ADOPTION OF PRECISION AGRICULTURAL TECHNIQUES IN VOCATIONAL AGRICULTURE TRAINING PROGRAMMES IN UNIVERSITIES IN ABIA STATE: A PATHWAY TO SUSTAINABLE WORKFORCE DEVELOPMENT

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Abstract

Precision Agriculture Techniques (PATs) offer economically efficient and environmentally sustainable practices in agriculture, which is salient for workforce development in vocational agriculture training programs (VATPs). Despite their potentials, challenges persist in adopting these technologies within educational settings, particularly in Nigeria. This study explored the adoption of precision farming techniques within VATPs as a strategy for sustainable workforce development in Abia State, Nigeria. Specifically, it assessed the availability of PFTs, their adoption levels among lecturers, awareness, and identified barriers hindering their effective integration. A descriptive survey approach was employed. This study conveniently sampling 25 lecturers from two public universities in Abia State. A validated questionnaire (Precision Agriculture Techniques Questionnaire-PATsQ-42) was used for data collection. After a pilot study, the reliability indexes of the five constructs of the instrument measuring the research objectives (RQ1-5) was determined using Cronbach's alpha coefficient method at 0.98, 0.87, 0.84, 0.89 and 0.86 respectively. Data collected for the study was analyzed using descriptive statistics like frequency counts and percentages. The study revealed a mixed availability of PATs within VATPs, with certain technologies like precision irrigation systems and data analytics software being relatively available, while GPS and remote sensing were notably absent. Smart sensors and data analytics were more commonly adopted compared to other technologies. Most lecturers demonstrated high awareness of PATs, but knowledge gaps existed. Significant barriers identified included curriculum integration challenges, funding limitations, inadequate institutional support, and lack of technological skills among lecturers. Addressing identified challenges and leveraging opportunities can facilitate the successful adoption of PATs within VATPs, enhancing vocational agriculture education in Abia State. This study recommended prioritizing institutional support, curriculum enhancements, faculty development, and increased funding for VATPs to overcome existing limitations.

Keywords: Precision Farming Techniques, Vocational Agriculture Training Programs, Workforce Development, Technology Adoption

Introduction

The use of Precision Farming Techniques (PFTs) within Vocational Agriculture Training Programs (VATPs) represents a critical pathway towards sustainable workforce development. Precision agriculture technologies (PATs) or PFTs offer economically efficient and environmentally sustainable practices (Kolady *et al.,* 2020). These technology-enabled, data-driven approaches observe, measure, and analyze the needs of individual fields and crops, promoting sustainable farming management (Monteiro *et al.*, 2021). It involves the integration of digital technologies into the agri-food supply chain, with the goal of improving food security and production, as proposed for Nigeria's post-COVID-19 era (Oruma *et al.,* 2021). These technologies include Wireless Sensor Networks (WSN), Internet of Things (IoT) devices, sensors, drones, and data analysis tools (Shafi *et al.,* 2019; Dokin & Aletdinova, 2021; "Smart Agricultural Internet of Things Remote Control System", 2022). PFTs utilize wireless sensor networks and automation to enable farmers to vary inputs and practices spatially and temporally,

such as the application of fertilizers, pesticides, and cultivation techniques, thereby promoting environmental sustainability (Jacobs *et al.,* 2018).

Furthermore, precision agriculture has the potential to reduce agricultural inputs, enhance sustainability, and increase production to meet the growing worldwide demand for food (Nicol & Nicol, 2018).The adoption of precision farming has been linked to economic advantages, farm size, and educational levels of farmers, indicating its potential to drive agricultural innovation (Balogh *et al.,* 2020). Furthermore, the adoption of precision agriculture technologies has been associated with within-field yield variability, indicating its potential to enhance productivity and efficiency in agriculture (Paxton *et al.,* 2011).

The application of PATs has been observed in various regions, such as India and Nigeria, indicating its global relevance and potential for widespread adoption (Afroj *et al.,* 2016; Rilwani & Ikhuoria, 2011). Additionally, the adoption of PATs has been studied in different contexts, such as cotton production and small-scale, highly mechanized Central European agriculture, demonstrating its versatility and applicability across diverse agricultural settings (Roberts *et al.,* 2004; Groher *et al.,* 2020). Moreover, the sustainable development goals, launched by the United Nations in 2015, emphasize the importance of workforce development and capacity building in contributing to sustainable agricultural practices (Mukhalalati *et al.,* 2021). Arguably, the adoption of PFT into VATPs aligns closely with the Sustainable Development Goals (SDGs) outlined by the United Nations. In the context of Nigeria, the adoption of PFTs can significantly impact agricultural practices. For instance, the use of unmanned aerial vehicle (UAV) technology for high-throughput 3-D monitoring of agricultural-tree plantations can enable site-specific management of homogenous zones, leading to increased economic returns for farmers by economizing on inputs and field operations (Torres-Sánchez *et al.,* 2015). Additionally, the implementation of precision in Nigeria's agricultural innovation generating sub-system, which includes universities, research institutes, and experimental stations, can further enhance the development and adoption of PFTs (Oyewole & Oyediran, 2022).

However, the adoption of precision agriculture in VATPs in Nigeria may face challenges related to knowledge gaps and the insufficiency of remote sensing technologies in the agricultural sector (Khanal *et al.,* 2020). Overcoming these challenges would require a competent approach to predict crop yield based on soil conditions, utilizing advanced technologies such as convolutional neural networks (CNN) and machine learning algorithms (Rajkumar *et al.,* 2022; Rehaan *et al.,* 2020). Furthermore, the role of precision agriculture in promoting conservation agriculture and sustainable practices in Nigeria should be carefully studied and integrated into the existing agricultural framework (Thierfelder *et al.,* 2018; JI *et al.,* 2022). Deductively, this study argues that the adoption of PFTs can offer significant potential for transforming agricultural practices in Nigeria, with the promise of improving productivity, sustainability, and economic returns for farmers. In light of this argument, this study explored the adoption of precision farming techniques within vocational agriculture training as a pivotal strategy for sustainable workforce development. More so, by harnessing the economic and environmental benefits of PATs, VATPs can nurture a skilled workforce capable of implementing and advancing sustainable agricultural practices. However, addressing knowledge gaps, adopting advanced technologies, and promoting sustainable agricultural practices are crucial for the successful implementation of precision agriculture in the Nigerian context.

Undoubtedly, precision farming has the potential to revolutionize modern agriculture in Nigeria by enhancing productivity and sustainability. However, the successful adoption of PATs in VATPs requires a comprehensive understanding of the current awareness and knowledge of lecturers, and barriers associated with this technology (Blair *et al.,* 2023). A study has shown

that the adoption of PFTs is influenced by economic and social barriers, such as lack of knowledge and attitude among farmers, which hinder the widespread implementation of precision farming practices (Balogh *et al.*, 2021). Arguably, farmers and potential farmers are educated through VATPs. Therefore, assessing the current awareness and understanding (knowledge) of precision farming among vocational agriculture Lecturers is crucial to identify any knowledge gaps that may impede effective use of this innovative technology. However, extensive literature search by this study on databases such as Google Scholar, Web of Science, Scopus, Science-Direct, Semantic Scholars and ProQuest reveals that there seems to be dearth of empirical evidence on this subject. Current literature reviewed focused on other aspects of agriculture, other than the use of PATs in VATPs. For instance, the study by Jitea *et al.* (2021) assessed the level of knowledge and awareness regarding farming practices, which can provide insights into the current awareness and understanding of precision farming among vocational agriculture lecturers (Jitea *et al.*, 2021). Additionally, Masi *et al.* (2022) understudied the complexity that can hinder technology adoption, which can be relevant to identifying barriers to the use of PFTs in the vocational agriculture training by lecturers. Furthermore, the study by Reimers & Klasen (2013) emphasized the role of education in agricultural productivity, which can be valuable in evaluating the impact of precision farming education on workforce development of vocational agriculture graduates.

The subject of precision agriculture (PA) has been extensively studied across different regions, reflecting a broad interest in understanding its adoption and impact. Researchers have investigated various aspects related to PA, including awareness and knowledge among students and farmers, workforce competencies, educational practices, and adoption trends in specific geographic contexts. Studies such as Khalilia *et al.* (2024) and Keskin & Sekerli (2016) have explored awareness and adoption of PA technologies among students and farmers in Palestine and Turkey, respectively. These studies revealed gaps in understanding and highlighted the role of education in promoting PA practices.nErickson *et al.* (2018) focused on assessing the knowledge, skills, and abilities required in the precision agriculture workforce, shedding light on industry demands and workforce development needs. Heidenreich (2018) examined teacher practices related to PA education in secondary agricultural programs, emphasizing educators' role in preparing students for careers in agriculture. Other studies, like Bournaris *et al*. (2022) and Vecchio *et al.* (2020), investigated the skills and training needs of students and farmers in euro-mediterranean regions and Italy, respectively. These studies provided insights into educational gaps and factors influencing PA technology adoption. Additionally, Register (2022) delved into the role of conservation specialists in promoting the adoption of precision agriculture in Nebraska, emphasizing the intersection of agricultural conservation practices and technology integration.

However, it is important to note that the literature reviewed lacked specific studies on PATs with regards to its adoption and availability in Vocational Agricultural training programs in Nigeria, lecturers' knowledge and awareness, and its impacts in skill force development of students, especially in Abia state. While some studies conducted in Nigeria, such as those by Ogwumike & Akinnibosun (2013) and (Obayelu *et al.*, 2020), addressed issues of agriculture in Nigeria, they do not specifically focus on precision farming or vocational agriculture technologies (Ogwumike & Akinnibosun, 2013; Obayelu *et al.*, 2020). Therefore, there is a gap in the literature regarding availability, adoption and barriers to PATs in VATPs, its impact on workforce development, and lecturers' level of knowledge and awareness, particularly in Universities in Abia state. Moreover, the identification of barriers to adopting PATs in vocational agriculture training is essential to address challenges faced by Agricultural Educators.

Research Objectives

The following objectives guided this study.

1. To find if PATs are available in Vocational Agriculture Training Programmes (VATPs) in Universities in Abia state.
2. To investigate the level of use of PFTs in VATPs in Universities in Abia state. .
3. To examine the existing level of awareness of PATs among Lecturers in VATPs in Universities in Abia state.
4. To identify the barriers to the use of PATs by Lecturers in VATPs in Universities in Abia state. .
5. To assess the potential impacts of PATs on the development of workforce skills among students in VATPs in Universities in Abia state.

Research Questions

The following research questions were posed and answered by this study.

1. What PATs are available in VATPs in Universities in Abia state?
2. What is the level of adoption of PATs in VATPs in Universities in Abia state?
3. What is the level of awareness of PATs among Lecturers in VATPs in Universities in Abia state?
4. What the barriers to adoption of PATs by lecturers in VATPs in Universities in Abia state?
5. What are the potential impacts of PATs on the development of workforce skills among in VATPs in Universities in Abia state?

Methods

This study adopted a descriptive survey research design. The research conveniently sampled 25 Vocational Agriculture and Agricultural lecturers, from two public universities in Abia State, who were accessible and willing to participate in the study. The sample size was determined based on feasibility and the focus of the research on obtaining in-depth insights from a manageable number of participants within the targeted academic setting. The primary data collection instrument used was the "Precision Agriculture Techniques Questionnaire (PATsQ=42)", made up of 42-items. This instrument had five clusters measuring each of the specific research questions (RQ1-5). The questionnaire was carefully structured, validated, and pilot-tested to ensure reliability, with a Cronbach's alpha coefficient of 0.98, 0.87, 0.84, 0.89 and 0.86, respectively for each of the five constructs (RQ1-5) in the PATsQ-42, indicating high internal consistency. Data collection for this study spanned over a period of 4 months, during which the validated questionnaire was administered to the selected lecturers. The researchers ensured ethical considerations throughout the data collection process, obtaining informed consent from participants and maintaining confidentiality and anonymity of responses. Descriptive analysis techniques, including frequency counts and simple percentages, were employed to analyze the collected data. This approach allowed for a comprehensive overview of the respondents' perceptions, attitudes, and practices related to PATs in vocational agriculture education.

Ethical Considerations

Prior to participation, lecturers were informed about the purpose of the study, the voluntary nature of their involvement, and the confidentiality of their responses. Informed consent was obtained from each participant to ensure voluntary and ethical participation. To protect the privacy of participants, all collected data were treated confidentially. Respondents' identities were anonymized during data analysis and reporting to maintain confidentiality and prevent any potential breach of privacy.

Results

The results of this study are presented in the Tables below.

Table 1: Availability of PATs in VATPs in Universities in Abia State **n=25**

S/N	Item Statements	Yes (f)	No (f)	Yes (%)	No (%)
1	Global Positioning System (GPS) for precision navigation	2	23	8	92
2	Variable Rate Technology (VRT) for fertilizer or pesticide application	0	25	0	60
3	Remote sensing (e.g., drones or satellites) for crop monitoring	0	25	0	100
4	Precision irrigation systems (e.g., drip irrigation)	19	6	76	24
5	Soil sensors for monitoring moisture, nutrients, or pH levels	16	9	64	36
6	Automated machinery for planting or harvesting	11	14	44	56
7	Data analytics software for yield mapping and analysis	15	10	60	40

*Yes (f)" represents the number of lecturers who responded "Yes" to each item statement. "No (f)" represents the number of lecturers who responded "No" to each item statement. "Yes (%)" represents the percentage of lecturers who responded "Yes" to each item statement. "No (%)" represents the percentage of lecturers who responded "No" to each item statement. Number of respondents (*n=25)

Results in Table 1 above describe the availability of PATs within Vocational Agriculture Training Programmes in Universities in Abia State based on responses from lecturers. Specifically, precision irrigation systems (e.g., drip irrigation), soil sensors for monitoring, data analytics software for yield mapping and analysis were relatively prevalent, with 76%, 64%, and 60% of lecturers reporting the availability of these technologies, respectively. Also, automated machinery for planting or harvesting was reported to be available by 44% of lecturers, against 66% who reported that they were not available. In contrast, small minority (8%) of lecturers reported availability of GPS for precision navigation, while the majority (92%) did not. More so, PATs like Variable Rate Technology (VRT) for fertilizer or pesticide application and remote sensing (e.g., drones or satellites) for crop monitoring were notably absent, as reported by 100% of the respondents surveyed. The findings show a mix of available and lacking PATs in VATPs in Universities in Abia state, thus, revealing opportunities for enhancing VATPs to align with modern and best global agricultural practices and technological advancements.

Table 2: Frequency Distribution on the Responses of Respondents on level of adoption of PATs in Vocational Agriculture Training Programmes in Universities in Abia State

S/N	PATs	Not Used (f)	Minimally Used (f)	Moderately used (f)	Highly Used (f)
1	GPS	23	1	1	0
2	VRT for fertilizer	25	0	0	0
3	RS	25	0	0	0
4	PIS	6	12	7	0
5	SS	6	14	2	0
6	AM	14	6	5	0
7	DA	10	6	9	0

*Number of respondents (*n=25**),** *f = frequency of responses of the respondent , Global Positioning System (GPS), Variable Rate Technology (VRT), Remote sensing (RS), Precision Irrigation System (PIS), Soil Sensors (SS), Automated machinery (AM), Data Analytics (DA).*

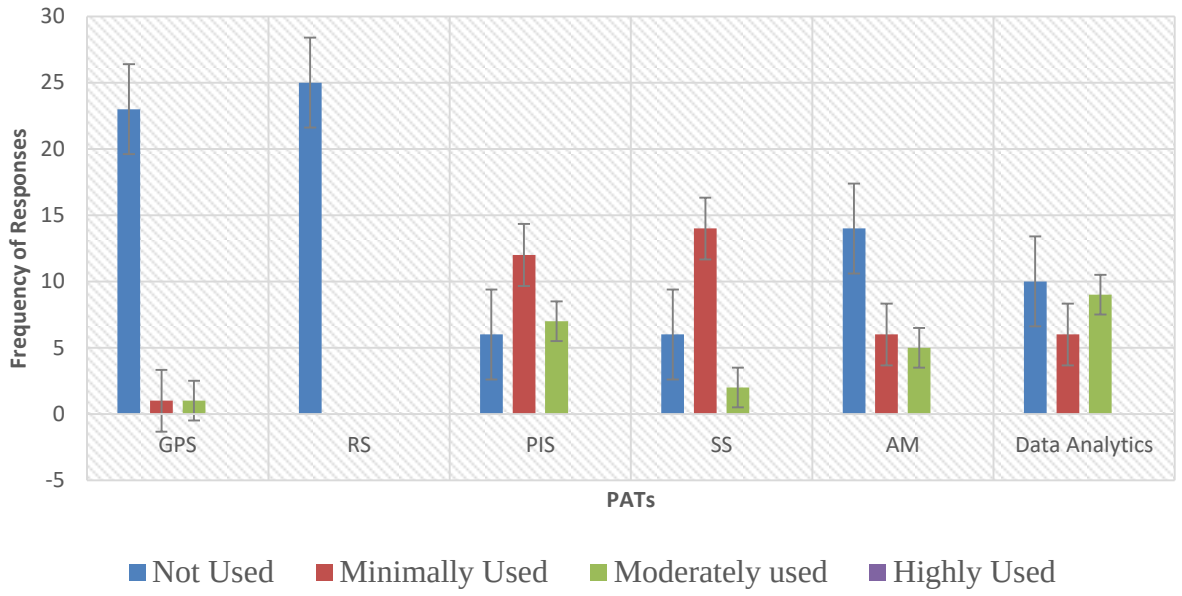

Fig. 1: Level of Adoption of PATs in Vocational Agriculture Training Programmes

Data in Table 2 and figure 1 above describe a varying degree of adoption of PATs in vocational agriculture training programs in universities in Abia State, with certain technologies like Smart Sensors and Data Analytics being more commonly used compared to others like Remote Sensing, Global Positioning System, Automation/Mechanization and VRT for fertilizer are predominantly not used in vocational agriculture training programmes in Abia State Universities. However, technologies like Precision Irrigation Systems, Smart Sensors, and Data Analytics show varying levels of adoption, with some respondents reporting these technologies to a minimal or moderate extent.

Table 3: Level of Awareness of PATs among Lecturers in VATPs in Universities in Abia State

S/N	Item Statements	NA		LA		MA		HA	
		f	%	*f*	%	*f*	%	*f*	%
1	I am familiar with the concept of Precision Agriculture Techniques (PATs).	**0**	**0**	**3**	**12**	**5**	**20**	**17**	**68**
2	I am aware of following PATs used in vocational Agriculture training programmes								
	GPS	0	0	7	28	2	8	16	64
	VRT for fertilizer	0	0	5	20	7	28	13	52
	RS	0	0	3	12	8	32	14	56
	PIS	0	0	5	20	5	20	15	60
	SS	0	0	3	12	4	16	18	72
	AM	0	0	0	0	0	0	25	100
	Data Analytics	0	0	2	8	1	4	22	88
	% Average		**0**		**14.28**		**15.42**		**70.30**

*NA = Not Aware, LA = Low Awareness, MA = Moderate Awareness, HA = High Awareness, Number of respondents (*n=25)

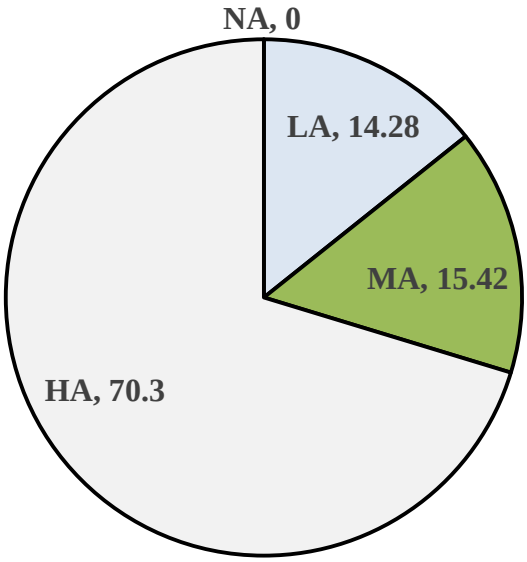

Figure 2: Percentage Distribution of the Responses of Respondents on Level of Awareness

Results in Table 3 and Figure 2 above indicate the level of awareness of Precision Agriculture Techniques (PATs) among lecturers in Vocational Agriculture Training Programmes in Universities in Abia State. The results indicate that the majority of lecturers (70.3%) are highly aware of PATs, indicating a high level of expertise in this area. However, a notable portion (around 30%-LA-MA) falls into the categories of low to moderate awareness, highlighting potential opportunities for further education and training to enhance awareness and knowledge of PATs among lecturers in vocational agriculture training programs.

Table 4: Barriers to adoption of PFTs by Lecturers in Vocational Agriculture Training Programmes in Universities in Abia State

S/N	Item Statements	Yes (*f*)	No (*f*)	Yes (%)	No (%)
1	Does integrating PATs into the curriculum face significant challenges in our program?	3	22	12	88
2	Is lack of funding limiting the effective adoption of PATs?	25	0	100	0
3	Is institutional support for adopting PATs inadequate?	21	4	84	16
4	Do lecturers lack technological skills and knowledge in PATs?	25	0	100	0
5	Is there a lack of equipment and machines for precision agriculture?	25	0	100	0
6	Is there a lack of training and professional development in PATs?	25	0	100	0

*Number of respondents (*n=25**),** *f= frequency of responses*

The results presented in Table 4 show several key barriers to the adoption of Precision Agriculture Techniques (PFTs) by lecturers in Vocational Agriculture Training Programmes in Universities in Abia State. Across the surveyed respondents, significant challenges were reported in integrating PATs into the curriculum, with 22% of the respondents indicating no such challenges. Funding emerged as a critical issue, with 100% of respondents identifying lack of funding as a barrier to effective PAT adoption. Additionally, institutional support was deemed inadequate by 84% of respondents. More so, the survey revealed unanimous agreement (100%

of respondents) regarding the lack of technological skills and knowledge among lecturers in PATs, as well as shortages in equipment and machinery for precision agriculture. Similarly, there was unanimous consensus on the absence of adequate training and professional development opportunities in PATs.

Table 5: Potential Impacts of PATs on Development of Workforce Skills of Students in Universities in Abia State

S/N	Item Statements	Yes (*f*)	No (*f*)	Yes (%)	No (%)
1	Do PATs significantly contribute to the development of workforce skills among students?	25	0	100	0
2	Does exposure to PATs enhance analytical and problem-solving skills of students?	25	0	100	0
3	Does PAT training improve student employability and productivity?	25	0	100	0
4	Do PATs positively impact the quality and relevance of vocational agriculture education?	25	0	100	0
5	Do PATs have the potential to enhance workforce readiness in the agricultural sector?	25	0	100	0
6	Do PATs prepare students for emerging trends and challenges in modern agriculture?	25	0	100	0
7	Will optimizing the integration of PATs into vocational education maximize workforce development outcomes?	25	0	100	0

*Number of respondents (*n=25)**,** *f= frequency of responses*

The results presented in Table 4 above indicated unanimous agreement among respondents regarding the potential impacts of Precision Agriculture Techniques (PATs) on the development of workforce skills among students in vocational agriculture education. Across all surveyed items, 100% of respondents (represented by 25 individuals) indicated "Yes" to statements addressing the contributions of PATs to workforce skills development, enhancement of analytical and problem-solving abilities, improvement in student employability and productivity, positive impact on the quality and relevance of vocational agriculture education, potential for enhancing workforce readiness in the agricultural sector, preparation for emerging trends and challenges in modern agriculture, and the optimization of workforce development outcomes through the integration of PFTs into vocational education.

Discussion of Findings

This explorative study found a mix of availability and absence of PATs within Vocational Agriculture Programmes in Universities in Abia State. Specifically, precision irrigation systems, soil sensors, and data analytics software were relatively available, while technologies like GPS for precision navigation, Variable Rate Technology (VRT), and remote sensing are notably absent. More so, this study observed a varying levels of PATs adoption among lecturers, with technologies such as smart sensors and data analytics being more commonly used compared to others like Remote Sensing, Global Positioning System, Automation/Mechanization and VRT for fertilizer which were not used. Additionally, technologies like Precision Irrigation Systems, Smart Sensors, and Data Analytics showed varying levels of adoption, with some respondents reporting these technologies to a minimal or moderate extent. Arguably, these findings indicate potential areas for further development and integration of modern PATs into vocational agriculture education to enhance teaching and learning practices in the field. Corroboratively, a study by McBratney *et al.* (2005) observed a slow advancement of precision agriculture

compared to initial predictions poses a hurdle to its widespread implementation. Similarly, McConnell (2019) argued that the limited adoption of precision agriculture technology, coupled with a lack of understanding of its economic benefits and conservation applications, further impedes its integration into vocational agriculture programs.

This investigation found a high level of awareness of PATs among lecturers, with most respondents being highly aware, although a notable portion falls into the low to moderate awareness categories, indicating potential areas for further education and training. Furthermore, this study identified significant barriers to the adoption of PATs, including challenges in curriculum integration, funding limitations, inadequate institutional support, lack of technological skills and knowledge among lecturers, and shortages in equipment and training opportunities. This study's findings that adoption of precision agriculture techniques by lecturers in vocational agriculture programs in universities faces significant challenges is consistent with evidence in other literature. For instance, Gusev *et al.*, (2020) reported financial constraints, high costs of precision farming technologies compared to traditional equipment, and a lack of personnel skilled as factors affecting the use of precision farming technologies. In line with one of the findings of this study, Salam & Shah (2019) asserted that lack of training is a major obstacle to the adoption of precision agriculture.

Arguably, these barriers enumerated above emphasize the need for comprehensive strategies to address challenges and promote effective PATs adoption in vocational agriculture education.Thus, future studies should develop realistic strategies to increase the adoption of PATs by lecturers in Vocational Agriculture Training Programmes in Universities in Abia state. In addition, the success of implementing precision farming depends on collaboration between government entities, academic institutions, agricultural companies, and farmers (Harnowo, 2024). The development of decision support systems and large-scale software tailored to stakeholder requirements is crucial for the effective implementation of precision agriculture in educational settings (Groeneveld *et al.*, 2020). Precision agriculture, which leverages information and technology to optimize productivity, profitability, and environmental sustainability, offers a promising solution to enhance agricultural practices (Bhat & Huang, 2021; Shrestha & Khanal, 2020). Thus, by utilizing communication and information technologies for farm management, precision agriculture can address spatial and temporal variability within fields to enhance overall agricultural productivity (Singh et al., 2021). The application of precision agriculture methods and approaches, supported by information and communication technologies, can revolutionize various agricultural sectors (Zacepins & Brusbardis, 2015).

Conclusion

This exploratory study conducted in public universities in Abia State, Nigeria, assessed the adoption of Precision Agriculture Techniques (PATs) within Vocational Agriculture Programmes (VATPs). The findings revealed a mixed availability of PATs, with certain technologies like precision irrigation systems, soil sensors, and data analytics software being relatively accessible, while others such as GPS, Variable Rate Technology (VRT), and remote sensing were notably absent. This reveals opportunities for enhancing VATPs to align with modern agricultural practices. The study also observed varying levels of PATs adoption among lecturers, with smart sensors and data analytics being more commonly used compared to other technologies. While most lecturers demonstrated a high level of awareness of PATs, there remains a need for further education and training to bridge knowledge gaps. Significant barriers to PATs adoption were identified, including curriculum integration challenges, funding limitations, inadequate institutional support, and lack of technological skills among lecturers. Addressing these barriers and capitalizing on identified opportunities will be essential for

promoting effective PATs adoption and advancing vocational agriculture education in the region.

Recommendations

Based on the findings of this study, the following recommendations were made.

1. Government and University administrators should prioritize providing adequate support for the integration and adoption of PATs within VATPs. This includes allocating resources for acquiring necessary technologies like GPS, Variable Rate Technology (VRT), and remote sensing equipment. Additionally, they should invest in faculty development programmes to enhance lecturers' technological skills and knowledge in PATs.
2. Government and University administrators should develop and implement curriculum enhancements that incorporate PATs to align with modern agricultural practices. This can involve revising existing courses or introducing new modules focused on precision irrigation systems, smart sensors, data analytics, and other relevant technologies. Collaborate with industry partners to ensure curriculum relevance and applicability to real-world agricultural scenarios.
3. Institutions should organize regular workshops, seminars, and training sessions to raise awareness and enhance knowledge of PATs among lecturers and students.
4. University administrators should increase funding and financial support for VATPs to overcome existing limitations in acquiring PATs equipment and resources. They should engage with government agencies, private sector stakeholders, and funding bodies to secure grants, sponsorships, or partnerships that can facilitate the procurement and maintenance of essential PATs infrastructure.
5. *Direction for future study:* Further studies should be geared towards adopting a more rigorous method to investigate the progression of PATs adoption and awareness among lecturers in VATPs over time.

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