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Smart Farming Revolution: Farmer's Perception and Adoption of Smart IoT Technologies for Crop Health Monitoring and Yield Prediction in Jizan, Saudi Arabia

Abdoh Jabbari [1,*], Abdulmalik Humayed [1], Faheem Ahmad Reegu [1], Mueen Uddin [2], Yonis Gulzar [3,*] and Muneer Majid [4]

[1] Department of Computer and Network Engineering, College of Computer Science and Information Technology, Jazan University, Jazan 45142, Saudi Arabia; ahumayed@jazanu.edu.sa (A.H.); freegu@jazanu.edu.sa (F.A.R.)
[2] College of Computing and Information Technology, University of Doha for Science and Technology, Doha 24449, Qatar; mueen.uddin@udst.edu.qa
[3] Department of Management Information Systems, College of Business Administration, King Faisal University, Al-Ahsa 31982, Saudi Arabia
[4] Glocal School of Science and Technology, Glocal University Delhi-Yamunotri Marg (State Highway 57), Mirzapur Pole, Saharanpur 247121, UP, India; muneerbazaz@gmail.com
* Correspondence: ajabbari@jazanu.edu.sa (A.J.); ygulzar@kfu.edu.sa (Y.G.); Tel.: +966-545719118 (Y.G.)

Abstract: This study examines the perception and adoption of IoT technologies for crop monitoring among farmers in Jizan, Saudi Arabia. The research investigates the relationship between farmers' awareness of IoT technologies, their perception of benefits, and willingness to adopt them. It also explores the influence of factors like access to information, training, and the perception of government support on adoption behavior. A structured questionnaire was distributed to 550 farmers, with a response rate of 90.91%. The analysis reveals a significant association between farmers' awareness of IoT technologies and their perception of benefits. The perceived benefits show a moderate positive relationship with farmers' willingness to adopt IoT technologies. Access to information, training, and the perception of government support also have a positive influence on adoption. The findings highlight the importance of increasing farmers' awareness and providing access to information and training on IoT technologies. The study emphasizes the need for government support in facilitating adoption. Recommendations include exploring additional factors, conducting longitudinal studies, and developing tailored training programs. Collaboration among stakeholders and financial support mechanisms is also crucial. This study contributes to the understanding of IoT technology adoption in agriculture, providing insights for policymakers, agricultural extension agencies, and technology providers. By embracing IoT technologies and implementing the recommended actions, farmers in Jizan can enhance their crop monitoring practices, improve productivity, and promote sustainable farming.

Keywords: IoT technologies; crop monitoring; farmers' perception; adoption behavior; perceived benefits of IoT; awareness of IoT

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1. Introduction

In recent years, the field of agriculture has witnessed significant advancements in technology, paving the way for improved monitoring and management practices. One such technological innovation that holds great promise is the use of Internet of Things (IoT) technologies for monitoring crop health, growth, and yield prediction. The integration of IoT devices, sensors, and data analytics offers new possibilities for farmers to gain real-time insights into their crops and make informed decisions for optimizing agricultural productivity [1,2].

Agricultural productivity cannot be overstated when it comes to the importance of crop monitoring. In order for farmers to make informed decisions concerning irrigation, fertilization, pest control, and other agronomic practices, accurate and timely information about crop health, growth, and yield potential is necessary [3]. There has been a long history of crop monitoring that relies on manual observation and a limited range of sampling methods, which often results in inadequate resource allocation and a reduction in productivity. This is in spite of the fact that farmers have been able to access continuous and detailed information about their crops as a result of IoT technologies, enabling them to practice precision agriculture [4].

In agriculture, IoT technologies have the potential to offer a number of benefits. As a first step, IoT enables farmers to collect real-time data on the health and growth of their crops, allowing them to gain valuable insights about them. This allows for proactive intervention and timely adjustments in irrigation, nutrient application, and pest management strategies. Secondly, IoT technologies enhance the accuracy of yield prediction models by capturing detailed data on environmental conditions, crop physiology, and growth patterns [5]. Accurate yield prediction enables better planning and resource allocation, optimizing overall agricultural productivity.

Moreover, IoT technologies facilitate resource management in agriculture by optimizing the use of water, energy, and fertilizers. By monitoring soil moisture, temperature, and nutrient levels, IoT systems can provide precise recommendations for irrigation and fertilization, reducing waste and the environmental impact [6]. Additionally, IoT-based monitoring can help to identify pest infestations and diseases at early stages, enabling targeted interventions and minimizing crop losses [4].

The Vision 2030 of Saudi Arabia aims to diversify the country's economy and reduce its oil dependence. Agri-food sustainability is the focus of the plan. The achievement of these goals will be dependent on technological advancements and innovations. The Centre for the Development of Agricultural Techniques (CDAT) is a research, development, and technology adoption center established to promote agricultural research, development, and technology adoption. In order to achieve this aim, advanced farming techniques must be implemented, water resources should be conserved, and agricultural productivity must be improved. AgTech Investments: There has been a lot of investment in agricultural technology startups and innovations in Saudi Arabia. A large portion of these investments are targeted towards fostering technological advancements in various aspects of agricultural production, such as crop monitoring and the optimization of yield.

The objective of this research is to explore the perception and adoption of IoT technologies for crop monitoring among farmers in Jizan, Saudi Arabia. Jizan, located in the southwestern region of Saudi Arabia, is known for its diverse agricultural activities and is a prime area for investigating the potential of IoT technologies in improving farming practices. By understanding the perceptions, challenges, and adoption intentions of farmers in Jizan regarding IoT-based crop monitoring, valuable insights can be gained to enhance the implementation and effectiveness of these technologies in the local agricultural context.

A major objective of this study is to determine how much awareness farmers in Jizan have regarding the use of IoT technologies for crop monitoring and what the level of awareness is. What are the perceived benefits associated with adopting these technologies? What is the intention of farmers to adopt IoT technologies for crop monitoring in the future? Additionally, this study will explore farmers' preferred IoT technologies, their perception of government support, access to information, and training resources.

By investigating these aspects, this research aims to contribute to the existing knowledge on the use of IoT technologies for crop monitoring and provide valuable insights for policymakers, agricultural practitioners, and technology providers in Jizan, Saudi Arabia. The findings of this study will help to identify the factors influencing the successful implementation and adoption of IoT-based crop monitoring solutions, ultimately leading to improved agricultural practices, enhanced productivity, and sustainable farming in the region. In this research paper, we aim to explore the perception and adoption of IoT technologies for monitoring crop health, growth, and yield prediction among farmers in Jizan, Saudi Arabia, by understanding the awareness, benefits, and adoption intentions of farmers regarding IoT technologies in the region.

2. Literature Review

In recent years, IoT technologies have gained substantial attention for crop monitoring due to the fact that they have the potential to revolutionize agriculture by enabling the provision of real-time data on crop health, growth, and yield prediction [7,8]. This emerging field offers promising opportunities for farmers to optimize resource management, enhance productivity, and make data-driven decisions for sustainable farming practices. However, the adoption and successful implementation of IoT technologies in agriculture depend on multiple factors that can vary across different regions and contexts.

IoT technologies have been shown to have a number of benefits in agriculture in previous research. In the study conducted by [7] in a different geographical context, it was found that farmers were able to collect precise and timely information about environmental factors such as soil moisture, temperature, and other elements through the use of IoT-based monitoring systems. This enhanced data availability allowed farmers to optimize irrigation schedules, resulting in improved water efficiency and increased crop yields. Similarly, ref. [8] emphasized the potential of IoT technologies in crop yield prediction, demonstrating their ability to integrate data from multiple sensors and provide accurate predictions for informed decision-making.

In Pathmudi et al. [9], IoT is considered a modern technology comprising physical entities that communicate over the Internet with one another. The Internet of Things is everywhere. Globally, connected systems/organizations are driving the growth of IoT devices [10]. Ref. [11] developed an irrigation management system that uses the Internet of Things. There was a discussion of various IoT architectures, deployment models, sensors, and controllers that are used in agriculture today, cloud platforms for IoT, irrigation scheduling software, and machine-learning algorithms that allow us to predict real-time irrigation water demand in the future [12]. A system of automated monitoring of the soil–plant–atmospheric continuum at a high spatiotemporal resolution is being developed to replace the current labor-intensive, experience-based methods of agricultural decision-making with a data-driven approach based on data collected by automated monitoring [13]. It is proposed to develop an Internet of Things (IoT) framework that consists of wireless sensor networks with intelligent algorithms based on an Internet of Things (IoT) approach that increases food production while combating climatic change [14]. An IoT system could be used for agricultural automation and could be governed by a variety of protocol communications that are used to describe its rules. Several factors must be considered when analyzing parameters such as the speed at which data are transferred, the mechanism by which data are transferred, the encryption level, range, latency, and number of items controlled when analyzing parameters.

It has been proven that agriculturalists and farmers can take advantage of the Internet of Things (IoT) not only in order to enhance the efficiency with which they are able to grow crops and to make them more profitable but also to improve their post-harvest processes and the end users' experience with agricultural products [15]. Furthermore, one of the most effective uses of the IoT for agriculture involves implementing technologies such as drones for agriculture through the use of the IoT [16], remote sensing [17], smart greenhouses [18], smart livestock management [19], computer imaging [20], and efficient climate monitoring [21] as indicated in Figure 1.

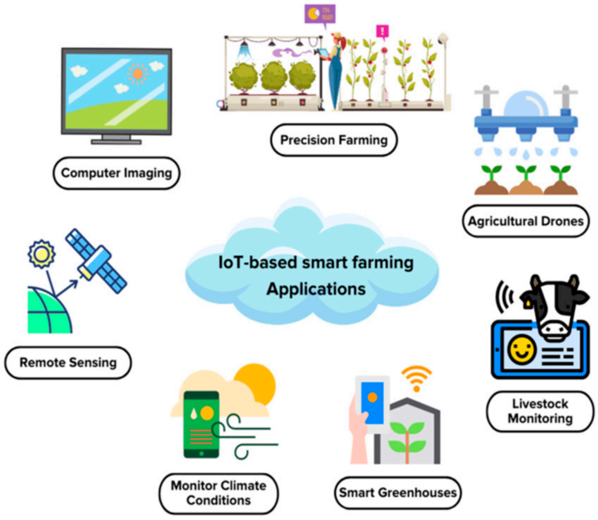

Figure 1. IoT based smart farming applications.

2.1. *A Smart Agriculture Approach to Predicting Yields*

There is an important aspect of crop yield in agriculture, and one of the most challenging and salient tasks is the prediction of crop yield. There are several factors that contribute to the prediction of a plant's or crop's overall yield, including soil properties, weather, seasonal fluctuations, seed quality, harvesting techniques, pest and disease monitoring, nutrient deficiencies, managing water requirements, and managing pest and disease problems. Since precision agriculture has been used for decades, researchers are now considering using sensor monitoring systems [22] and management systems so that crops can be kept healthy [15], productivity can be increased [16], and product quality can be improved in Figure 2 [23]. There has been an increased amount of attention devoted to sensors and drones used to monitor the quality of horticultural crops [24,25] and sensors that predict yields in various agronomic crops [26,27] and can be placed on harvesters for various crops [28], as well as the use of real-time data simulators [29]; moreover, the use of the Internet and real-time data simulators in crop production are gaining increasing attention.

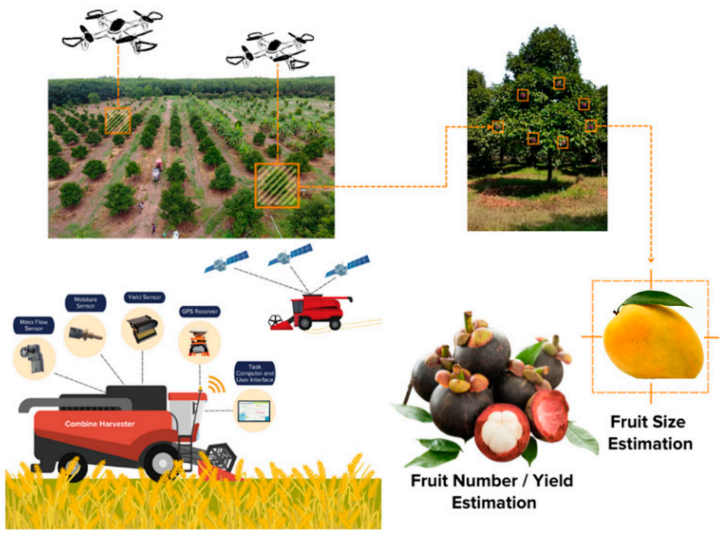

Figure 2. IoT devices of crop monitoring.

A number of studies have been conducted in the past that have shed light on the benefits of the Internet of Things in agriculture. However, there is a lack of research, which specifically focuses on the perception and adoption of these technologies among farmers in Jizan, Saudi Arabia. The agricultural landscape in Jizan is distinct, characterized by unique climate conditions, crop varieties, and farming practices. Such contextual factors can significantly influence farmers' attitudes, awareness, and willingness to adopt IoT technologies for crop monitoring and management.

Understanding the specific factors that influence the adoption intentions of farmers in Jizan is crucial for the successful implementation and utilization of IoT technologies in the region's agricultural sector. Factors such as farmers' level of awareness, perceived benefits and challenges, preferred IoT technologies, and perception of government support play a significant role in shaping their attitudes towards adopting these technologies. However, the literature lacks empirical evidence and insights into these factors in the context of Jizan.

To address this research gap, this study aims to investigate the perception and adoption of IoT technologies for crop monitoring among farmers in Jizan, Saudi Arabia. By conducting surveys and analyzing the collected data, this research will provide valuable insights into the specific factors influencing farmers' adoption intentions and inform the development of strategies to promote the successful integration of IoT technologies in Jizan's agricultural practices.

2.2. Level of Awareness of IoT Technologies in Agriculture

It has become increasingly apparent in recent years that IoT technologies can be used for improving agricultural productivity and efficiency. IoT technologies offer numerous opportunities for enhancing crop monitoring, improving productivity, and optimizing resource management in the agricultural sector. This section discusses the evolving level of awareness among farmers and stakeholders regarding the potential benefits of IoT technologies in agriculture.

Using IoT technologies, the authors of [8] argue that farmers will be able to make more informed decisions regarding the allocation of resources in order to maximize crop health and growth during the growing season. The study highlights the importance of creating awareness among farmers about the capabilities and benefits of IoT technologies. Similarly, [30] emphasize the role of IoT-based crop growth monitoring systems in enabling farmers to monitor key parameters such as soil moisture, temperature, and nutrient levels, leading to improved crop management practices.

In a survey conducted by [31], it was found that a majority of farmers had some level of awareness regarding IoT-based smart agriculture. However, the study also revealed variations in awareness levels across different regions and farm sizes. This suggests the importance of tailoring awareness campaigns and educational initiatives to specific contexts and target groups.

The authors discuss the importance of bridging the digital divide and ensuring equal access to information and resources related to IoT technologies in agriculture. They emphasize the need to address technological literacy and provide adequate training and support to farmers to enhance their awareness and adoption of IoT solutions.

2.3. The Adoption of IoT Technologies in Agriculture

The adoption of IoT (Internet of Things) technologies in the agricultural sector has gained significant attention in recent years. Farmers are increasingly recognizing the potential benefits of using IoT technologies for monitoring crop health, growth, and yield prediction. This section explores the adoption of IoT technologies among farmers and highlights key factors influencing their adoption decisions.

A study conducted by [32] among farmers in the United States found that 70% of the respondents were aware of IoT technologies and expressed a positive attitude toward their adoption. This indicates a growing interest and acceptance of IoT technologies among farmers.

The adoption of IoT technologies is influenced by various factors. One crucial factor is the perceived benefits of using these technologies. Research by [30] demonstrated that farmers perceive IoT technologies as beneficial for the real-time monitoring of crop health, enabling proactive decision-making and optimizing resource allocation. The ability to obtain accurate and timely information about crop conditions and environmental factors is seen as a significant advantage of IoT technologies [33].

However, there are also challenges associated with the adoption of IoT technologies in agriculture. Limited technical knowledge and skills to operate IoT devices have been identified as a barrier to adoption [34]. Farmers may require training and support to effectively utilize IoT technologies in their farming practices. Additionally, concerns about data privacy and security pose challenges to adoption. Farmers want assurance that their data will be protected and not misused [2,35].

Government support plays a crucial role in facilitating the adoption of IoT technologies in agriculture. Policies and initiatives that promote the use of IoT technologies and provide financial incentives can positively influence farmers' adoption decisions. Research by [36] showed that farmers who perceived strong government support were more likely to adopt IoT technologies.

Moreover, the availability of information and training resources is vital for successful adoption. Farmers need access to reliable and relevant information about IoT technologies, their benefits, and how to effectively implement them. Training programs and workshops can enhance farmers' understanding and competence in utilizing IoT technologies for crop monitoring [37–39].

2.4. Perceived Benefits of IoT Technologies

The perception of benefits of IoT (Internet of Things) technologies in agriculture plays a significant role in determining their adoption. Farmers are increasingly recognizing the potential advantages that IoT technologies offer for monitoring crop health, optimizing resource allocation, and improving overall agricultural productivity.

Real-time monitoring and data collection: One of the key perceived benefits of IoT technologies is the ability to monitor crop conditions and collect data in real time. IoT devices equipped with sensors can provide farmers with accurate and up-to-date information about soil moisture levels, temperature, humidity, and other environmental factors. There is a growing need for farmers to be given access to data in real-time so that they can make good decisions regarding irrigation, fertilization, and pest control and thus improve crop health and maximize resource utilization [30,33].

Proactive decision-making: IoT technologies enable farmers to take a proactive approach to agricultural management. By continuously monitoring crop health and environmental conditions, farmers can identify potential issues or anomalies early on and take necessary actions to mitigate risks. For example, if a sensor detects a sudden drop in soil moisture levels, the system can automatically trigger an irrigation schedule adjustment or send an alert to the farmer, allowing for prompt intervention and preventing potential crop damage [34].

Yield prediction and crop planning: IoT technologies also contribute to yield prediction and crop planning. Through data analysis and machine-learning algorithms, IoT systems can generate insights and forecasts regarding crop yield potential. This information enables farmers to plan their harvesting, storage, and marketing activities more effectively. Additionally, yield prediction helps farmers estimate their future produce, allowing for better financial planning and decision-making [36].

2.5. Willingness to Adopt IoT Technologies

The willingness to adopt IoT (Internet of Things) technologies is a critical factor in the successful implementation and integration of these technologies in the agricultural sector. This section explores the factors influencing farmers' willingness to adopt IoT technologies and the potential benefits associated with their adoption.

Perceived usefulness: Farmers' perception of the usefulness of IoT technologies significantly influences their willingness to adopt them. Studies have shown that farmers are more likely to adopt IoT technologies when they perceive them as valuable tools that can enhance their farming practices and decision-making processes. The perceived usefulness of IoT technologies stems from their ability to provide real-time data on crop health, optimize resource management, and improve overall agricultural productivity [30,33].

Perceived ease of use: The perceived ease of use refers to farmers' perception of how easy it is to learn and operate IoT technologies. Farmers are more likely to adopt IoT technologies when they perceive them as user-friendly and accessible. Factors such as the simplicity of the interface, ease of installation and maintenance, and availability of training and technical support influence farmers' perception of the ease of use. User-friendly IoT technologies increase farmers' confidence in their ability to adopt and utilize these technologies effectively [2,34].

2.6. Access to Information and Training, Perception of Government Support

Access to information and training, as well as the perception of government support, are important factors that influence farmers' willingness to adopt IoT technologies in our targeted area. Here, we explore the impact of these factors on farmers' adoption decisions based on recent studies conducted from 2020 onward.

Access to information and training: Farmers' access to relevant information and training on IoT technologies is crucial for their successful adoption. Studies have shown that farmers who have access to comprehensive information and training programs are more likely to adopt and effectively use IoT technologies in their farming practices. Accessible information channels, such as agricultural extension services, workshops, seminars, and online resources, contribute to farmers' understanding of the potential benefits and functionalities of IoT technologies. Training programs that provide hands-on experience and technical knowledge further enhance farmers' confidence and competency in utilizing these technologies [8,40].

Perception of government support: Farmers' perception of government support plays a significant role in their decision to adopt IoT technologies. When farmers perceive that the government actively supports the adoption and implementation of IoT technologies in agriculture, they are more likely to embrace these technologies. Government support can take various forms, including financial incentives, subsidies, policy frameworks, and the establishment of dedicated support programs. The perception of government support creates a favorable environment for farmers, instilling confidence and reducing potential barriers to adoption. It also signals the government's commitment to the modernization of the agricultural sector and the promotion of sustainable farming practices [6,41].

In our targeted area, the availability of relevant and up-to-date information on IoT technologies through government initiatives and agricultural extension services is vital. Farmers should have access to training programs that provide them with the necessary skills and knowledge to effectively use IoT technologies for crop monitoring. Additionally, the government should demonstrate a supportive stance by offering financial assistance, subsidies, and policy measures that incentivize the adoption of IoT technologies in agriculture. These efforts foster a positive perception of government support, encouraging farmers to embrace IoT technologies and integrate them into their farming operations [42].

2.7. Research Gap

Despite the growing body of research on the use of IoT technologies in agriculture, there is still a notable gap when it comes to understanding the perception and adoption of these technologies among farmers in specific regions, such as Jizan, Saudi Arabia. Most of the existing studies have focused on general discussions of IoT applications in agriculture or have examined adoption patterns in different geographical contexts [8,43]. However, the specific factors influencing the perception and adoption of IoT technologies in the context of Jizan's agricultural sector remain largely unexplored.

Jizan, located in the southwestern region of Saudi Arabia, has its own unique agricultural landscape, characterized by specific climatic conditions, crop varieties, and farming practices. These contextual factors can significantly influence farmers' attitudes, awareness, and willingness to adopt IoT technologies for crop monitoring and management. Therefore, it is crucial to conduct region-specific studies to bridge the gap in knowledge and provide insights that are tailored to the needs and challenges faced by farmers in Jizan.

By conducting a focused investigation on the perception and adoption of IoT technologies for crop monitoring among farmers in Jizan, this study aims to fill this gap in the literature. It is hoped that the findings will allow us to better understand the specific factors that influence the adoption intentions of farmers in Jizan. These factors include the farmers' level of awareness, their perception of the benefits, and their perception of the challenges associated with IoT, as well as their perception of the government's support. This knowledge can inform the development of targeted strategies and policies to promote the successful implementation and utilization of IoT technologies in Jizan's agricultural sector.

Objective and Hypothesis

Objective 1: To examine the association between farmers' level of awareness of IoT technologies and their perception of the benefits.

Hypothesis 1. *There is a significant association between farmers' level of awareness of IoT technologies and their perception of the benefits.*

Objective 2: To assess the influence of perceived benefits of using IoT technologies for crop monitoring on farmers' willingness to adopt these technologies.

Hypothesis 2. *The perceived benefits of using IoT technologies for crop monitoring have a significant and positive influence on farmers' willingness to adopt these technologies.*

Objective 3: To explore the influence of access to information and training, as well as the perception of government support, on farmers' willingness to adopt IoT technologies.

Hypothesis 3. *The access to information and training and perception of government support have a positive influence on farmers' willingness to adopt IoT technologies.*

3. Methodology

3.1. Research Design

It is the aim of this research study to identify the factors that influence farmers in Jizan, Saudi Arabia, to adopt Internet of Things (IoT) technologies for crop monitoring using the quantitative method as part of the research design. In quantitative research, numerical data are collected and analyzed in a systematic way, with the objective of testing hypotheses and drawing objective conclusions based on the statistical analysis of the data.

3.2. Sampling Technique

An examination of a representative sample of farmers in Jizan was conducted by using a sampling technique based on stratification. Based on relevant criteria such as farm size, farming experience, and geographic location, the population of the study was divided into distinct strata, which were categorized according to relevant factors. To ensure that a proportionally representative sample of each subgroup was selected, a random sampling algorithm was used within each stratum in order to select participants.

3.3. Data Collection

Data were collected through a structured questionnaire administered to the selected sample of farmers. The questionnaire consists of multiple-choice and Likert scale items to gather both demographic information and respondents' perceptions, attitudes, and behaviors related to the adoption of IoT technologies for crop monitoring. The questionnaire was pre-tested with a pilot group of farmers to ensure clarity and validity.

3.4. Data Analysis

To address the research objectives and test the hypotheses that have been proposed, the collected data have been analyzed using appropriate statistical methods. In order to summarize the demographic information and the responses from the participants, descriptive statistics such as frequencies and percentages were used. Correlations, associations, and yield predictions were all examined by using inferential statistical techniques, such as reliability analysis, correlation tests, and regression analysis.

According to methodology, we aim to gather reliable and representative data that can contribute to a comprehensive understanding of the factors influencing the adoption of IoT technologies for crop monitoring among farmers in Jizan, Saudi Arabia.

4. Results

Descriptive statistics were calculated to provide an overview of a variety of characteristics related to the demographics of the participants, as well as their perceptions and behaviors in relation to the use of the IoT for crop monitoring technologies. Frequencies and percentages were computed to present the distribution and central tendencies of the variables under investigation. In addition to hypothesis testing, other relevant findings emerged from the data analysis. These findings provide further insights into the factors influencing the adoption of IoT technologies for crop monitoring among farmers in Jizan, Saudi Arabia. The results highlight patterns, trends, and relationships that are important in understanding the research topic. This study has some limitations that need to be acknowledged in order for the results to be reliable. Among the limitations of the study are the constraints on sample size, the possibility of bias during data collection, and the generalizability of the findings beyond the sampled population. These limitations should be considered when interpreting the results and implications of the study. The results section presents the findings of the statistical analyses conducted, providing evidence to support or reject the formulated hypotheses and offering insights into the research objectives. The results contribute to our understanding of the factors influencing the adoption of IoT technologies for crop monitoring among farmers in Jizan, Saudi Arabia. Table 1 presents the details of the questionnaire.

Table 1. Details of the questionnaire.

Respondent Type	Total Questionnaire	Return Questionnaire	Percentage Rate of Questionnaire
Farmer	550	500	90.91

According to Table 1, the study specifically targeted farmers in Jizan, Saudi Arabia, as the primary respondents. The total number of questionnaires distributed to farmers for data collection was 550. Out of the 550 questionnaires distributed, 500 questionnaires were returned by the farmers. These results indicate that there was a high response rate among the farmers, with 90.91% of the questionnaires being returned and providing valuable data for the study. This suggests a good level of engagement and interest from the farmers in the topic of using IoT technologies for crop monitoring in Jizan, Saudi Arabia. According to [44], 70% or more is considered to be a good response rate and the response rate can be considered as being excellent if that rate is greater than 70%.

According to Table 2 and a graphical representation of demographics analysis, the survey included 500 respondents, of which 68.8% were male and 31.2% were female. The participation of both genders indicates a diverse representation among farmers in Jizan, Saudi Arabia. Among the respondents, 21.5% had an undergraduate degree, 54.0% were graduates, 19.3% held a master's degree, and 5.3% had a Ph.D. The majority of farmers in the study had attained higher levels of education, indicating a potential correlation between education and the adoption of IoT technologies. The distribution of farming experience shows that 36.0% of respondents had no prior farming experience. Among those with experience, 32.8% had 1 to 3 years, 19.4% had 4 to 5 years, 10.0% had 6 to 7 years, and only 1.8% had more than 7 years of farming experience. The findings suggest a mix of experienced farmers and individuals relatively new to farming, providing insights into the perspectives of both experienced and novice farmers regarding IoT technology adoption. The marital status of the respondents indicates that 20.8% were single, 53.8% were married, 20.2% were divorced, and 5.2% were widowed. The diversity in marital status reflects the varied life situations of farmers and allows for a comprehensive understanding of different perspectives on IoT technology adoption. Among the surveyed farmers, 68.8% of males and 31.2% of females have adopted IoT technologies. This finding highlights a potential gender disparity in the adoption of IoT technologies among farmers in Jizan, Saudi Arabia.

Table 2. Demographical details.

Variables	Frequency	Percentage (%)
Gender		
male	344	68.8
female	156	31.2
What is your educational level?		
Undergraduate	86	21.5
Graduate	216	54.0
Master	77	19.3
Ph.D	21	5.3
Years of farming experience		
No experience	180	36.0
1 to 3 years' experience	164	32.8
4 to 5 years' experience	97	19.4
6 to 7 years' experience	50	10.0
more than 7 years' experience	9	1.8
What is your marital status?		
Single	104	20.8
Married	269	53.8
Divorced	101	20.2
Widowed	26	5.2
Farmers who have adopted IoT technologies or non-adopted		
Male	344	68.8
Female	156	31.2

The demographic results provide a snapshot of the gender distribution, educational backgrounds, farming experience, marital status, and the adoption of IoT technologies among farmers in Jizan, Saudi Arabia. This information serves as a foundation for understanding the farmers' perceptions and adoption patterns regarding IoT technologies for crop monitoring, health assessment, growth tracking, and yield prediction.

According to the results in Table 3, the topic of using IoT technologies to monitor crop health, growth, and yield prediction exhibits a relatively moderate mean, a relatively high variance and standard deviation, and a good level of internal consistency. The high variance and standard deviation indicate a significant degree of variability in the data, and the good internal consistency suggests that the measured items or variables in the analysis are reliable. The Cronbach's alpha value for the Likert scale was 0.872, which indicates that all factors in the Likert scale have an internal consistency of 0.872. As a result, all factors are internally consistent with each other. In order to verify the reliability of a test, a good measure is a Cronbach's alpha value of 0.7 or higher, which, when using Cronbach's alpha as a guideline, is generally considered a good measure of reliability [45]. This study was able to determine a Cronbach's alpha value of 0.872, considered to be excellent based on the results of the study.

Table 3. Reliability statistics.

Mean	Variance	Std. Deviation	Cronbach's Alpha α	N of Items
110.89	302.142	17.382	0.872	44

Table 4 presents the results of the interpretation of the correlation coefficient (r = 0.835 **) for Hypothesis 1, which examines the relationship between farmers' level of awareness of IoT technologies and their perception of the benefits of using these technologies for crop monitoring. The correlation coefficient of 0.835 ** indicates a strong positive correlation between farmers' level of awareness of IoT technologies and their perception of the benefits associated with using these technologies for crop monitoring. This suggests that as farmers' awareness of IoT technologies increases, their perception of the benefits also tends to increase. The strength of the correlation coefficient suggests that there is a substantial relationship between these two variables. The positive correlation implies that farmers who have a higher awareness of IoT technologies are more likely to perceive greater benefits from using these technologies for crop monitoring. This finding supports the hypothesis that there is a significant association between farmers' level of awareness of IoT technologies and their perception of the benefits. It indicates that farmers who are more aware of IoT technologies are more likely to recognize the advantages and positive outcomes associated with implementing these technologies in their crop monitoring practices.

Table 4. Correlations.

Correlations		FWAIT	PBIT
FWAIT	Pearson Correlation	1	0.835 **
	Sig. (2-tailed)		<0.001
	N	500	500
PBIT	Pearson Correlation	0.835 **	1
	Sig. (2-tailed)	<0.001	
	N	500	500

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

Based on Table 5, all of the *p*-values that are reported from Levene's test are greater than 0.05, which means that there is no significant evidence to suggest that the variances between the groups are different from one another. Furthermore, there is no strong reason why the null hypothesis should be rejected, as the assumption of homogeneity of variance is met. These results are considered good because they imply that the variability within each group is relatively consistent, which makes it more appropriate to use statistical methods that assume equal variances, such as the analysis of variance (ANOVA) or *t*-tests.

According to the results in Table 6, the correlation coefficient (R) represents the strength and direction of the relationship between the independent variable (perceived benefits) and the dependent variable (willingness to adopt IoT technologies). In this case, the correlation coefficient is 0.458, indicating a moderate positive correlation between the perceived benefits and willingness to adopt IoT technologies. The coefficient of determination (R Square) explains the proportion of variance in the dependent variable that can be accounted for by the independent variable(s). In this model, the R Square value is 0.210, which means that approximately 21% of the variance in farmers' willingness to adopt IoT technologies is explained by the perceived benefits. The adjusted R Square is a calculation that takes into account the number of predictors that are included in a model and calculates the adjusted R Square value accordingly. A more accurate R Square in this case is 0.209, which is slightly lower than the standard R Square in this case. As a result, it is suggested that when taking into consideration the other variables in the model, the perception of the benefits alone explains about 20.9% of the variance in farmers' willingness to adopt IoT technologies. The standard error is a measure of how much uncertainty the observed values have around the predicted values, or how much scatter they have around the observed values. The standard error of the estimate of farmers' willingness to adopt IoT technologies in this model is 5.14266, which represents an average difference between the observed values and the predicted values of farmers' willingness to adopt IoT technologies in this model.

Table 5. Test of homogeneity of variance.

		Levene Statistic	df1	df2	Sig.
FWAIT	Based on mean	0.191	1	498	0.662
	Based on median	0.236	1	498	0.628
	Based on median and with adjusted df	0.236	1	493.566	0.628
	Based on trimmed mean	0.203	1	498	0.653
LAIT	Based on mean	0.111	1	498	0.739
	Based on median	0.121	1	498	0.728
	Based on median and with adjusted df	0.121	1	495.976	0.728
	Based on trimmed mean	0.113	1	498	0.737
AIT	Based on mean	2.169	1	498	0.141
	Based on median	2.427	1	498	0.120
	Based on median and with adjusted df	2.427	1	493.565	0.120
	Based on trimmed mean	2.132	1	498	0.145
PGS	Based on mean	2.490	1	498	0.115
	Based on median	2.283	1	498	0.131
	Based on median and with adjusted df	2.283	1	489.073	0.131
	Based on trimmed mean	2.378	1	498	0.124

Table 6. Model summary.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.835 [a]	0.698	0.697	3.18166

[a] Predictors: (Constant), PBIT; Dependent Variable: FWAIT.

Table 7 provides the ANOVA table of a regression analysis for the second hypothesis, which examines the relationship between the perceived benefits of using IoT technologies for crop monitoring (PBIT) and farmers' willingness to adopt these technologies (FWAIT). This section of the ANOVA table provides information regarding the overall fit of the regression model in terms of the regression section. Farmers' willingness to adopt IoT technologies has an unexplained variability of 13,170.590, the sum of squares for the residuals. As indicated by the degree of freedom of the residuals, there were 498 cases minus the number of predictors. There is an average unexplained variability of 26.447 in the residuals, indicating the mean square for the dependent variable. In the total section of the ANOVA table, you can see how much variability there is in the dependent variable as a whole. A total of 16,675.448 squares represents the total variability in the farmers' willingness to adopt IoT technologies.

Table 7. ANOVA.

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	3504.858	1	3504.858	132.524	<0.001 [a]
	Residual	13,170.590	498	26.447		
	Total	16,675.448	499			

Dependent Variable: FWAIT; [a] Predictors: (Constant), PBIT.

According to Table 8 and the graphs in Figure 3, the regression standard residuals show coefficients representing the outcomes of a regression analysis for Hypothesis 2, which examines the relationship between the perceived benefits of using IoT technologies for crop monitoring (PBIT) and farmers' willingness to adopt these technologies (FWAIT). When all of the independent variables are zero, then the constant coefficient (B = 6.352) represents the estimated value of the dependent variable (FWAIT) when all of the independent variables are equal to zero. In this case, it indicates the estimated baseline level of farmers' willingness to adopt IoT technologies for crop monitoring when the perceived benefits are zero. The constant coefficient is statistically significant (t = 5.028, $p < 0.001$), suggesting that it has a significant influence on the dependent variable. The coefficient for the perceived benefits variable (B = 0.930) represents the estimated change in the dependent variable (FWAIT) for each unit increase in the perceived benefits score, while holding other variables constant. The standardized coefficient (Beta = 0.458) indicates the standardized effect size, representing the relative importance of the perceived benefits compared to other variables. The coefficient for the perceived benefits variable is statistically significant (t = 11.512, $p < 0.001$), indicating that it has a significant impact on farmers' willingness to adopt IoT technologies for crop monitoring. The positive coefficient suggests that as farmers perceive greater benefits from using IoT technologies, their willingness to adopt these technologies also increases.

Table 8. Coefficients.

Model		**Unstandardized Coefficients**		**Standardized Coefficients**	*t*	**Sig.**
		B	**Std. Error**	**Beta**		
1	(Constant)	6.352	1.263		5.028	<0.001
	PBIT	0.930	0.081	0.458	11.512	<0.001

Dependent Variable: FWAIT.

According to the results in Table 9, the model summary provides information about the overall fit of the regression model for the third hypothesis. The correlation coefficient (R) represents the strength and direction of the relationship between the predictors (access to information and training, perception of government support) and the dependent variable (farmers' willingness to adopt IoT technologies). A regression model is a method that models the data in such a way as to predict the values as well as the observed values. The standard error is the difference between the predicted and the observed values. The standard error of the estimate in this case is 5.21093, which indicates an average amount of error that is associated with predicting farmers' willingness to adapt IoT technologies based on the given predictors.

Table 9. Model summary.

Model	**R**	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**
1	0.437 [a]	0.191	0.187	5.21093

[a] Predictors: (Constant), PGS, AIT. Dependent Variable: FWAIT.

According to Table 10, the ANOVA table provides information about the overall significance of the regression model for the third hypothesis. The regression sum of squares represents the amount of variance in the dependent variable (farmers' willingness to adopt IoT technologies) that is explained by the predictors (access to information and training, perception of government support). In this particular case, the regression sum of squares is 3180.032, which is a significant value. The amount of unexplained variance in a dependent variable is represented by the residual sum of the factor of the square. By using this method, we can measure the difference between the observed values and the values predicted by the regression model based on the observed data. According to this equation, the residual sum of squares is 13,495.416, which is a significant value. In order to calculate the variance in the dependent variable, the total sum of squares must be calculated. The sum of squares is calculated based on the regression sum of squares and the residual sum of squares. This means that the total sum of the squares is 16,675.448 in this case. There are degrees of freedom that serve as a measure of the amount of independent information that can be gathered for estimation. In the regression model, the degrees of freedom for the predictors are two, which is the number of predictors (access to information and training, perception of government support). The degrees of freedom for the residual are 497, which is the total number of observations minus the number of predictors. The mean square is calculated by dividing the sum of squares by the degrees of freedom. It represents the average amount of variance. The F statistic is the ratio of the mean square for regression to the mean square for the residual. It indicates whether the regression model as a whole is statistically significant. In this case, the F statistic is 58.556. As a result of the F statistic, you will be able to determine the significance level (*p*-value). In other words, it represents the probability of obtaining an observable F value by chance alone, rather than using an algorithm. Using this method of analysis, the *p*-value in this case is 0.001, which is a highly significant value.

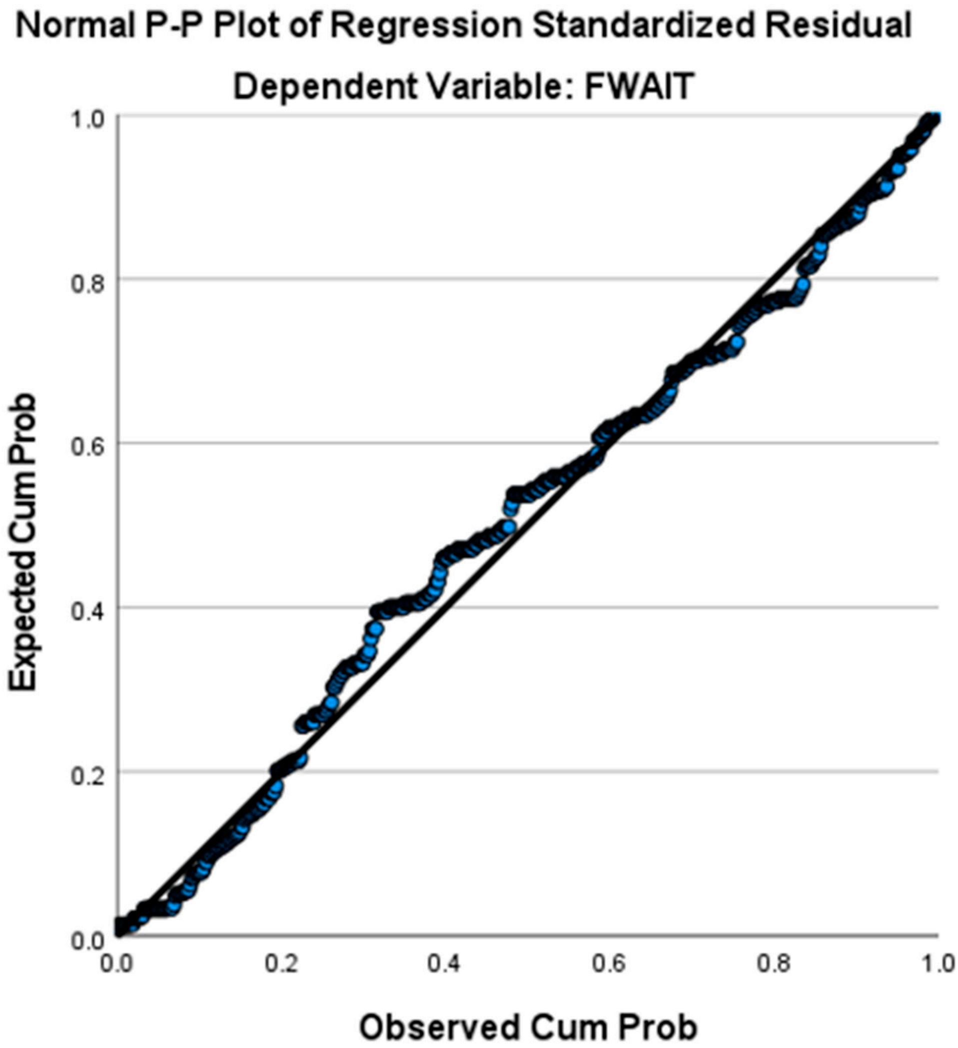

Figure 3. Normal P-P Plot of regression standardized residual.

Table 10. ANOVA.

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	3180.032	2	1590.016	58.556	<0.001 [a]
	Residual	13,495.416	497	27.154		
	Total	16,675.448	499			

Dependent Variable: FWAIT. [a] Predictors: (Constant), PGS, AIT.

The regression model, which includes the predictors (access to information and training, perception of government support), is statistically significant in explaining the variance in farmers' willingness to adopt IoT technologies. The predictors collectively contribute significantly to the model, as indicated by the F statistic and the associated *p*-value.

Table 11 details the estimated coefficients, standard errors, *t*-values, and significance levels associated with the predictor variables (access to information and training, perception of government support) within the regression model for Hypothesis 3 based on the estimation coefficients. In the case when all predictor variables have a zero value, the constant term represents the estimated intercept. There is a constant term in this case of 5.493. As a result, the *t*-value for the study is 3.682 with a *p*-value of 0.001, indicating a statistically significant result. In terms of access to information and training, there is a coefficient of 0.763. For the purpose of the analysis, we are trying to estimate how much a one-unit increase in AIT will affect farmers' willingness to adopt IoT technologies while holding the other variables constant for a one-unit increase in AIT. This coefficient has a *t*-value of 9.112 and a *p*-value of 0.001 which indicates that the coefficient is statistically significant. This standardized coefficient (Beta) of 0.387 suggests that the adoption of IoT technologies by farmers is moderately positive as shown by the effect of AIT. A coefficient of 0.194 has been found for the perception of government support (PGS). The change in the dependent variable is calculated as the change in the dependent variable by a one-unit increase in PGS, whereas the other variables are kept constant. Statistically, the coefficient is significant, with a *t*-value of 2.695 and a *p*-value of 0.007. This study found that PGS has a small positive impact on farmers' willingness to adopt IoT technologies based on its standardized coefficient (Beta), which suggests that PGS has a small positive impact.

Table 11. Coefficients.

Model		Unstandardized Coefficients		Standardized Coefficients	*t*	Sig.
		B	Std. Error	Beta		
1	(Constant)	5.493	1.492		3.682	<0.001
	AIT	0.763	0.084	0.387	9.112	<0.001
	PGS	0.194	0.072	0.114	2.695	0.007

Dependent Variable: FWAIT.

5. Summary of Findings

This study highlights the importance of increasing farmers' awareness of IoT technologies in order to enhance their perception of the benefits and promote the adoption of these technologies for effective crop monitoring. The perceived benefits of using IoT technologies for crop monitoring (PBIT) have a moderate positive relationship with farmers' willingness to adopt these technologies. However, it is important to note that the perceived benefits alone explain only a portion of the variance in the willingness to adopt, and there may be other factors influencing farmers' adoption behavior that are not accounted for in the current model. The ANOVA table indicates that the regression model with the perceived benefits of using IoT technologies (PBIT) as the predictor variable explains a significant amount of variability in farmers' willingness to adopt these technologies. The *p*-value (<0.001) suggests that the relationship between the perceived benefits and willingness to adopt IoT technologies is statistically significant. Overall, these findings support the second hypothesis, indicating that the perceived benefits of using IoT technologies for crop monitoring have a significant and positive influence on farmers' willingness to adopt these technologies. The results suggest that highlighting the advantages and positive outcomes of using IoT technologies can enhance farmers' motivation to adopt them in their crop monitoring practices.

The predictors (access to information and training, perception of government support) have a moderate positive relationship with farmers' willingness to adopt IoT technologies, and they collectively explain a significant proportion of the variance in the dependent variable. The regression model, which includes the predictors (access to information and training, perception of government support), is statistically significant in explaining the variance in farmers' willingness to adopt IoT technologies. The predictors collectively contribute significantly to the model, as indicated by the F statistic and the associated *p*-value. Overall, the coefficient table provides information about the estimated effects of the predictors on farmers' willingness to adopt IoT technologies. The significant coefficients indicate that both access to information and training and the perception of government support have a positive influence on farmers' willingness to adopt IoT technologies, although the effect of access to information and training (AIT) is relatively stronger compared to the perception of government support (PGS).

6. Conclusions

The purpose of this study is to make contributions to the understanding of how farmers perceive IoT technologies and their adoption for crop monitoring among themselves. The findings shed light on the roles of these technologies in enhancing agricultural practices and emphasize the need for further research and support in promoting their effective implementation in the agricultural sector. The discoveries of the study show the importance of increasing farmers' awareness of IoT technologies to enhance their perception of the benefits and promote the adoption of these technologies for effective crop monitoring. The perceived benefits of using IoT technologies for crop monitoring have a moderate positive relationship with farmers' willingness to adopt these technologies. However, it is important to note that the perceived benefits alone explain only a portion of the variance in the willingness to adopt, suggesting the presence of other factors influencing farmers' adoption behavior that were not accounted for in the current model. The predictors, namely access to information and training and the perception of government support, also have a moderate positive relationship with farmers' willingness to adopt IoT technologies. Collectively, these predictors explain a significant proportion of the variance in farmers' willingness to adopt. The regression model including these predictors is statistically significant, indicating their influence on farmers' adoption behavior.

6.1. Decision

According to the results, it is recommended that IoT technologies be promoted to farmers and highlighted for the benefits associated with their use. Agricultural IoT technology benefits and practical applications can be explained to farmers through targeted information dissemination and training programs. IoT technologies should also be improved to ensure farmers have access to information and training to adopt and use these technologies effectively. Additionally, government initiatives and policies can foster a supportive environment for IoT adoption among farmers. Farmers' adoption behavior may not be captured by the current model. IoT technologies in agriculture should be explored further in future research. These variables include economic considerations, social dynamics, and technological infrastructure.

As a result of the study, we conclude that the key drivers of the adoption of IoT technologies for crop monitoring in Jizan, Saudi Arabia include raising awareness, promoting perceived benefits, and providing access to information and training. To improve crop health, growth, and yield prediction, policymakers, agricultural extension agencies, and tech providers can use these findings to develop strategies and interventions.

6.2. Future Recommendations

1. In-depth analysis of other factors: Conduct further research to explore and understand additional factors that may influence farmers' adoption behavior towards IoT technologies in crop monitoring. Consider variables such as economic viability, social dynamics, technological infrastructure, and regulatory contexts. This will offer a more comprehensive considerate of the barriers and drivers of adoption.
2. Longitudinal studies: Conduct longitudinal studies to track the adoption of IoT technologies over time among farmers in Jizan, Saudi Arabia. This will help to identify trends, challenges, and opportunities associated with long-term adoption, as well as to assess the impact of IoT technologies on crop health, growth, and yield prediction.
3. Tailored training programs: Develop and implement tailored training programs for farmers in Jizan, Saudi Arabia, focusing on building their skills and knowledge related to IoT technologies. These programs should be designed to address specific challenges and opportunities in the local context, making them more effective in promoting adoption and maximizing the benefits of IoT technologies in crop monitoring.
4. Collaboration and partnerships: Foster collaboration and partnerships among key stakeholders, including farmers, agricultural extension agencies, technology providers, and government entities. Such collaborations can help in knowledge sharing, capacity building, and the co-development of IoT solutions that are relevant and practical for the local agricultural sector.
5. Financial support: Explore financial support mechanisms, such as subsidies, grants, or loans, to assist farmers in the adoption of IoT technologies. Financial incentives can help to alleviate the initial investment costs associated with acquiring IoT devices and implementing the necessary infrastructure, thus encouraging more farmers to adopt these technologies.
6. Demonstration farms: Establish demonstration farms or pilot projects in Jizan, Saudi Arabia, where farmers can observe and learn firsthand about the benefits and practical applications of IoT technologies in crop monitoring. These farms can serve as living examples to showcase the effectiveness and economic viability of IoT solutions, encouraging other farmers to adopt similar practices.
7. Policy and regulatory frameworks: Develop supportive policies and regulatory frameworks that facilitate the adoption and integration of IoT technologies in agriculture. This can include standards for data privacy and security, streamlined approval processes for IoT devices, and policies promoting open data sharing for research and innovation.

By implementing these recommendations, stakeholders can contribute to the broader adoption of IoT technologies in crop monitoring in Jizan, Saudi Arabia, ultimately leading to improved agricultural practices, enhanced productivity, and sustainable farming systems.

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Abbreviations

AIT	Access to information and training
PGS	perception of government support
FWAIT	Farmer willingness to adopt IoT technologies
PBIT	Perceived benefits of IoT technologies
LAIT	Level of awareness of IoT technologies
FAIT	Farmer adoption of IoT technologies

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