.

To address these gaps, educational institutions in SSA must prioritize updating agricultural curricula to integrate PA concepts and tools. Providing students with practical training on technologies such as drones, GPS systems, and data analytics is essential to preparing them for the evolving demands of modern agriculture. Investment in digital infrastructure is critical to ensure access to the necessary tools for hands-on learning.

Additionally, supporting faculty development through workshops, seminars, and certifications will enhance their ability to teach PA effectively and bridge existing knowledge gaps. By equipping both students and educators with the skills and resources required for PA adoption, institutions can foster a skilled workforce capable of leveraging advanced technologies for sustainable agriculture and improved food security.

REFERENCES

Adepoju, O., Esan, O., and Akinyomi, O. (2022). Food Security in Nigeria: Enhancing Workers' Productivity in Precision Agriculture. Journal of Digital Food, Energy & Water Systems. https://doi.org/10.36615/digital_food_energy_water_systems.v3i2.

Ajao, H., Alegbeleye, I., and Westfall-Rudd, D. (2022). Curriculum Design In An Agricultural Education Program In Nigeria: Towards Advancing Career Readiness. Advancements in Agricultural Development, 3(2), 17-30. https://doi.org/10.37433/aad.v3i2.159

Chaudhary, S., Patel, J., and Raval, K. (2023). Attitude And Aspiration Of Undergraduate Agricultural Students. Gujarat Journal of Extension Education. https://doi.org/10.56572/gjoee.2023.35.2.0007.

Ekea, U. U. (2019). Weed Science Education At The Tertiary Educational Level In Nigeria. Agriculture, Forestry And Fisheries, 8(1), 27. https://doi.org/10.11648/j.aff.20190801.15

Eweoya, I., Okuboyejo, S., Odetunmibi, O., and Odusote, B. (2021). An empirical investigation of acceptance, adoption and the use of E-agriculture in Nigeria. Heliyon, 7. https://doi.org/10.1016/j.heliyon.2021.e07588.

Food and Agriculture Organization (FAO). (2020). The State of Food Security and Nutrition in the World 2020.

Fountas, S., Mylonas, N., Malounas, I., Gemtos, T. A., & Blackmore, S. (2020). Precision Agriculture Technology in Fruit Production: Status, Challenges and Future Trends. *Computers and Electronics in Agriculture*, 170, 105309

Gebbers, R., & Adamchuk, V. I. (2010). Precision agriculture and food security. *Science*, 327(5967), 828-831.

Lee, C., Strong, R., Briers, G., Murphrey, T., Rajan, N., and 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. https://doi.org/10.3390/foods12112208.

Luka, J., Murtala, N., and Sani, M. H. (2023). Socio-Economic Factors Influencing Choice Of Agribusiness As Career Option After Graduation Among Agricultural Students Of Tertiary Institutions In Bauchi State, Nigeria. *Nigerian Journal of Agriculture and Agricultural Technology*, *3*(1), 85-96.

Mabaya, E., & Gahakwa, D. (2022). *Precision Agriculture in Africa: Addressing Food Security and Economic Transformation*. African Journal of Science, Technology, Innovation and Development, 14(1), 50-58.

Nyaga, J., Onyango, C., Wetterlind, J., and Söderström, M. (2021). Precision agriculture research in sub-Saharan Africa countries: a systematic map. Precision Agriculture, 1-20. https://doi.org/10.1007/S11119-020-09780-W.

Nguyen, L., Khuu, D., Halibas, A., and Nguyen, T. (2023). Factors That Influence the Intention of Smallholder Rice Farmers to Adopt Cleaner Production Practices: An Empirical Study of Precision Agriculture Adoption.. Evaluation review, 193841X231200775. https://doi.org/10.1177/0193841X231200775.

Obi, B., and Oladokun, B. (2023). Security Measures in Meeting Information Needs and Seeking Behaviour of Agricultural Science Students in Nigerian Universities. Southern African Journal of Security. https://doi.org/10.25159/3005-4222/14383.

Omotosho, A., Emmanuel, A., Ayegba, P., and Ayoola, J. (2020). Impact of Agricultural Education on Students' Career Choice: A Survey. Int. J. Emerg. Technol. Learn., 15, 51-61. https://doi.org/10.3991/ijet.v15i03.11260.

Paustian, M., & Theuvsen, L. (2017). Adoption of precision agriculture technologies by German crop farmers. *Precision Agriculture*, 18(5), 701–716. https://doi.org/10.1007/s11119-016-9482-5

Reichardt, M., & Jürgens, C. (2009). Adoption and future perspective of precision farming in Germany: Results of several surveys among different agricultural target groups. *Precision Agriculture*, 10(1), 73–94. https://doi.org/10.1007/s11119-008-9101-1

Roberts, M. J., Schimmelpfennig, D., & Livingston, M. (2021). Precision Agriculture Adoption and Technical Efficiency. *American Journal of Agricultural Economics*, 103(2), 589–615

Tey, Y. S., and Brindal, M. (2012). Factors influencing the adoption of precision agricultural technologies: A review for policy implications. *Precision Agriculture*, 13(6), 713–730. https://doi.org/10.1007/s11119-012-9273-6

Tsan, M., Totapally, S., Hailu, M., & Addom, B. K. (2019). The Digitalisation of African Agriculture Report 2018–2019. CTA. Retrieved from https://cgspace.cgiar.org/handle/10568/101498

Yekinni, O., Ladigbolu, T., Adeniyi, R., and Oluwasusi, S. (2021). Information and Communication Technologies Usage among Agricultural Students of Tertiary Institutions in Southwest of Nigeria. The Journal of Agricultural Extension, 24, 1-10. https://doi.org/10.4314/JAE.V25I1.1.