ADOPTING PRECISION AGRICULTURE IN ALGERIA: INSIGHTS AND CHALLENGES FROM THE PERSPECTIVE OF ALGERIAN AGRICULTURAL ENGINEERS

Abderrahmane Soum[1], Abbassia Ayache[2]

Abstract

Precision agriculture represents a transformative approach for enhancing the sustainability and productivity of Algerian agriculture. The application of advanced technologies, including GPS, remote sensing, drones, and data analytics, enables precision agriculture to facilitate more precise resource management, thereby reducing waste and minimizing environmental impacts. The success of precision agriculture is contingent upon a comprehensive grasp of its methodologies. This study examines the awareness and utilization of precision agriculture technologies among Algerian agricultural engineers, who play a pivotal role in the sector's modernization. A descriptive research design was employed to ensure the reliability of the data, with a Cronbach's alpha coefficient of 0.834. The content validity was further corroborated through an expert review by a panel of university professors. The findings indicate that while theoretical knowledge of precision agriculture is high among engineers (mainly bachelors in agricultural studies), (with 84.3% of respondents indicating awareness), practical involvement is significantly lower, with only 19.7% of respondents engaged in precision agriculture applications. This discrepancy highlights significant obstacles to the implementation of precision agriculture, including limited access to technology, insufficient training, and inadequate institutional support. The resolution of these impediments could facilitate a greater alignment between theoretical understanding and practical application, thereby accelerating the broader adoption of precision agriculture in Algeria.

Key words: Algeria, agricultural engineering, precision agriculture, technology adoption.

JEL[3]: Q10, Q16, O13

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1 Abderrahmane Soum, PhDs., Agro-biotechnology and Nutrition in Semi-arid Zones Laboratory, Faculty of Natural and Life Sciences, Ibn Khaldoun University, BP 14000, Tiaret, Algeria, Phone: +002 134 645 34 94, E-mail: abderrahmane.soum@univ-tiaret.dz, ORCID: 0000-0001-9082-8028

2 Abbassia Ayache, Ph.D., Full Professor, Life and Nature Science Faculty, Djillali Liabes University, Sidi Bel Abbes, Algeria, Phone: +002 134 879 90 06, E-mail: abayache4@gmail.com, ORCID: 0000-0003-0374-3515

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Introduction

Agriculture, employing over 1.23 billion individuals, continues to be a predominant economic sector worldwide (Davis et al., 2023). Despite recent technological advancements, the agricultural sector faces numerous challenges, including the swift increase of the global population, the effects of climate change, the declining availability and quality of arable land, and significant economic and social transformations (FAO, 2022). The interrelated nature of these concerns requires the formulation of new and sustainable measures to guarantee future food security and economic stability (IPCC, 2022).

Precision agriculture has been introducing as a solution to guarantee sustainable advancement in agricultural output, enhance worldwide supply chains, minimize food loss and waste, and protect the ecological environment (Kendall et al., 2021). In the current state of climate, where the costs of pesticides, herbicides, and seeds are rising, agriculture depends on extensive, accurate data regarding a specific area (Petrović et al., 2024).

Historically, farmers possessed an intimate knowledge of their small parcels of land and the animals they tended, enabling them to implement detailed, site-specific management practices. This transformation was precipitated by the advent of agricultural mechanization in the mid of XX century (Binswanger, 1986). Mentioned shift resulted in formation of larger, more consolidated fields (parcels), but generally with concomitant loss of detailed land knowledge. Subsequent advancements in technologies for soil and water analysis, geographic location systems, and computing capabilities currently enable detailed monitoring and management of fields at micro level (Stafford, 2000; Bordes, 2017). In the present era, data from harvesting machines equipped with sensors provides insights into crop quality and quantity, thereby informing future agricultural practices (Bordes, 2017).

Precision agriculture

As an integrated farm management system (Ahmad, Mahdi, 2018), precision agriculture employs modern technologies (Rilwani, Ikhuoria, 2006; Getahun et al., 2024) to enhance productivity, quality and sustainability (Karunathilake et al., 2023), both, at large-scale farms (where a positive relationship has been established between the farm returns and the adoption of precision agriculture), (Sanyalou, Sadowski, 2024), or medium and small-scale farms (UNDP, 2021). The system comprises five principal components: geolocation systems, data collection sensors, data analysis and evaluation systems, decision-making frameworks, and field implementation systems (Balafoutis et al., 2017). These technologies collectively facilitate the precise application of agricultural inputs based on a detailed understanding of soil, weather patterns, and crop conditions, thereby optimizing the farming system (Gebbers, Adamchuk, 2010; Monteiro et al., 2021).

Agricultural engineers' role and importance

Agricultural engineers are instrument in facilitating the transfer of knowledge from the realm of scientific research to the practical application of agricultural techniques. They are responsible for the development and implementation of agricultural production processes, ensuring that they are efficient, effective, and compliant with quality and safety standards (Buchele, 1969). Their expertise and direct interaction with farmers enable them to adapt technology applications to the specific needs of the agricultural sector, thereby facilitating improvements in both quantity and quality of production (Sindir et al., 2008).

Agricultural engineers in Algeria

The profile of agricultural engineers in Algeria has undergone a notable evolution. The number of graduated engineers was moved from 170 in 1962. (El Mahi, 2022) to 4,693 in 1998. (Benslimane, 2017) to comprises approximately 60,000 engineers in 2020., according to information provided by the head of the Algeria National Union of Agricultural Engineers. This expanding cohort of professionals is strategically positioned to drive the uptake of new technologies within the Algerian agricultural sector.

Knowledge and adoption

The adoption of precision agriculture is significantly affected by the availability of reliable information (Vecchio et al., 2020). In several studies (Pierpaoli et al., 2013; Allahyari et al., 2016; Far, Rezaei Moghaddam, 2018), previously developed original Technology Acceptance Model (Davis, Venkatesh, 2004), has been employed to assess the impact of knowledge on the adoption of precision agriculture technologies. Performed research underscore the critical role of awareness and understanding of precision agriculture in fostering its adoption. They suggest that both, individual and systemic awareness are necessary for its effective implementation (Pierpaoli et al., 2013; Vecchio et al., 2020).

Literature review

The agricultural industry significantly contributes to Algeria's economic growth, accounting for over 12% of the nation's GDP in 2017., while providing direct and indirect employment for around 13 million persons (Bouznit et al, 2022).

This sector is also facing significant challenges, including drought and soil degradation triggered by climate change. These challenges limit agricultural productivity and influence technological adoption among agricultural engineers (FAO, 2022).

There are vast corpus of studies examining the technological, economic, and environmental impacts of precision agriculture (McBratney et al., 2005; Schieffer, Dillon, 2015; Koutsos, Menexes, 2019; Medici et al., 2021). Underscored the transformation of traditional farming knowledge into a technology-driven practice in precision agriculture, some research (Finger et al., 2019) indicates that the adoption rates of precision agriculture technologies vary considerably across various countries and crops. This suggests the presence of underlying economic or informational barriers to technology utilization. Moreover, the work of Lowenberg DeBoer (2019) examines the multifaceted toolkit of precision agriculture, underscoring its adaptability and integration capabilities, what is of huge importance for Algerian agriculture.

This research aims to evaluate the knowledge of Algerian agricultural engineers concerning precision agriculture and related technologies, and their practical use, as well as involvement of engineers in precision agriculture initiatives.

Materials and Methods

Study population

The study was conducted over a four-month period (June-September) during 2020., while its completion was influenced by the COVID-19 epidemic, which substantially disrupted global academic and research activity, particularly affecting university operations in Algeria. The study focusing on Algerian citizens possessing either an engineering (bachelor), or a master's degree in agricultural sciences. The specific fields of expertise observed in survey include crop production, plant protection, soil and water management, agricultural machinery, and agricultural economics.

Participant recruitment and data collection methods

A total of 1,503 engineers were approached through various means (different communication channels), including the direct (in vivo) interviews conducted with agricultural engineers from the Directorate of Agricultural Services of the Wilaya of Sidi Bel Abbes, the Algerian National Institute of Agronomic Research, the National Institute for Seed Control and Certification, and members of the National Board of the Algerian Agricultural Engineers Union. Respondents are also approached by telephone interviews with engineers from the National Institute of Extensive Crops, or by e-mail communication, that was realized by study coordinators at the agricultural services directorates of several Wilayas offices, or officials from the national office of the National Union of Algerian Agricultural Engineers, and various agricultural consultancy firms. Besides, survey also involve digital questionnaire distribution through the utilized internal communication platforms of the National Union of Algerian Agricultural Engineers, or by professional networking, done by contacted professors, chief researchers, and engineers from the Technical Institute of Fruit Growing and Vine, Bayer Corporation, ORUS, universities, research institutes, and other related companies. One part of respondents is contacted through the social media outreach, such is directly reached out to agronomists via LinkedIn, Twitter, and Facebook. Identities were verified before sending the digital questionnaire to ensure data integrity.

Sample size and participant selection

According to the head of the Algeria National Union of Agricultural Engineers, there is approximately 60,000 engineers, while 1,503 engineers (with bachelor and master degree) were approached, where 563 of them have agreed to participate in the study research. Following the application of screening criteria to ensure relevance to the study's focus and the removal of incomplete submissions, a total of 395 valid responses covering all the 48 wilaya (Provence) of Algeria were obtained for analysis.

Research instrument and validation

Relevance and comprehensiveness of the questionnaire was validated by university professors, resulting in a final document consisting of 57 questions. A pilot study was conducted to further finetune the predeveloped questions. The final sample size of 395 respondents was determined based on the total population size of 60,000 Algerian agricultural engineers, with the aim to achieve 5% margin of error and 95% confidence level. This resulted in a statistically valid study.

Reliability testing

The questionnaire demonstrated high reliability, as was indicated by Cronbach's Alpha of 0.834, which reflects a high level of internal consistency.

Content validity

The content validity of the instrument (questionnaire) was ensured through experts' review by academic staff from the University Djilali Liabes of Sidi Bel Abbes (Algeria) and the University Ibn Khaldoun of Tiaret (Algeria). Engaged experts have been provided critical feedback, later incorporated into the final survey instrument (questionnaire).

Pilot study

As was previously mentioned, preliminary exploratory study was conducted under the sample of engineers from the Wilaya of Sidi Bel Abbes (Algeria). The main objective was to refine the survey questions based on the feedback received, leading to development of the final questionnaire used in survey.

Data analysis

This study utilized a descriptive statistical method, augmented by factor analysis and correlation testing. The data analysis implies the use of statistical software package SPSS (version 26), in order to perform the requisite statistical computations and to ensure the robust processing of the study results.

The lack of previous research, the early stage of precision agricultural implementation in Algeria, and constraints imposed by the COVID-19 epidemic were the principal limitations of this study.

Results and Discussion

Personal and professional characteristics of engineers participating in the study

Understanding demographic characteristics is critical to the proper interpretation of survey data and its relevant application to Algerian agriculture, particularly in precision agriculture:

- *Gender distribution:* the respondents were predominantly male (54.9%), while female respondents account to 45.1%.
- *Age distribution:* the largest age group of respondents was 26-35 years (58.5%), followed by 36-45 years (24.1%), while the age groups of 46-55 years and 56-65 years constituted only 4.1% each.
- *Educational qualification:* majority of respondents (91.4%) had obtained an engineering or master's degree, while 4.8% of them hold a magister degree, or 3.8% of them have a doctorate.
- *Professional status:* the most prevalent job title was "operating engineer", representing 40% of respondents. It is noteworthy that around 22.5% of all respondents were unemployed during the survey period.
- *Experience levels:* the majority of respondents had less than five years of experience (42.5%), while those with over the 20 years of experience were the smallest group (5.1%).

Knowledge of precision agriculture

The Table 1. provides a detailed examination of respondents' computer literacy, their level of familiarity with precision agriculture, the sources from which they acquired their knowledge, and insights into their training experiences.

Table 1. Knowledge of precision agriculture

<table>
<tr><th>Question</th><th colspan="7">Frequency (in %)</th></tr>
<tr><td rowspan="3">Computer literacy</td><td>Very low</td><td colspan="2">Low</td><td colspan="2">Medium</td><td>Good</td><td>Very good</td></tr>
<tr><td>1</td><td colspan="2">6</td><td colspan="2">75</td><td>234</td><td>79</td></tr>
<tr><td>0.3</td><td colspan="2">1.5</td><td colspan="2">19.0</td><td>59.2</td><td>20.0</td></tr>
<tr><td rowspan="3">Knowledge of precision agriculture</td><td colspan="4">Yes</td><td colspan="3">No</td></tr>
<tr><td colspan="4">344</td><td colspan="3">51</td></tr>
<tr><td colspan="4">87.1</td><td colspan="3">12.9</td></tr>
<tr><td rowspan="3">Precision agriculture knowledge method</td><td>Study</td><td>Media</td><td>Work</td><td>Agric. dealers</td><td>Colleagues</td><td>Training</td><td>Exhibitions</td></tr>
<tr><td>158</td><td>73</td><td>51</td><td>21</td><td>16</td><td>15</td><td>10</td></tr>
<tr><td>45.9</td><td>21.2</td><td>14.8</td><td>6.1</td><td>4.7</td><td>4.4</td><td>2.9</td></tr>
<tr><td rowspan="3">Training in precision agriculture</td><td colspan="2">I have not received any training</td><td colspan="3">I have received training during my studies</td><td colspan="2">I have received training outside of my studies</td></tr>
<tr><td colspan="2">259</td><td colspan="3">87</td><td colspan="2">49</td></tr>
<tr><td colspan="2">65.6</td><td colspan="3">65.6</td><td colspan="2">12.4</td></tr>
</table>

Source: Soum, Ayache, 2020.

- *Computer literacy:* a substantial share of respondents reported possession of proficient computer skills, while 59.2% rate their abilities as "good", and 20% as a "very good".
- *Awareness of precision agriculture:* a high level of familiarity was observed, with 87.1% of respondents indicating awareness of precision agriculture, primarily through academic studies (45.9%) and media (21.2%).
- *Training in precision agriculture:* only 34.4% of respondents had received formal training in precision agriculture, while 22% of them was trained during the academic studies, or 12.4% of them through external programs.

Knowledge of precision agriculture technologies

The following table (Table 2.) offers insights into the respondents' familiarity with various precision agriculture technologies. The technologies are classified according to respondents' knowledge levels:

- The technology most readily identified was weather forecasting software, followed by real-time soil sensors and satellite positioning systems in agricultural works.
- Technologies that were less familiar to respondents are soil electrical conductivity measurement in real time, as well as agricultural robots and soil gamma radiation maps.

Table 2. Knowledge of precision agriculture technologies

Technologies	Don't know it	Know it	Know it very well	Mean	Sd	Rank	Overall trend
	Frequency (in %)						
Agricultural weather forecasting software	94	142	159	2.4	1.154	1	Know it very well
	23.8	35.9	40.2				
Real-time soil sensors	80	154	161	2.21	0.755	2	Know it
	20.3	39	40.8				
Satellite positioning systems in agri-works	81	156	158	2.19	0.754	3	Know it
	20.5	39.5	40				
GIS and digital agricultural maps	123	143	129	2.02	0.8	4	Know it
	31.1	36.2	32.7				
Variable rate irrigation machines	111	172	112	2	0.752	5	Know it
	28.1	43.5	28.4				
Weed and pesticide VRT sprayers	119	167	109	1.97	0.76	6	Know it
	30.1	42.3	27.6				
Best farming practices software	139	141	115	1.94	0.801	7	Know it
	35.2	35.7	29.1				
Fertilizer/gypsum VRT machines	138	152	105	1.92	0.781	8	Know it
	34.9	38.5	26.6				
Aerial and spatial crop monitoring	128	175	92	1.91	0.742	9	Know it
	32.4	44.3	23.3				
Farm management software	154	159	82	1.91	0.953	10	Know it
	39	40.3	20.7				
Aerial and spatial pest and disease detection	142	174	79	1.84	0.732	11	Know it
	35.9	44.1	20				
Harvest productivity maps creating	148	165	82	1.83	0.745	12	Know it
	37.5	41.8	20.8				
Agri equipment driving assisted by GNSS	140	186	69	1.82	0.706	13	Know it
	35.4	47.1	17.5				
Variable rate seeding machines	171	143	81	1.77	0.767	14	Know it
	43.3	36.2	20.5				
Expected yield simulating software	168	148	79	1.77	0.759	15	Know it
	42.5	37.5	20				
Soil EC measurement in real time	183	125	87	1.76	0.791	16	Know it
	46.3	31.6	22				
Agricultural robots	165	176	54	1.72	0.69	17	Know it
	41.8	44.6	13.7				

Technologies	Don't know it	Know it	Know it very well	Mean	Sd	Rank	Overall trend
	Frequency (in %)						
Precision soil leveling equipment	188	149	58	1.67	0.718	18	Know it
	47.6	37.7	14.7				
Soil gamma radiation maps	274	101	20	1.36	0.576	19	Don't know it
	69.4	25.6	5.1				

Source: Soum, Ayache, 2020.

Use of different precision agriculture technologies

The following table (Table 3.) offers insights into the respondents' usage of the various precision agriculture technologies. The technologies are classified according to respondents' usage levels.

Table 3. Use of precision farming technologies

Technologies	didn't used it	used it	Mean	Sd	Rank	Overall trend
	Frequency (in %)					
Satellite positioning systems in agri works	304	91	0.23	0.422	1	didn't used it
	77	23				
Agricultural weather forecasting software	328	67	0.17	0.376	2	didn't used it
	83	17				
GIS and digital agricultural maps	344	51	0.13	0.336	3	didn't used it
	87.1	12.9				
Real-time soil sensors	344	49	0.12	0.331	4	didn't used it
	87.1	12.4				
Best farming practices software	360	35	0.09	0.285	5	didn't used it
	91.1	8.9				
Expected yield simulating software	363	32	0.08	0.273	6	didn't used it
	91.9	8.1				
Variable rate irrigation machines	364	31	0.08	0.269	7	didn't used it
	92.2	7.8				
Soil EC measurement in real time	368	27	0.07	0.253	8	didn't used it
	93.2	6.8				
Aerial and spatial crop monitoring	367	28	0.07	0.257	9	didn't used it
	92.9	7.1				
Harvest productivity maps creating	371	24	0.06	0.239	10	didn't used it
	93.9	6.1				
Farm management software	371	24	0.06	0.239	11	didn't used it
	93.9	6.1				
Aerial and spatial pest and disease detection	370	25	0.06	0.244	12	didn't used it
	93.7	6.3				
Variable rate seeding machines	376	19	0.05	0.214	13	didn't used it
	95.2	4.8				

Technologies	didn't used it	used it	Mean	Sd	Rank	Overall trend
	Frequency (in %)					
Fertilizer / gypsum VRT machines	376	19	0.05	0.214	14	didn't used it
	95.2	4.8				
Weed and pesticide VRT sprayers	376	19	0.05	0.214	15	didn't used it
	95.2	4.8				
Agri equipment driving assisted by GNSS	379	16	0.04	0.197	16	didn't used it
	95.9	4.1				
Precision soil leveling equipment	384	11	0.03	0.165	17	didn't used it
	97.2	2.8				
Agricultural robots	385	10	0.03	0.157	18	didn't used it
	97.5	2.5				
Soil gamma radiation maps	389	6	0.02	0.122	19	didn't used it
	98.5	1.5				

Source: Soum, Ayache, 2020. Note: Deviation in survey structures are caused by fact that some respondents were not answered certain questions.

The most utilized technology was the Satellite positioning systems in agricultural works, which has been used by 23% of respondents, Agricultural weather forecasting software was used by 17%, or GIS and Digital agricultural maps was used by 12.9% respondents, while all other technologies were used by less than 10% of population (e.g. soil gamma radiation maps were observed in only 1.5% of cases).

Participation in projects using precision agriculture

Only 19.7% of the surveyed agricultural engineers had been previously involved in realization of certain precision agriculture projects. Mentioned is comparatively similar to the results obtained by Keskin and Sekerli (2016), who found that approximately 0-21% of agricultural professionals were engaged in precision agriculture implementation, depending on the type of precision agricultural technology used.

Factor analysis of knowledge and usage of precision agriculture technologies

A factor analysis of agronomists' knowledge of technologies used in precision agriculture revealed that it can be classified into the four groups. The group with the highest level of knowledge was oriented to agricultural data processing and use of analysis software, followed by remote sensing and geographic positioning technologies for agriculture, precision agriculture variable rate technologies, and at the end, soil analysis technologies.

Table 4. Ranking factors of knowledge of precision farming technologies

Factor	Average	Standard deviation	Rank	Overall trend
Agricultural data processing and analysis software	1.924	0.639	1	Know It
Remote sensing and geographic positioning technologies for agriculture	1.904	0.539	2	
Precision agriculture variable rate technologies.	1.867	0.625	3	
Soil analysis technologies	1.773	0.561	4	

Source: Soum, Ayache, 2020.

Another factor analysis for the agronomists' usage of technologies applied in precision agriculture revealed that it can be classified into four groups also. The group with the highest level of usage was Use of geo-specific agricultural data collection technologies, followed by the Use of software for processing and analysis of agricultural data, the Use of variable rate technologies, and at the end the Use of soil works related technologies (Soum, Ayache, 2020).

Table 5. Ranking of factors for the use of precision farming technologies

Factor	Average	Standard deviation	Rank	Overall trend
Use of geo-specific agricultural data collection technologies	0,103	0,201	1	didn't used it
Use of software for processing and analysis of agricultural data	0,100	0,231	2	
Use of variable rate technologies	0,057	0,183	3	
Use of soil works related technologies	0,022	0,115	4	

Source: Soum, Ayache, 2020.

Knowledge and adoption of precision agriculture among Algerian agricultural engineers

This study provides crucial insights into the awareness, knowledge, and adoption of precision agriculture technologies among Algerian agricultural engineers. It is notable that 87.3% of engineers surveyed indicated awareness of precision agriculture, while the majority was reporting that they had acquired this awareness during the academic training. This figure surpasses prior findings obtained in similar survey performed in similar countries (Elsafty, Ashraf, 2022). It is noteworthy that younger engineers demonstrate a greater familiarity with precision agriculture, which can be attributed to their enhanced computer literacy and exposure to modern technologies during their education. This finding is consistent with the results reported by (Daberkow, McBride, 2003), who found that while age is negatively correlated with knowledge of precision agriculture, computer literacy has mainly a positive effect.

Prevalence and familiarity with specific precision agriculture technologies

Survey findings corroborate those of Keskin and Sekerli (2016), indicating that weather monitoring software, soil sensors, and global positioning systems are among the most recognized technologies. Mentioned can be attributed to the critical role these technologies play in enhancing the efficiency of agricultural operations and their increasing affordability and accessibility. The pervasive incorporation of geolocation systems into agricultural machinery and emergence of cost-effective sensors serve to reinforce this phenomenon (Romero Andrade et al., 2019).

Training and media influence

The influence of academic study and media in disseminating knowledge about precision agriculture is evident. However, the depth of understanding remains superficial for the majority of engineers. The absence of specialized training programs and comprehensive curriculum coverage of precision agriculture technologies, highlights a pressing need for educational reform and targeted professional development initiatives.

Barriers to adoption and practical application

Notwithstanding the high level of theoretical knowledge, there is a glaring disparity between the practical application and training in precision agriculture among Algerian engineers. The findings of this study indicate that only 16.7% of engineers have engaged in precision agriculture projects, which highlights a significant discrepancy between theoretical knowledge and its practical application. The underutilization of more advanced technologies, such as agricultural robotics and soil gamma radiation measurement, can be attributed to their nascent stage in the market and the high costs associated with cutting-edge research and development, those results are comparatively similar to the results obtained by Bagheri et al. (2024).

Technological hierarchy and utilization patterns

The stratification of technology familiarity and usage reveals a broader trend. While software for agricultural data processing and analysis is widely recognized due to its inclusion in university programs and the availability of applications, remote sensing and geographic positioning systems are the most utilized. This is indicative of their extensive applicability across a multitude of sectors and their incorporation into the fabric of contemporary technology.

Correlations

The correlation analysis highlights significant positive relationships between training in precision agriculture and participation in precision agriculture projects ($r = 0.317$, $p < 0.01$). Additionally, computer literacy positively correlates with training in precision agriculture ($r = 0.228$, $p < 0.01$).

Furthermore, it elucidates the cyclical relationship between the knowledge of specific technologies and their practical application. These findings indicate that improvements in computer literacy and the implementation of targeted training programs could enhance the adoption and effective utilization of precision agriculture technologies along with the reduction of cost acquisition and operation of precision agriculture equipment.

Conclusion

Algerian agricultural sector is confronted with a multitude of challenges that impede its overall performance and efficiency. The objective of this study was to evaluate the knowledge and utilization of precision agriculture technologies among Algerian agricultural engineers. The findings indicate a notable familiarity with the concept of precision agriculture and fundamental comprehension of its associated technologies among the participants. Nevertheless, the practical implementation of these technologies and involvement in precision agriculture projects remains significantly limited due to the initial capital expenditures, inadequate compatibility and standardization among equipment from various manufacturers, and the intricacy of analyzing and managing extensive data sets (Hundal et al., 2023). In light of the government's policy objectives pertaining to food security and the integration of modern technologies in agriculture, it is imperative to prioritize investments in precision agriculture education. This issue can be effectively addressed by:

1. The introduction of specialized precision agriculture programs is recommended. The creation of dedicated precision agriculture specializations within agricultural science departments at universities is essential to ensure that new engineers are not only aware of, but also proficient in, the latest agricultural technologies.
2. The enhancement of continuous professional development is next key objective, i.e. creation of comprehensive training programs for practicing engineers with the objective of enhancing their practical abilities and enabling them to utilize precision agriculture technologies in efficacious manner.

Furthermore, there is a necessity for a more comprehensive investigation into the comprehension and enthusiasm for precision agriculture among the diverse stakeholders within the agricultural sector. Such studies would assist in the adaptation of educational programs and policies to the particular requirements and capabilities of diverse agricultural stakeholders, thereby enhancing the comprehensive uptake and efficacy of precision agriculture in Algeria.

This conclusion highlights the urgent necessity for strategic educational and policy initiatives to bridge the gap between theoretical knowledge and practical application of precision agriculture in Algeria. Such measures are essential for transforming agricultural practices towards greater efficiency and sustainability.

Subsequent research needs to investigate precision agriculture in collaboration with Algerian stakeholders and end-users to guide forthcoming socio-technological advancements.

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