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Research Article

# An Analysis of the Readiness of Agricultural Extension Centers in Iraq for Adopting Artificial Intelligence Applications in Integrated Pest and Disease Management: A Comparative Study Based on the SWOT Model

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**ABSTRACT**

The current study aimed to evaluate the readiness of agricultural extension centers in Iraq to adopt artificial intelligence (AI) applications for integrated pest and disease management. It also assessed internal strengths and weaknesses, as well as external opportunities and threats, using a SWOT framework to determine institutional preparedness. In addition, a development strategy was planned to augment the efficiency of the extension system in adopting and implementing AI technologies, alongside a comparative analysis of preparedness levels across Iraqi governorates. The study sample encompassed 234 employees working in agricultural extension centers across fifteen Iraqi governorates, selected using a stratified sampling approach based on geographic distribution. The findings showed that agricultural extension centers displayed a moderate level of preparedness for AI adoption. Baghdad Governorate demonstrated the highest readiness, followed by neighboring governorates, whereas more distant governorates exhibited relatively lower levels of preparedness. SWOT analysis discovered numerous strengths and promising opportunities within the extension environment, mainly the availability of skilled personnel and institutional support for the adoption of AI technologies. Nonetheless, major limitations were also recognized, such as scarce financial resources, inadequate training programs, and insufficient technological infrastructure. The study concludes that Iraq's agricultural extension system provides a solid foundation for the gradual implementation of AI-based plant protection tools, such as decision support systems for integrated pest management and pest and disease forecasting models. To ensure successful adoption, the study recommends the implementation of a national development strategy focused on upgrading infrastructure, strengthening human capacity, and reinforcing research, extension, and institutional partnerships.

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## Introduction

Agriculture is the basis for economic and social growth of any nation, particularly in developing countries. This issue has gained increasing importance in recent years, because it is known that land provides people with food and is the main source of national income for many countries. It also provides manufacturing industries with what they need to make things. It also contributes to

several other aspects to a great extent (Shada et al., 2023). So, the development of this sector is one of critical priorities for many countries. Science and technology, including all processes and scientific methods and validated procedures, is indispensable for developing countries. This adoption largely contributes to the development progress (Amin and Ali, 2021). Agricultural extension is an integral part of this process, which involves using agricultural inputs efficiently in order to achieve the greatest profit from agro-based products. This entails improving production methods on a technical and organizational level, introducing modern technical skills to farmers and managing resources in a way that can reduce the cost of produced product per unit; reduce production and operational costs or increase farm output from crops and agricultural products. This is facilitated by the adoption of advanced production methods (Hamed and Abdullah, 2024). Considering the growing pressures on the agricultural sector, including climate change, water scarcity, and population growth, the adoption of artificial intelligence-based technologies has emerged as a promising approach to enhance future food security.

Further research into such technologies has become highly necessary with the rapid urbanization and consequent reduction in arable land. It implies that it ceases to be a question of pure planting and harvesting, but it is more of a pure science and utilizes data, the Internet of Things (IoT), artificial intelligence, and big data analytics (Ahmed and Abdullah, 2025). Digital agriculture strategies involve artificial intelligence (AI), which is developing more rapidly than it was estimated before. Though technological revolution was anticipated, its soaring speed was not anticipated. This change in speed necessitates the need to adjust the institutions so that they keep up with the current changes in technology (Javaid et al., 2023). AI is also emerging as an essential part of the agricultural development and pest management. Developed countries have been long encouraging the use of its applications in agricultural fields. However, the AI technology has developed at very high rates and is currently extensively used, exceeding expectations. The technological revolution was predicted, but at the same time, the pace of the technological revolution was much faster than it had been expected (Elbehri, 2021). In recent times, AI has become highly embraced and prominent in agricultural industry. It is widely used in crop and soil-borne pests, processing of aerial images taken by the drones, and processing mass data to detect plant diseases and measure crop maturity. AI devices also allow accurate measurements in the field; aid in decision-making according to the weather conditions in the region, and help calculate the best input rates per planting area, including nutrients and pest control agents. Moreover, accurate pest identification technologies like insect detection through the use of visible or ultraviolet light enhance early detection and management plans. These applications used in unison allow farmers to make smart and data-driven decisions that not only optimize the use of resources, defend crops, but they further increase production (High, 2025).

It is also much easier to monitor the health of livestock as sensors will constantly show the condition of animals. This will enable breeders to detect early symptoms of diseases at the initial stage and take necessary measures to safeguard the health of their animals. This will also enable them to use modern methods to spray pesticides precisely with the aid of drones that can help in drawing accurate maps about the status of crops, soil moisture and other factors that might affect the growth of plants; and this will increase productivity and make agriculture cleaner (Olawumi et al., 2025).

The future of artificial intelligence in agriculture sector appears very bright with increasing potential of improving agricultural outputs and at the same time maximizing the utilization of natural resources. Increased food demand will lead to significant rises in food demand because the world population will reach close to 9.9 billion by 2050. That is where technology plays a part in helping farmers meet this demand more efficiently and sustainably. Digital extension is one of the promising contemporary applied techniques, which seeks to compensate for the limitations of direct traditional methods and techniques (Abdullah et al., 2025a) Agricultural extension also works to include agriculture system and honors modern technological innovating tools for effective crop production. Iraq has a rich history of human and natural resources but its agriculture sector still has many challenges to contend with. Modern technologies are still weakly adopted in agricultural institutions, usually due to poor digital infrastructure (Abdullah et al., 2025b). In spite of Iraq's natural and human resources in agriculture, its institutions have yet to find a way to harness artificial intelligence. This might be due to inexperience and insufficient data processing capabilities. The development rate in Iraqi rural areas is much lower than expected, despite the fact that

agricultural extension services play an important role in stimulating agricultural and rural development. It exposes either weaknesses or drawbacks in how some extension services are doing business, or obstacles to becoming more effective users of AI as a tool to assist making better decisions and increasing agricultural productivity (Ayisi et al., 2025).

The use of artificial intelligence in agricultural extension within the subject of integrated pest and disease control is a current problem in agricultural research, which highlights the significance of the present study. It displays evaluation findings that aid in identifying the existing state of affairs and suggesting workable, relevant remedies. The study's findings also form a knowledge base to support decision-makers in the General Authority for Agricultural Extension and the Iraqi Ministry of Agriculture, thus strengthening efforts to develop technological transformation policies in the agricultural sector. The study's importance also lies in bridging the knowledge gap between the theoretical potential of modern technologies and the practical capabilities of agricultural extension institutions. Assessing institutional and human readiness is a fundamental step towards effective preparation for the smart transformation of the Iraqi agricultural sector. Adopting the SWOT model provides a comprehensive analytical framework for identifying future development areas. Therefore, the purpose of this study was to present a comparative scientific analysis of the reality of agricultural extension centers in Iraqi governorates, evaluate their preparedness to use AI technologies, and suggest a development strategy that helps improve agricultural extension's effectiveness and advance Iraq's sustainable agricultural development. The main objectives of the present study are: 1). to assess the readiness of agricultural extension centers in Iraq to adopt artificial intelligence applications in integrated pest and disease management, 2). to analyze the internal strengths and weaknesses, and the external opportunities and threats affecting the adoption of artificial intelligence technologies in agricultural extension centers, 3). to compare the level of readiness among agricultural extension centers in Iraqi governorates to implement artificial intelligence in integrated pest management, and 4). to propose a development strategy to enhance the readiness of agricultural extension centers in Iraq for smart transformation, using the results of a SWOT analysis.

## Materials and Methods

### Research population and sample

Iraq consists of three main geographical regions: the northern region (including governorates such as Nineveh, Dohuk, Erbil, Sulaymaniyah, and Kirkuk), the central region (Baghdad, Diyala, Anbar, Salah al-Din, Wasit, Karbala, and Babylon), and the southern region (comprising Basra, Najaf, Dhi Qar, Muthanna, Qadisiyah, and Maysan). The governorates of the Kurdistan region of Iraq (Erbil, Sulaymaniyah, and Dohuk) were excluded from the research population as these governorates are under self-administration and function within a regional system, and their extension or agricultural institutions are not affiliated with the central government in Baghdad. The research sample consisted of employees of the Agricultural Extension and Training Department of the Ministry of Agriculture. These employees are distributed across extension centers in various Iraqi governorates. According to the sample size determination table of Krejcie and Morgan (1970), populations exceeding 600 require a sample size of 234. After determining the overall sample size, the sample size for each governorate was calculated using the proportional stratified sampling method, based on the distribution of population size within each governorate and is shown in Table 1.

Table 1. Research populations and samples in various governorates of Iraq.

| Sr. No. | Name of Governorate | Number of employees in agriculture extension | Sample |
|---|---|---|---|
| 1 | Baghdad | 100 | 37 |
| 2 | Nineveh | 30 | 11 |
| 3 | Anbar | 67 | 25 |
| 4 | Kirkuk | 33 | 12 |
| 5 | Diyala | 62 | 23 |
| 6 | Babylon | 80 | 30 |
| 7 | Salah ad-Din | 33 | 12 |
| 8 | Dhi Qar | 45 | 17 |
| 9 | Diwaniyah | 18 | 7 |
| 10 | Wasit | 21 | 8 |
| 11 | Muthanna | 19 | 7 |
| 12 | Karbala | 25 | 9 |
| 13 | Maysan | 14 | 5 |
| 14 | Najaf | 32 | 12 |
| 15 | Basra | 51 | 19 |
| | Total | 630 | 234 |

**Research methodology**

The research adopted the descriptive approach, which focused on describing a specific phenomenon, collecting information about it, and then analyzing the characteristics of that phenomenon, interpreting it, the factors affecting it, and proposing appropriate solutions, as this approach is suitable for this type of research.

**Preparation of questionnaire form**

By reviewing scientific sources and previous studies, and consulting with experts and specialists, a questionnaire was prepared and formulated according to the research problem and the type of data it would receive, in order to achieve the study's objectives. The questionnaire consisted of 30 items to be answered according to a five-point Likert scale (very high, high, moderate, low, very low), distributed throughout five primary categories connected to the preparedness level of agricultural extension centers in Iraq to utilize artificial intelligence technologies in integrated pest and disease control as shown in Table 2.

Table 2. Distribution of research items by domain.

| Sr. No. | Domain | Number of items |
|---|---|---|
| 1 | Technological infrastructure | 6 |
| 2 | Human capabilities (digital skills) | 6 |
| 3 | Administrative and organizational support | 6 |
| 4 | Funding and financial resources | 6 |
| 5 | Organizational culture towards innovation | 6 |
| | Total of items in domains | 30 |

**Theoretical framework to be used in developing the research tool (questionnaire)**

The questionnaire designed in this study was founded on a theoretical framework that examined the readiness of institutions to embrace modern technology in the area of plant protection in terms of agricultural extension practices that involve the application of artificial intelligence programs. The organizational and technological readiness models, the adoption of smart technologies, which is based on smart technological infrastructure integration, human resources, administrative and organizational support, financial resources and innovation-supportive organization culture served as the materialization grounds with five axes of the questionnaire. Another analytical tool applied was the SWOT model to connect external opportunity and the threat with internal strengths and weaknesses to harvest the benefits of these great power relations in a comprehensive assessment of the readiness of the agricultural extension centers to adopt artificial intelligence application in plant protection.

**The willingness of agricultural extension services to apply AI applications in the protection of plants**

In recent years, artificial intelligence has gained the necessary role in the creation of the modern plant protection system, both due to the developed methods of data analysis and predictions of the risks, and owing to the presence of this technology in the decision making of the integrated pest management (IPM) programs. The willingness of agricultural extension centers to disseminate these applications on the agriculture sector and transform them into practicable extension practice is a significant factor to the success of AI application in the industry. Simply, putting AI in the field of plant protection includes DIA-based early plant disease detection, intelligent pest and disease spread prediction model based on algorithm (intelligent models + climate), IPM decision support system. To determine the best control strategies and the most appropriate intervention time through extension agents, IPM will result in minimizing dependence on chemical pesticides and related damages to the environment. The AI technology has also made it easier to work out specific spraying techniques so that pesticides may be applied to the infestations of pests and diseases in the most targeted way. Moreover, AI has led to the emergence of plant health monitoring technologies that are improving border cross-disease and pest detection and early warning. It needs technical infrastructure in order to execute these applications and human skills are very essential in comprehending the products of the intelligent systems and putting them into practice. Administrative and organizational support develops a framework of integration of AI applications in institutional agricultural extension programs and funding and finances determine sustainability of introduction and upgrading to newer versions of the applications. A creative or ingenious corporate culture is another reason

that promotes the adoption of ingenious strategies and adaptation to more productive methods of extension. Thus in evaluating them, it gives a solid scientific ground in determining the position where agricultural extension services are prepared to apply AI applications in integrated management of pests and diseases.

**Pre-test**

To establish the reliability and validity of the questionnaire, a random sample of 30 research population respondents was administered. Cronbach alpha was applied and the obtained alpha coefficient was 0.84 with a validity coefficient 0.91.

**Determining the degree of agricultural extension preparedness**

**Artificial intelligent technologies**

The extent of preparation of the Iraqi agricultural extension centers towards using the artificial intelligence technologies were evaluated using a questionnaire tool containing 30 items that express each indicator representing the preparation. The potential readiness was calculated as the total of the scores in the responses of the participants to the questions in the questionnaire that reflects how much the agricultural extension centers are prepared to use AI applications. The answers of the respondents were converted into the numeric statistical data, through the recoding of the answer options of 5-point Likert-type scale: very high, high, moderate, low and very low.

**Statistical methods**

In order to achieve the objectives of the current study, the data were classified and analyzed statistically. The statistical methods used were percentage, frequency, standard deviation, range, mean, and one-way ANOVA.

**Results and Discussion**

**Objective 1**

**Assessment of readiness of agricultural extension centers in Iraq to adopt AI applications in integrated pest and disease management**

To achieve the first objective of the study, the questionnaire data related to measuring the level of readiness of agricultural extension centers in Iraq to adopt artificial intelligence applications in integrated pest and disease management were analyzed. The mean and standard deviation were used to determine the readiness level according to a five-point Likert scale as shown in Table 3.

The results in Table 3 regarding the level of general readiness of the agricultural extension centers in Iraq to use artificial intelligence applications was 3.05 with standard deviation of 0.75. This showed that the average readiness level was medium based on the five-interval Likert scale. This tier represented the starting capacity of AEIs to absorb some AI applications in crop protection (e.g., image-based early diagnosis of plant diseases, pest outbreak alerts and IPM decisions support). Nevertheless, such a method is still limited for broad real applications. The findings further revealed that the mean value of organizational culture relative to innovation was relatively high at 3.21 which reflected positive attitudes on the part of agricultural extension personnel towards embracing smart interventions and modern technologies. This, in turn, can be a driving force for adoption of AI-based applications in preventive extension. The example could be the dissemination of information about using disease prediction systems and encouraging farmers toward precision spraying as well as reducing chemical based and indiscriminate use of pesticides. On the other hand, funding and finance showed the lowest readiness at 2.87, indicating a low capacity to mobilize resources needed. On-farm required actions to adopt AI applications are up-gradation of center-level smart devices, provision of specific pest and disease diagnostic softwares at centers and connecting the extension centers with advanced agricultural databases for plant monitoring and biosecurity. Field experience from some extension leaders shows that lack of funding is the most critical challenge, delaying the transformation of theoretical recognition on importance of AI towards practical application in plant protection.

Table 3. General readiness level of agricultural extension centers in Iraq.

| Domain of study | Mean | Standard deviation (SD) | Readiness level |
|---|---|---|---|
| Technical infrastructure | 3.05 | 0.74 | Moderate |
| Human capabilities (digital skills) | 2.98 | 0.82 | Moderate |
| Administrative and Organizational Support | 3.12 | 0.69 | Moderate |
| Funding and financial resources | 2.87 | 0.77 | Moderate tending towards low |
| Organizational culture towards innovation | 3.21 | 0.71 | moderate tending towards high |
| Average overall level of readiness | 3.05 | 0.75 | Moderate |

**Objective 2**

**Analysis of internal strengths, weaknesses, opportunities, and threats affecting adoption of AI technologies in agricultural extension centers**

To achieve this objective, an analysis of the internal and external environment of agricultural extension centers in Iraq was conducted using the SWOT model. This analysis aimed to identify factors that promote or limit the adoption of artificial intelligence applications as shown in Table 4.

Table 4. Analysis of internal strengths, weaknesses, opportunities, and threats.

| Dimension | Element | Arithmetic mean | Standard deviation | Impact level |
|---|---|---|---|---|
| Strengths | Availability of experienced field counselors | 3.42 | 0.71 | Moderate tending towards high |
| | Initial willingness among counselors to use technology | 3.36 | 0.76 | Moderate tending towards high |
| | Existence of an organizational structure that can be digitally developed | 3.18 | 0.80 | Moderate |
| Overall average of strengths | 3.32 | 0.76 | | moderate tending towards high |
| Weaknesses | Limited financial resources and technical equipment | 2.68 | 0.79 | Moderate tending towards low |
| | Lack of training in artificial intelligence | 2.73 | 0.82 | Moderate tending towards low |
| | Limited digital infrastructure in guidance units | 2.81 | 0.77 | Moderate |
| Overall average of weaknesses | 2.74 | 0.79 | | moderate tending towards low |
| Opportunities | Supporting the government's drive towards digital transformation | 3.45 | 0.70 | Moderate tending towards high |
| | Possible collaboration with universities and agricultural research centers | 3.28 | 0.73 | Moderate |
| | Providing agricultural AI applications | 3.31 | 0.75 | Moderate |
| Overall average of opportunities | 3.35 | 0.73 | | Moderate tending towards high |
| Threats | Weak national internet infrastructure | 2.86 | 0.80 | Moderate |
| | Resistance to change and innovation among some personnel | 2.91 | 0.78 | Moderate |
| | Lack of clarity in national agricultural digital policies | 2.79 | 0.81 | Moderate tending towards low |
| Overall average of threats | 2.85 | 0.80 | | Moderate |

The results of the statistical analysis in Table 4 indicate that the elements of strengths and opportunities relatively outweigh the elements of weaknesses and threats, as the overall average for each of the strengths was 3.32 and the average for the opportunities was 3.35. Resultantly, they fall within the average level tending towards high, which reflects that the agricultural extension environment in Iraq has organizational and human foundations that can be built upon if institutional support is available. In contrast, the results showed that the average of the weaknesses was 2.74 and the average of the threats was 2.85. It means that there are real challenges related to weak funding, lack of training, and limited digital infrastructure in the extension units, as

well as the slowness of policies supporting the smart transformation. This might be explained by the fact that preparedness of agricultural extension centers to use artificial intelligence is influenced by internal elements such as efficiency and resources, as well as external factors such as the technology environment and government policy. Although there are opportunities to support the adoption of artificial intelligence applications in agricultural extension services, their implementation necessitates ongoing training programs and clear strategic plans. This must be ensured that opportunities and strengths are considered to counter threats and weaknesses. Based on SWOT analysis, the agricultural extension system in Iraq is ready for using AI applications to some extent in plant protection with an emphasis on integrated pest and disease management. This can be elevated through investment in technology infrastructure and capacity building of Agricultural extension staff.

**Objective 3**

**Comparison of the level of readiness of agricultural extension centers in Iraqi governorates to implement AI in integrated pest management**

To achieve this objective, a comparative analysis was conducted to assess the readiness of agricultural extension centers in various Iraqi governorates to adopt AI technologies. This analysis was based on the arithmetic mean for each governorate. A five-point Likert scale was used to determine the relative level of readiness, along with one-way ANOVA as shown in Table 5.

Table 5. Comparison of Iraqi governorates in readiness level.

| Sr. No. | Governorate Name | Sample size | Arithmetic mean | Significance | Readiness level |
|---|---|---|---|---|---|
| 1 | Baghdad | 37 | 3.42 | 0.013 | High |
| 2 | Babylon | 30 | 3.31 | | Moderate tending towards high |
| 3 | Salah ad-Din | 12 | 3.29 | | Moderate tending towards high |
| 4 | Najaf | 12 | 3.27 | | Moderate tending towards high |
| 5 | Karbala | 9 | 3.25 | | Moderate tending towards high |
| 6 | Nineveh | 11 | 3.22 | | Moderate |
| 7 | Diyala | 23 | 3.09 | | Moderate |
| 8 | Kirkuk | 12 | 3.05 | | Moderate |
| 9 | Wasit | 8 | 3.02 | | Moderate |
| 10 | Anbar | 25 | 3.00 | | Moderate |
| 11 | Diwaniyah | 7 | 2.96 | | Moderate tending towards low |
| 12 | Dhi Qar | 17 | 2.92 | | Moderate tending towards low |
| 13 | Maysan | 5 | 2.89 | | Moderate tending towards low |
| 14 | Basra | 19 | 2.84 | | Moderate tending towards low |
| 15 | Muthanna | 7 | 2.75 | | Low |
| General Average | | 234 | 3.08 | | Moderate |

The results of the one-way analysis of variance in Table 5 indicate that there are significant differences between the Iraqi governorates in the level of readiness of agricultural extension centers to adopt artificial intelligence technologies at a significance level of 0.05. This indicates that these differences are not due to chance, as the overall average reached 3.08, which indicates that the overall level of readiness is average. The results showed that Baghdad governorate stood first (with an average of 3.42), followed by the governorates of Babylon, Salah al-Din, Najaf, Karbala, and Nineveh with average levels tending towards high. On the other hand, other governorates such as Basra, Maysan, Muthanna, and Dhi Qar appeared with levels below average. The superior readiness of Baghdad governorate can be attributed to the fact that the capital hosts the headquarters of the general authority for agricultural extension, providing direct institutional support, intensive administrative oversight, and greater opportunities to attend training courses, seminars, and technical workshops. These contribute to enhancing staff preparedness and updating their skills. Governorates near Baghdad also benefit from this geographical proximity through easier administrative communication and participation in central activities, which positively impacts their readiness to adopt modern technologies. Conversely, other governorates suffer from weak technological infrastructure, limited field training opportunities, and challenges in transportation and

administrative communication, resulting in a relatively lower level of readiness. Therefore, a balanced national strategy is needed to develop the capabilities of extension units in all regions, with a focus on the least prepared governorates, to ensure an equitable transition to smart extension in Iraq.

**Objective 4**

**Development of strategy to enhance the readiness of agricultural extension centers in Iraq for smart transformation, using the results of a SWOT analysis**

Based on SWOT analysis results, which showed a relative balance between strengths and opportunities on the one hand, and weaknesses and threats on the other, and considering the variation in readiness levels among the governorates, in order to improve the effectiveness of plant protection services, support integrated pest and disease management decisions, and achieve agricultural sustainability, the development strategy was created with the goal of strengthening the Iraqi agricultural extension system's capacity to adopt artificial intelligence technologies within the framework of smart agricultural transformation at the national level as indicated in Table 6. The strategy proposed in Table 6 is based on the principle of aligning internal capabilities with the external environment. It intends to gradually raise the preparedness of agricultural extension centers from average to high levels by leveraging existing strengths and capitalizing on possibilities. The concept is changing from centralized administrative control to enabling agricultural extension units in governorates to use smart technology for planning, engaging with farmers, and analyzing agricultural data. It also prioritizes human resource development as the major engine of smart transformation, in addition to reforming digital infrastructure and strengthening research collaborations. Therefore, applying this technique would result in:

1. Increasing the effectiveness of agricultural extension in reacting to technological challenges.
2. Reducing the preparedness gap between governorates.
3. Increasing the role of artificial intelligence in attaining sustainable agricultural growth in Iraq.

Table 6. Proposed development strategy to enhance the readiness of agricultural extension centers in Iraq for smart transformation, using the results of a SWOT analysis.

| Type of relationship | Proposed strategy | Type of strategy |
|---|---|---|
| Leveraging strengths to capitalize on opportunities (SO) | 1. Establishing technical support units within agricultural extension centers for artificial intelligence applications.<br>2. Linking field training programs to national digital transformation plans.<br>3. Enhancing cooperation between the General Authority for Agricultural Extension, universities, and research centers to develop smart field applications. | Investment strategy (growth and development) |
| Overcoming weaknesses by capitalizing on opportunities (WO) | 1. Developing specialized training programs for workers in the field of agricultural artificial intelligence<br>2. Investing government support for digital transformation in financing the modernization of the digital infrastructure of extension units<br>3. Activating partnerships with the private sector to provide low-cost technological solutions. | Development strategy (capacity building) |
| Using strengths to mitigate the impact of threats (ST) | 1. Forming technical supervisory committees in the governorates to monitor technical and administrative challenges<br>2. Adopting incentive policies for agricultural personnel who adopt smart technologies<br>3. Diversifying sources of funding and support to reduce dependence on the central budget. | A preventative strategy (enhancing institutional resilience) |
| Reducing weaknesses and countering threats (WT) | 1. Preparing a national plan to unify agricultural information systems and link them centrally<br>2. Launching a national project for e-training in agricultural artificial intelligence via digital platforms<br>3. Improving the work environment in governorates far from the headquarters of the General Authority for Agricultural Extension to ensure benefit from development opportunities. | Defensive strategy (improving sustainability) |

**Comparison of research results with similar studies in different regions**

The results of this study are consistent with those of Klerkx et al. (2019) who concluded that poor infrastructure and lack of specialized human resource capacity is poised to adopt AI plant protection applications moderately by the agricultural extension services in developing countries of the world. They can also be compared to the results of Rose and Chilvers (2018) who suggested that a positive organizational culture is an important factor in the adoption of smart technologies within the extension organizations, despite constraints being placed based on finances. Similarly, Liakos et al. (2018) showed that institutional funding and professional training are necessary to guarantee the efficacy of AI applications in pest monitoring and plant disease detection. These findings, however, deviate from those carried out in a few European nations. Eastwood et al. (2019) demonstrated greater levels of preparedness as a result of institutional support and national policies that encouraged astute transition in the agriculture sector.

**Conclusions**

1. The results revealed that Iraqi agricultural extension centers are fairly ready to apply artificial intelligence applications in plant protection. This suggests that in achieving the desired smart transformation, AI technology adoption by extension institutions (notably for integrated pest and disease management), has a need for further support such as financial capital, infrastructure development and training.
2. The SWOT analysis results demonstrated that there are encouraging levels of both internal and external strengths and opportunities. It is concluded that the extension environment has the ability to advance technology, but in order to achieve a balance between skills and technical goals, it is still necessary to resolve training and finance deficiencies.
3. It was concluded that Iraqi governorates exhibit a noticeable gap in their preparedness to use artificial intelligence technologies for protection of crops. Baghdad ranked highest, with core governorates such as Babylon, Karbala, Najaf and Salah al-Din next in line while most of others governorates were ill-prepared. This means that physical proximity to the capital introduces robust effects on the degree of institutional support and technical supervision for a governorate. In response, decentralized training and development programs are needed so that technical capacity building of agricultural extension workers can be universally provided.
4. The results also demonstrated that the proposed SWOT-based growth plan provides a practical basis for guiding agricultural extension centers toward intelligent transformation. To accomplish these goals, defensive, preventive, developmental, and investment strategies must be employed. It is concluded that implementing this strategy will increase institutional and individual readiness to apply artificial intelligence technology and enhance the efficacy of extension services in accordance with the goals of sustainable agricultural development in Iraq.

**Recommendations**

In light of the findings of the present study, it is recommended that:

1. There is an urgent need to strengthen capacities of extension centers in Iraq by providing specific training programs on developing artificial intelligence applications for plant protection, especially the crop disease diagnostics, pest monitoring, and adoption of decision support systems for the management of integrated plant diseases and pests and setting up IT infrastructure inside extension institutions.
2. Maximize the strengths and opportunities identified in the SWOT analysis by developing strategies to enhance technical capabilities and strengthen cooperation with academic institutions and research centers, while mitigating the negative impacts of weaknesses and threats through improved funding and the provision of ongoing training programs.
3. A decentralized policy for the management and support of AI-based agricultural extension programs is required, permitting lesser-prepared governorates to receive similar training and qualifications while ensuring that at least a minimum level of technical infrastructure exists to support plant protection applications in every governorate.
4. Adopting the recommended SWOT-based development strategy as a practical guideline to enhance extension work performance. It must integrate investments, development, preventative and defensive measures in a national strategy for smart transformation of AE that can underpin sustainable agricultural growth and the application of modern

technologies to support farmers.

5. Establishing periodic monitoring and evaluation plans to measure progress in adopting artificial intelligence technologies across the governorates.

**Authors' Contributions**

ASA conducted the data analysis and contributed to the interpretation of the results. MNA developed and wrote the theoretical framework of the study. OADM reviewed and edited the manuscript for English-language accuracy and clarity. All authors contributed to the study, critically reviewed the manuscript, approved the final version, and agreed to be accountable for all aspects of the work.

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**Conflict of Interest**

The authors declare no conflict of interest.

**Sustainable Development Goals Targeted**

SDG 2: Zero Hunger

SDG 9: Industry, Innovation and Infrastructure

SDG 12: Responsible Consumption and Production

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