



Expected Impact of Adoption Precision Agriculture in Algeria According to Algerian Agricultural Engineers

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ABSTRACT

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Precision agriculture aims to increase the efficacy of agricultural operations by using the right number of inputs at the right time and the right place, this study examined 329 Algerian agricultural engineers regarding the perceived impacts and future of precision agriculture, revealing a robust consensus that its adoption is important. Expected advantages encompass increased economic efficiency, ecological and resource optimization, improved chemical oversight, and favorable socio-economic results, including the attraction of youth to the sector and a decrease in migration. Compatibility with existing systems and perceived utility were recognized as the primary factors influencing adoption. Translating this perception into practice necessitates policy and extension initiatives aimed at showcasing the measurable advantages of Precision Agriculture and ensuring that technological solutions correspond with Algerian agricultural conditions.

1. INTRODUCTION

Algeria is one of the world's major importers of cereals [1] and the agricultural sector fails to meet the needs of the population [2] as it suffers from significant imbalances, some of which are due to the nature of Algeria's geographical location and the resulting lack of high-productivity agricultural land, as well as the lack of rainfall, which is exacerbated by changing climatic conditions, some of which are due to the lack of effective management of the Algerian agricultural sector and problems related to the transfer of ownership of land and the way it is managed and distributed, and the low capacity to make optimal use of it, in addition to the lack of a strategy to control the agricultural chain from the production of seeds and fertilizers to the storage and distribution stage.

In light of these conditions and the pressures caused by climate change that have become more severe in recent years, in addition to high food prices on world markets due to political tensions and health crises, precision agriculture can offer a means of increasing the efficiency, yield and profitability of Algerian agriculture and provide accurate information that allows for better planning and better exploitation and optimization of available resources.

Precision agriculture utilizing technologies such as GPS, remote sensing, and data analytics, signifies a revolutionary method for enhancing agricultural productivity and sustainability. In nations like Algeria, characterized by

significant agroecological challenges such as water scarcity and desertification, precision agriculture presents a crucial potential for modernization.

Several studies on the impacts of precision agriculture have found that precision agriculture techniques require a significant investment in capital and time, but can result in cost savings and higher yields through more precise input management. This is consistent with the work of Yost et al. [3] who found that the use of precision agriculture increases resource use efficiency.

Morais et al. [4] pointed out that the use of precision agriculture leads to a reduction in nitrogen fertilizer use by up to 25%, Schieffer and Dillon [5] also explained that the use of precision agriculture leads to a reduction in the variation of crops from one season to another, Morais et al. [4] also explained that it allows sustainable crop management and increases each of the crop yields in line with the work of Fabiani et al. [6], which was explained that it reduces the general cost of production and increases the gross profit margin, estimated this increase at 21% for individual profit and 26% for social profit.

Nonetheless, adoption rates are still in their nascent stages. The agricultural engineer in Algeria serves as a crucial channel for technical transfer; yet, their perspectives on the potential impacts and challenges of precision agriculture are insufficiently documented.

In the course of this study, the attitudes of Algerian agricultural engineers who declared to be familiar with

precision agriculture were surveyed regarding their opinion on its effects on productivity, sustainability and efficiency of precision agriculture, as well as its expected effects in the social and professional field. Precision farming can be used in both crop and livestock production.

However, this study focused on its effects on crop production.

2. MATERIALS AND METHODS

2.1 Research framework and hypotheses

The implementation of precision agriculture can be explained through a comprehensive theoretical framework that combines the Technology Acceptance Model (TAM) and the Innovation Diffusion Theory (IDT).

This hybrid methodology offers a comprehensive framework to analyze the factors influencing technological adoption in agricultural settings.

- 1) **Technology Acceptance Model (TAM):** The TAM asserts that the adoption of new technologies is fundamentally influenced by two cognitive factors: Perceived Usefulness (PU), which measures the extent to which a technology improves performance, and Perceived Ease of Use (PEOU), which indicates the level of effort required for its implementation. These constructs influence engineers' beliefs on adoption, which in turn affects their behavioral intentions and actual adoption behavior.
- 2) **Innovation Diffusion Theory (IDT):** IDT broadens the adoption framework by highlighting the significance of innovation attributes, such as compatibility (congruence with established values and practices), complexity (perceived ease of use), trialability (capacity for experimentation with the technology), and observability (visibility of outcomes). These variables collectively affect the speed and probability of adoption among various user demographics.
- 3) **Integrated TAM-IDT Framework:** The proposed model integrates TAM and IDT principles to offer a thorough explanation of PA adoption. TAM's Perceived Usefulness (PU) and Perceived Ease of Use (PEOU) encapsulate the cognitive assessment of a technology's usefulness and usability, whereas IDT's compatibility, complexity, trialability, and observability pertain to the perceptual evaluation of innovation characteristics.

In this context, Behavioral Attitude characterized as the engineer's perceived significance of adapting to precision agriculture functions as a vital mediator connecting these perceptual elements to actual adoption results.

This model posits that the adoption of precision agriculture is dependent on the interaction of perceived advantages, compatibility with existing agricultural methods, ease of implementation, and the visibility of results, with Behavioral Attitude serving a crucial mediating function.

Research hypothesis

Based on the empirical coefficients illustrated in the structural model (Figure 1), the following hypotheses are established to examine the interactions within the integrated TAM-IDT framework:

TAM-oriented Hypotheses:

- H1: Perceived Utility (PU) positively influences Engineers Behavioral Attitude toward the adoption of Precision Agriculture.
- H2: Perceived Ease of Use (PEOU) positively influences Engineers Behavioral Attitude toward the adoption of Precision Agriculture.
- H3: Perceived Utility (PU) exerts a direct beneficial influence on the opinion about the future increase of the adoption of Precision Agriculture.
- H4: Perceived Ease of Use (PEOU) exerts a direct beneficial influence on the future increase in the adoption of Precision Agriculture.

Hypotheses based on IDT:

- H5: Compatibility positively affects engineers' behavioral attitude towards the adoption of Precision Agriculture.
- H6: Compatibility exerts a beneficial influence on the opinion about the future increase of the adoption of Precision Agriculture.
- H7: Complexity adversely affects engineers' behavioral attitude towards the adoption of Precision Agriculture.
- H8: Complexity adversely affects engineers on the opinion about the future increase of the adoption of Precision Agriculture.
- H9: Trialability positively affects engineers' behavioral attitude towards the adoption of Precision Agriculture.
- H10: Trialability positively affects engineers on the opinion about the future increase of the adoption of Precision Agriculture.
- H11: Observability has a good effect on engineers' behavioral attitude towards the adoption of Precision Agriculture.
- H12: Observability exerts a beneficial influence on the opinion about the future increase of the adoption of Precision Agriculture.

Attitude as a mediating factor:

- H13: The behavioral attitude of Engineers positively impacts on the opinion about the future increase of the adoption of Precision Agriculture.

This hypothesis will be empirically evaluated using structural equation modeling and statistical analysis.

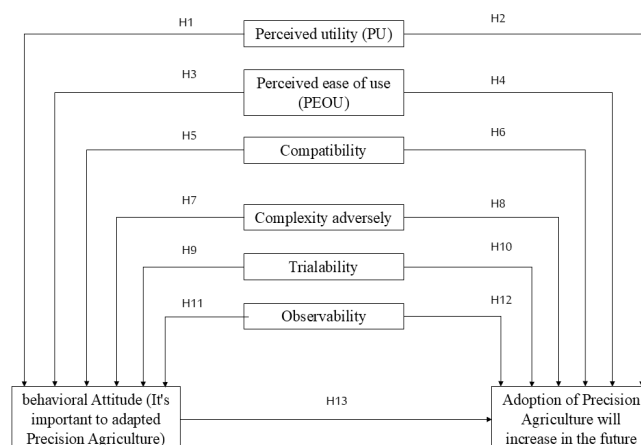


Figure 1. Theoretical framework
Source: The Researcher

2.2 Research method

This research was performed from June to September 2020 among Algerian agricultural experts possessing either an engineering or a master's degree in disciplines like crop production, plant protection, soil and water management, agricultural machinery, and agricultural economics.

A total of 1,503 engineers were contacted via multiple channels, including direct interviews with professionals from national and regional agricultural institutions, telephone communication organized by the National Institute of Extensive Crops, and email correspondence with agricultural directorates and consultancy firms. Further outreach was conducted via professional networks encompassing universities, research institutions, and private enterprises, in addition to verified contacts on LinkedIn, Twitter, and Facebook.

Of all those approached, 563 consented to participate. Following the application of eligibility criteria and the exclusion of incomplete replies, 329 valid questionnaires were

retained for analysis. The sample size was deemed representative of the national population of agricultural engineers (162,565), satisfying the criteria of a 5% margin of error and a 95% confidence level.

The survey instrument comprised 22 items examining factors that affect the adoption of precision agriculture technologies. The questionnaire underwent evaluation by academic specialists for clarity and comprehensiveness, followed by a pilot test with engineers from Sidi Bel Abbes to enhance the items. The completed instrument exhibited robust reliability, evidenced by a Cronbach's Alpha of 0.916. The Cronbach's alpha coefficients for the variables are presented in Table 1. Data were analyzed with SPSS software (version 26), employing both descriptive and inferential statistical methods to evaluate the research hypotheses.

In Table 1, content validity was additionally corroborated by professional evaluations from professors at the University Djilali Liabes (Sidi Bel Abbes) and the University Ibn Khaldoun (Tiaret).

Table 1. Cronbach's alpha coefficients for research variables

Variables	Precision Agriculture Expected Impact	Cronbach's Alpha Coefficient
Perceived utility (PU)	Facilitate agricultural work	0.883
	Reduction in the amount of water used for irrigation	
	Increase the productivity of exploited agricultural land	
	Increase the profitability of Algerian agriculture	
	Effective management and control of diseases and pests	
	Increase the efficiency of fertilizer use	
	Increase the efficiency of agricultural pesticide use	
	Increase the efficiency of weed management and control	
	Increase the efficiency of energy consumption	
	Reduce the cost of agricultural inputs	
	Preserve surface and ground water and reduce pollution	
	Preserve soil from erosion and compaction	
	Reduce greenhouse gas emissions	
	Increase the income of workers	
Perceived ease of use (PEOU)	Increase employment opportunities	
	Increase the amount of farmland in use	
	Facilitate agricultural work	0.768
	Reduce the time needed for the execution of agricultural works	
Compatibility	Reduce the depreciation rate of farm machinery	
	Increase the orientation of young people to the agricultural field	
	Reduce internal migration	0.786
	Reduce immigration to other countries	
Complexity adversely	Increase employment opportunities	
	Develop a database for monitoring the state of the land and the effects of different agricultural works.	0.733
	Effective management and control of diseases and pests	
	Preserve soil from erosion and compaction	
Triability	Reduction in the amount of water used for irrigation	0.797
	Increase the efficiency of fertilizer use	
	Increase the efficiency of agricultural pesticide use	
	Increase the efficiency of weed management and control	
	Preserve soil from erosion and compaction	
Observability	Increase the productivity of exploited agricultural land	0.737
	Increase the profitability of Algerian agriculture	
	Preserve surface and ground water and reduce pollution	
	Increase the amount of farmland in use	
	Reduce greenhouse gas emissions	
	Increase the income of workers	
	Increase employment opportunities	

Source: The Researcher

3. RESULTS

3.1 Descriptive statistics

This study examined Algerian agricultural engineers' perspectives of precision agriculture's impact on several aspects of farming techniques. Perceptions were assessed via a structured survey, with results presented in Table 2 as arithmetic means of respondents' agreement levels and rated in descending order of importance.

- The results indicate that the improvement of agricultural practices was regarded as the most significant benefit of precision agriculture, attaining a mean score of 4.13. A significant percentage of engineers supported this benefit, with 63.1% in agreement and 26.5% in strong agreement, while criticism was minimal at 0.9%. Water use efficiency

was notably highlighted, with a mean score of 4.10.

- The predominant consensus (59.8% agreement and 28.0% strong agreement) highlights the recognized significance of precision agriculture in tackling Algeria's urgent issues of water scarcity and irrigation efficiency.
- The capacity of precision agriculture to improve land production was broadly recognized, yielding a mean score of 4.04. Over two-thirds of respondents (65.2%) indicated agreement, with an additional 22% strongly endorsing this influence. Similar levels of acknowledgment were noted for database creation in land monitoring ($M = 4.03$) and profitability and disease management ($M = 4.03$), indicating a robust belief that digital tools and data-driven methodologies are essential for the modernization of Algerian agriculture.

Table 2. Different variables

Excepted Impact	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
	%				
Facilitate agricultural work	26.5	63.1	7.6	1.8	0.9
Reduction in the amount of water used for irrigation	28.0	59.8	7.3	4.0	0.9
Increase the productivity of exploited agricultural land	22.0	65.2	9.1	1.8	1.8
Develop a database for monitoring the state of the land and the effects of different agricultural works.	23.5	61.6	11.6	1.5	1.8
Increase the profitability of Algerian agriculture	22.9	62.2	11.3	2.7	0.9
Effective management and control of diseases and pests	22.6	60.7	13.1	2.4	1.2
Increase the efficiency of fertilizer use	22.9	58.8	13.7	3.0	1.5
Reduce the time needed for the execution of agricultural works	22.3	60.4	12.2	3.7	1.5
Preserve surface and ground water and reduce pollution	24.7	54.0	16.5	3.7	1.2
Increase the efficiency of agricultural pesticide use	22.9	54.7	16.8	3.7	1.8
Increase the orientation of young people to the agricultural field	22.0	55.2	16.5	4.6	1.8
Increase the efficiency of weed management and control	18.9	55.5	20.4	2.7	2.4
Reduce the cost of agricultural inputs	19.2	53.4	19.8	5.5	2.1
Preserve soil from erosion and compaction	20.1	52.4	18.3	6.1	3.0
Reduce the depreciation rate of farm machinery	14.9	54.3	21.3	7.0	2.4
Increase the amount of farmland in use	16.2	54.6	17.7	8.2	3.4
Increase the efficiency of energy consumption	12.5	51.2	26.2	6.7	3.4
Reduce internal migration	13.4	40.5	32.3	8.8	4.9
Increase the income of workers	13.4	36.3	31.1	11.9	7.3
Reduce greenhouse gas emissions	8.2	36.3	40.5	10.4	4.6
Reduce immigration to other countries	11.6	28.0	35.7	14.3	10.4
Increase employment opportunities	10.4	26.5	28.7	22.9	11.6

Source: Field Survey, 2020

Table 3. The mean of the impacts of the precision agriculture technologies from the view point of engineers

Expected Impact on	Average	Standard Deviation	Rank	Overall Trend
Perceived ease of use	3.94	0.65	01	Agree
Compatibility	3.93	0.81	02	
Trialability	3.93	0.62	03	
Complexity adversely	3.89	0.68	04	
Perceived utility	3.80	0.52	05	
Observability	3.63	0.57	06	

Source: Field Survey, 2020

3.2 Ranking of variables

The six variables have been ranked in Table 3.

3.3 Correlation among variables

The correlation was significant between all Variables at the 0.01 significance level.

The coefficients indicated a substantial positive correlation

between perceived usefulness and perceived ease of use, compatibility, complexity, tribality and observability were calculated as 0.757, 0.592, 0.831, 0.878 and 0.902 respectively. The coefficients were significant at the 0.01 significance level.

The coefficients indicated a substantial positive correlation between perceived ease of use and compatibly, complexity, tribality, observability were calculated as 0.468, 0.632, 0.620 and 0.652 respectively.

Correlation study of compatibility with other variables

revealed a positive association with complexity, tribality and observability were calculated as 0.397, 0.341 and 0.709 respectively.

The Pearson correlation analysis results indicated a favorable link between complexity and tribality and

observability were calculated as 0.841 and 0.657 respectively.

Simultaneously, a positive correlation existed between the tribality and observability which were calculated as 0.631.

Table 4 presents the correlation among the variables.

Table 4. Correlation among variables

	Correlations					
	Perceived Utility	Perceived Ease of Use	Compatibility	Complexity	Trialability	Observability
Perceived utility						
Perceived ease of use	.757**					
COMPATIBILITY	.592**	.468**				
Complexity	.831**	.632**	.397**			
Trialability	.878**	.620**	.341**	.841**		
Observability	.902**	.652**	.709**	.657**	.631**	

** . Correlation is significant at the 0.01 level (2-tailed).

Source: The Researcher

3.4 Importance to adopt precision agriculture in Algeria

The data in Table 5 indicate that respondents demonstrated a robust positive disposition on the significance of precision agriculture in Algeria. A significant majority (93.8%) concurred on the importance of adopting precision agriculture, evidenced by a mean score of 0.94 and a low standard deviation (0.241), signifying a strong consensus among agricultural engineers. This indicates that the strategic significance of precision agriculture as a means to improve efficiency, sustainability, and competitiveness is broadly acknowledged among engineers. Conversely, anticipations concerning the actual progression of precision agriculture in Algeria were rather more reserved. A majority (75.9%) concurred that the utilization of such technology will increase, while nearly one-quarter (24.1%) voiced dissent. The mean score of 0.76 and the comparatively elevated standard deviation of 0.428 underscore increased diversity in perceptions. This result indicates a notable level of doubt among experts, possibly associated with prevailing obstacles such as inadequate infrastructure, substantial investment expenses, and insufficient training initiatives. The findings indicate that agricultural engineers recognize the significance of precision agriculture for the nation's agricultural future, although they are divided on the speed and practicality of its extensive implementation. This dual tendency highlights the necessity for supportive policies, capacity-building programs, and infrastructural investment to convert favorable sentiments into effective implementation.

Table 5. Attitude of Algerian agricultural engineers on the expected effects of precision agriculture

Attitude	Disagree	Agree	Mean	Standard Deviation	Overall Trend
	%				
Adoption of precision agriculture is important in Algeria	6.2	93.8	.94	.241	Agree
The use of precision agriculture will develop in Algeria	24.1	75.9	.76	.428	Agree

Source: Field Survey,2020

3.5 Factors influence adaption

Figure 2 illustrates the behavioral and technological determinants affecting engineers' propensity to adopt precision agriculture approaches.

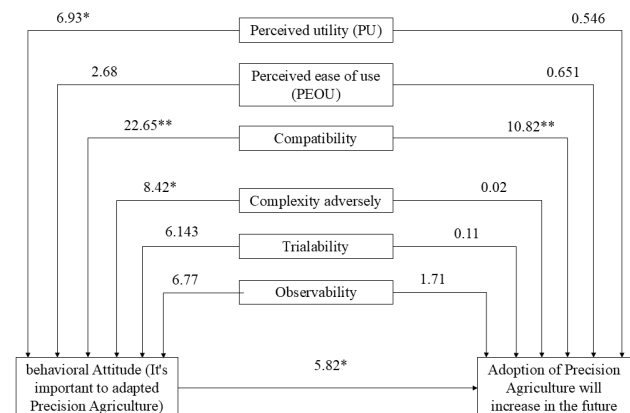


Figure 2. Structural equation modeling and path coefficients among variables

The figure differentiates between factors influencing Engineers' views toward adoption and those that actually drive the opinion about the on the opinion about the future increase of the adoption of precision agriculture.

Behavioral attitude (5.82)* strongly influences the relationship between perception and adoption, underscoring the pivotal role of engineers psychological preparedness in technology spread.

The data indicates that compatibility is the primary factor influencing Engineers attitudes (22.65**) and directly facilitating adoption (10.82**). This highlights the necessity of integrating precision agriculture technologies with current farming methods, cultural practices, and operational requirements.

Perceived utility (6.93) and observability (6.77) significantly influence attitude formation, whereas trialability (6.14) has a minor yet beneficial impact.

Conversely, ease of use (2.68; 0.651) and complexity (0.02) had negligible impact, suggesting that technological sophistication is not regarded as a significant obstacle when compatibility and utility are apparent.

4. DISCUSSION

A comprehensive review of the literature on precision agriculture was conducted, encompassing its conceptual frameworks, international adoption patterns, and associated impact.

A survey was then developed to assess the perception of Algerian agricultural engineers regarding the feasibility of these frameworks within the Algerian agricultural context. The survey also solicited their viewpoint on the significance of adopting precision agriculture and their future outlook on its potential in Algeria.

The results indicated that Algerian agricultural engineers consider it imperative to adopt precision agriculture in Algeria, perceiving it as a future-oriented development. The positive impacts of precision agriculture, as categorized by respondents, were grouped into five overarching groups.

4.1 Improvements in economic efficiency and productivity

The most significant effects, as perceived by Algerian agricultural engineers, are those on productivity and profitability.

They anticipate that precision agriculture will lead to an expansion in the area cultivated of agricultural land being cultivated, in accordance with the perspectives articulated by agricultural engineers in the Islamic Republic of Iran in the study undertaken by Tohidyan Far and Rezaei-Moghaddam [7].

The study by Koutsos and Menexes [8] also supports this claim, as it found that American agricultural producers have a favorable attitude towards precision agriculture. According to their research, precision agriculture will increase the profitability of Algerian agriculture. This assertion is further substantiated by the findings of Fabiani et al. [6], who demonstrated that precision agriculture leads to a reduction in production costs. This claim is corroborated by the studies of Lowenberg-DeBoer [9] and McBratney et al. [10].

These studies also posit that precision agriculture facilitates agricultural work, in accordance with the results of Thompson et al. [11] in their study on the perceptions of agricultural producers. Furthermore, the results of Groher et al. [12] demonstrate that the adoption of precision agriculture This adoption has been shown to reduce the physical demands of agricultural work and to decrease the time required for its execution [13]. The utilization of agricultural robots has also been demonstrated to reduce the time required for agricultural work [14].

The development of a database to monitor the condition of the land and the effects of the different agricultural works is one of the effects mentioned by the Algerian agricultural engineers, and it is an effect to which they refer [14].

4.2 Ecological factors and resource optimization

Parihar et al. [15] demonstrated in their study on the effect of precision agriculture that it leads to efficiency in water consumption, while Jochinke et al. [16] demonstrated that it increases the efficiency of pest, disease and weed control. Algerian agricultural engineers identified the reduction of water use as the most significant impact on this axis, with the efficiency of disease and pest management and control and the efficiency of weed control ranking second and fourth, respectively.

The preservation of surface and groundwater, along with their reduction in pollution, was identified as the second most significant impact. This finding aligns with the results reported in the study by Tohidyan Far and Rezaei-Moghaddam [7].

The preservation of soil from pollution, erosion, and compression ranked fifth. This finding is in line with the studies conducted by Ahmad and Mahdi [17]. The list of impacts continues with similar findings, as outlined in the work by Bora et al. [18].

4.3 Chemical use and environmental impact

Numerous studies have indicated the role of precision agriculture and its techniques in increasing the efficiency of fertilizer and pesticide use. For instance, a study by Cao et al. [19] examined the role of precision agriculture in increasing the efficiency of fertilizer use even in small fields. Similarly, a study by Jensen et al. [20] explained its effect on reducing fertilizer use, and study of Koutsos and Menexes [8] shows that precision agriculture increases the efficiency of agricultural pesticide use, and Batte and Ehsani [21] demonstrated the benefit of using precision pesticide spraying machines in reducing the cost of agricultural inputs.

The Algerian agricultural engineers identified the enhancement of fertilizer efficiency as the primary effect in this axis, the augmentation of pesticide efficiency as the secondary effect, and the reduction in input costs as the tertiary effect.

4.4 Impact on the efficiency of agricultural machinery

The Algerian agricultural engineers identified the reduction in the depreciation rate of agricultural machinery as the most significant effect in this axis, and Gusev et al. [22] noted a comparable effect, while they regarded the enhancement in the efficiency of energy consumption as the secondary effect. In this axis, Bora et al. [18] identified a similar effect in their study, while the reduction of greenhouse gas emissions was the third effect in this axis, as Ahmad and Mahdi [17] indicated.

4.5 Socio-economic impacts and social equity

Ofori and El-Gayar [23] indicated through their analysis of publications about precision agriculture on social media platforms that the attitude towards it is positive among young people, as they indicated that it can lead to an increase in the number of jobs, while Tohidyan Far and Rezaei-Moghaddam [7] indicated that agricultural engineers in the Islamic Republic of Iran believe that precision agriculture has a positive impact on immigration and workers' income.

In contrast, Algerian agricultural engineers identified the increasing trend of youth entering the agricultural sector as the most significant impact of precision agriculture in this axis. The impact of precision agriculture in reducing internal migration was ranked second, followed by the impact on increasing workers' income in third place. The impact of limiting migration abroad was ranked fourth, and the impact of increasing job opportunities in the center was ranked fifth.

4.6 Comprehensive education and practical training

Adoption of precision agriculture technology integrates effortlessly into existing farming operations, reducing disruption while enhancing established values and practices.

Which highlighting the necessity for explicit demonstrations of concrete advantages, including enhanced efficiency, financial returns, and sustainability improvements. Training programs, demonstration farms, and extension services can function as essential tools to enhance behavioral attitudes by rendering the benefits apparent and relatable. Technology vendors must build solutions that correspond with local agricultural systems and articulate their benefits clearly to mitigate adoption reluctance. The image demonstrates that the transition from perception to adoption is not merely technological but also behavioral, necessitating interventions that address both engineers practical requirements and psychological motivations.

5. CONCLUSION

The Algerian agricultural engineers possess a favorable and optimistic perspective on Precision Agriculture, deeming its adoption essential for the future of the country's agricultural sector.

This consensus is founded on the potential of this technology to address substantial economic, environmental, and social challenges in the Algerian agricultural sector, such as increased agricultural operations efficiency, substantial ecological and resource optimization, enhanced chemical management, and favorable socio-economic effects, especially in engaging youth in agriculture.

The shift from attitude to adoption is fundamentally dependent on two factors: compatibility with current farming systems and perceived utility. Consequently, to leverage this favorable perspective, policy and extension services must emphasize showcasing concrete, measurable economic and environmental advantages. Technological solutions must be strategically aligned with the practical realities and established systems of Algerian farms to alleviate reluctance and effectively convert this widespread support into actual implementation.

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