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Perceived Benefits and Implementation Challenges of IoT-Based Monitoring Systems:A Pilot Study of Grape Farmers in Nashik District

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Abstract
This pilot study investigates the primary factors that influence the adoption and effective application of Internet of Things (IoT)-based automated monitoring systems among grape farmers in the Nashik district. The studies used a cross-sectional descriptive survey methodology, gathering data from 30 farmers using a questionnaire. Descriptive statistics, such as medians, interquartile ranges, and frequencies, were the main emphasis of the data analysis for ordinal data derived from Likert-scale questions. Thematic analysis of open-ended responses was also conducted to provide qualitative insights. Although possible differences and correlations were investigated using Kruskal-Wallis and Spearman's correlation tests, these tests were not statistically significant. The findings revealed that farmers generally perceive benefits from IoT, particularly in terms of improved crop yield consistency and optimized resource use, but they also encounter major deployment obstacles, including technical difficulties, high initial costs, and difficulties with understanding and use. Farmers are utilizing the data in their operations, but many are dissatisfied with how quickly the technological assistance they have got has responded to their needs. The research underscores the need for technology developers and extension services to address these challenges and provide better support to farmers.

Keywords: IoT in Agriculture, Automated Monitoring Systems, Grape Farming, Farmer Perceptions, Viticulture

1. INTRODUCTION

The world's total population was 2.5 billion in 1950. Currently, the figure is nearly equivalent to the entire population of the Indian subcontinent. The U.S. Population Department estimates that the world population will reach 9.7 billion by 2050 [1]. The data demonstrates the accelerated growth of the global population. This should be a matter of grave concern to the global community. There is an additional issue that is of greater concern than the growing population, despite their relation. The world's greatest concern is the provision of sustenance for the expanding population. Despite the fact that food is among the most fundamental biological requirements of humans, its availability has become the most significant source of concern for the populace. Climate change and a range of natural and unnatural calamities are among the primary causes of this food crisis. Urbanization and industrialization are contributing factors to the escalating food crisis by reducing the availability of agricultural land. Most farmers continue to adhere to their traditional agricultural methods, which impedes their ability to achieve improvements in crop production.

The IoT has expanded its applications in every social sector in previous times few decades. The IoT had a substantial influence on farming throughout period by Dealing with problems such as

Environmental concerns and food scarcity concerns, and resource management. The agricultural environment is monitored and controlled by IoT to reduce environmental impact and maximize resources utilization, and maximize productivity in accurate or clever farming.

IoT is a concept that is currently in development and facilitates the interaction between electrical devices and sensors via the Internet [2]. Various sensors, including moisture sensors for soil, temperature, humidity sensors, and motion detector sensors, are employed in IoT-based smart farming to monitor and control the field or firm from any location, as well as to automate the system of irrigation [3]. Drones are employed to facilitate this process. Farmers can oversee the field alongside make the requisite decisions by transmitting the data collected and conveyed by IoT sensors from farms to a main receiver. Soil moisture sensors are used, for example. By employing capacitance or resistant techniques, irrigation practices can be directed to reduce the consumption of water by providing real-time data on water levels in the soil. [4]. Real-time observation is facilitated by IoT technology, which enables producers to oversee health, location, and behavior of livestock in real time. This results in enhancements to productivity and development.

1.1 BACKGROUND OF STUDY

Farming industry is an essential part of India's economy, accounting for 16% of the national GDP and generating $421 billion in gross value added (GVA). As the nation's largest employer, it engages 44% of the workforce and holds the 9th position globally in agricultural exports. The sector has achieved remarkable production levels, reaching nearly 300 MTs each in food grains and horticultural crops. The current state of IoT implementation in agriculture shows limited adoption, with only 2% of farmers utilizing mobile apps for farm-related activities. While 50% of enterprise adopters remain at the Proof of Concept or Trial stage, mainstream adoption is projected to take 2-3 years or more. The sector is witnessing a gradual progression from isolated IoT solutions to integrated farm-to- market systems, incorporating precision farming techniques and comprehensive knowledge platforms that combine various agricultural inputs. Technical implementation faces both opportunities and challenges. While sensor costs have decreased dramatically by 70% (from $1.3 in 2004 to $0.4 in 2019), the industry struggles with standardization of data formats and insufficient integration frameworks. The adoption landscape shows that 90% of AgriTech startups focus on pre-harvest solutions, though widespread implementation is expected to take at least 5 years, with higher adoption rates currently observed in Agri-distribution and processing sectors. The sector's growth potential is substantial, with global AgriTech funding reaching $20 billion. Technology standardization continues to improve through IoT, M2M, and IOTA implementations, with 1.3% of funding directed toward pre-harvest farm robotics, software, and sensors. Success in this transformation requires comprehensive credit risk management practices, stronger stakeholder collaborations, and continued technological innovation.

2.0 LITERATURE REVIEW

The application of IoT in agriculture is a quickly evolving field that has the potential to revolutionize agricultural practices. This review provides a concise overview of key themes in this area, including automated monitoring systems, sensor technologies, data analytics, and implementation challenges, with a focus on viticulture (grape cultivation). The comprehension of the adoption of IoT is influenced by a variety of theoretical structures, such as the Technology Acceptance Model (TAM), the DeLone & McLean IS Success Model, the Implementation Science Framework, and the Technology-Organization-Environment (TOE) Structure.

2.1 Iot In Agriculture

IoT offers solutions to address challenges such as food scarcity, environmental issues, and resource management [1] [2] [3]. Studies show that IoT enables real-time monitoring and control, leading to increased productivity and optimized resource use [4]. The global IoT agriculture market is rapidly expanding [5], with increasing adoption in various regions [6].

A. Automated Monitoring Systems And Sensor Technologies:

Research focuses on developing automated monitoring systems using various sensors [7] [8]. Wireless sensor networks (WSNs) are also being investigated for real-time data collection [9].

B. Data Analytics And Decision Support:

Effective IoT application requires robust data analytics and decision support systems. Machine learning and AI are employed for agricultural purposes damage prediction, resource optimization, and pest/disease detection [10] [11] [12] . Cloud-based platforms and mobile applications are being developed [13].

C. Challenges Of Technology Transfer And Implementation:

Despite the potential, challenges hinder widespread adoption, including technical difficulties, high costs, lack of standardization, and insufficient integration [14] [15] [16]. The human element, including training and support, is also crucial [17].

D. Several Theoretical Frameworks Provide A Lens For Understanding Iot Adoption:

- Technology Acceptance Model (TAM): TAM emphasizes the significance of individual acceptability factors, asserting that perceived benefit as well as ease to use are essential determinants in technology adoption.
- DeLone & McLean IS Success Model: This model evaluates information system success based Regarding the system's performance, the accuracy of the data, and net benefits.
- Implementation Science Framework: This framework examines the translation of technology from theory to practice, focusing on implementation strategies, outcomes, and service.
- Technology-Organization-Environment (TOE) Framework: This structure considers the ambient, organizational, and technological factors that influence acceptance.

2.2 Gaps In The Literature:

Although the literature on IoT in agriculture is extensive, there currently are still some voids that necessitate attention. More investigation is required to investigate the specific obstacles and opportunities connected to the implementation of IoT in various agricultural contexts, particularly in developing regions. Additional research is required to investigate the long-term consequences of IoT on the livelihoods of farmers, sustainability, and agricultural productivity. Additional research is required to develop cost-effective and user-friendly IoT technologies designed specifically to satisfy the distinctive needs of producers.

3.0 METHODOLOGY

To explore the attitudes of grape producers in the Nashik district towards the implementation and efficacy of IoT-based automated monitoring systems, this investigation implemented a cross-sectional descriptive survey approach. A cross-sectional design was used since it facilitated data collecting at a singular moment in time.(October to November 2024), providing a snapshot of farmers' current perceptions and experiences. This approach is suitable for a pilot study aimed at gaining initial information about the phenomenon of interest. Rather than testing particular hypotheses or demonstrating causal correlations, the study is descriptive in nature and focusses on describing farmers' impressions of the advantages and difficulties connected with IoT adoption. The Technology Acceptance Model (TAM) is a theoretical structure that guides the adoption process by emphasizing the perceived utility and simplicity of the system's use.

The recruitment of people that took part in this pilot study was conducted using a convenient sampling technique. Thirty grape farmers in the Nashik district who are making use of some form of IoT technology in their farming practices were included in the sample. Referrals and pre-existing professional relationships were used to attract members. Although this approach enabled the effective gathering of data, it is imperative to acknowledge that a sample may not be wholly as it appears. representative of the more extensive grape farmer population in the Nashik district. The small sample size is a limitation of this pilot study.

Data was collected using a self-administered Google Forms is used to deliver the online survey. (Google Forms Link: https://forms.gle/ZF69tLvKmYHzrtmk6). The questionnaire was shared with farmers through direct contact and referrals, ensuring that only farmers meeting the inclusion criteria (current use of IoT technology) were invited to participate. The Google Form included clear instructions regarding the goal of the research and the application of a five-point Likert scale for most questions. The questionnaire was intended to be complete within 25-35 minutes. The information was gathered during October and November of 2024. No other data was collected besides the questionnaire responses.

The questionnaire was created in accordance with the study objectives and pertinent constructs from the Technology Acceptance Model (TAM). The questionnaire included demographic questions as well as questions related to perceived benefits, ease of use, implementation challenges, and satisfaction with technical support. The initial questionnaire consisted of 110 questions, which were reviewed by experts for face validity and clarity. A pre-pilot testing process was conducted to identify any confusing or ambiguous questions. Based on feedback from experts and the pre-pilot, the questionnaire was reduced to 80 questions. Most of the questions used a five-point Likert scale, with the range being "Strongly Disagree" to "Strongly Agree." The questionnaire's The Cronbach's alpha was used to assess internal consistency, which produced a value of.851.

Before the survey was completed, informed permission was acquired from each participant. Participants knew the purpose of the study, the right to cancel their participation at any time, and the assurance of confidentiality and anonymity with respect to their responses. Before the poll was completed, each participant gave their informed consent. Learners were made aware of the study's objective, the right to cancel their participation at any time, and the assurance of confidentiality and anonymity with respect to their responses. No personal identifying information was collected. This pilot project did not seek approval from ethics.

Descriptive statistics were used to analyze the information, which included medians, interquartile ranges (IQR), frequencies, and percentages for each Likert-scale question. Given the ordinal nature of the data, non-parametric tests, for instance, Kruskal-Wallis's test was employed to compare subgroups if needed. Using Spearman's rank correlation, caution to explore potential relationships between ordinal variables. Parametric tests were avoided. The data was analyzed using SPSS. Thematic analysis was implemented to analyze the open-ended responses, identifying key themes and providing illustrative quotes.

There are many restrictions on this pilot project. The extent to which the results are applicable to the broader population of grape producers in the Nashik district is restricted by the small sample size (30 participants) and the use of convenience sampling. Response bias may be present when employing a self-reported questionnaire. The determination of causal connections is impossible due to the cross-section of character of the study. The data collected is primarily based on farmers' perceptions and reported experiences, rather than objective measurements of outcomes. These limitations will be acknowledged in the discussion section of the paper.

4.0 DATA ANALYSIS

The data acquired from a pilot study of 30 grape producers in the Nashik district who have implemented IoT-based automated monitoring systems is analyzed in this section. The main goal of this investigation is to recognize key factors, encompassing both perceived benefits and implementation challenges, that influence the adoption and effective application of these systems. Descriptive statistics, such as frequencies, percentages, medians, and interquartile ranges (IQR), are the data analysis's main emphasis, which is derived from Likert-scale questions regarding ordinal data. While Kruskal-Wallis tests were conducted to explore potential differences across subgroups, and Spearman's correlation tests were used to explore relationships between select variables, there was no statistical significance in these tests. The analysis also incorporates a thematic analysis of open-ended responses to provide qualitative insights. The analysis is guided by three hypotheses related to perceived benefits, implementation challenges, and adoption and effective application.

4.1 Demographic Analysis

This section provide a summary of the demographic characteristics of the 30 grape farmers who participated in the pilot study. Age group is one of the demographic factors, education level, years of farming experience, and farm size. most farmers (40%) were in the 31-40 age group, followed by the 41-50 age group (33.3%). Also, most farmers (53.3%) had a graduate-level education. The majority of farmers (30%) had been farming for 11–15 years, and 30% had been farming for over 20 years. Most farmers operated small to medium-sized farms, with the largest group (30%) operating farms of 6-10 acres. (Note: The full frequency distributions for these variables are provided in the appendix (or as separate tables).

4.2 Perceived Benefits (Hypothesis 1)

Grape farmers in the Nashik district who have adopted IoT-based automated monitoring systems will report a moderate to high level of perceived benefits related to improved yield consistency, reduced crop losses, and optimized resource use.

4.2.1 Descriptive Statistics:

Table 1 shows the descriptive statistics for the variables related to perceived benefits.

TABLE 1 : DESCRIPTIVE STATISTICS FOR PERCEIVED BENEFITS

Variable (Question Text)	Median	IQR
To what extent do you agree that IoT-based monitoring has improved your crop yield consistency?	4	1
How would you rate the impact of IoT monitoring on reducing crop losses?	4	1
How has your water usage changed since implementing IoT monitoring?	4	0.25
To what extent has IoT monitoring helped in optimizing fertilizer use?	4	1
Rate the improvement in energy efficiency due to IoT monitoring	2	1
How would you rate the accuracy of data collected by IoT sensors compared to traditional methods?	4	0
To what extent do you agree that IoT monitoring provides more reliable data for decision-making?	4	0
Do you believe using IoT has increased your grape yield?	4	1

Has IoT helped improve grape quality?	1	0
Has IoT helped reduce water consumption?	4	0
Has IoT helped optimize fertilizer application?	4	1

Note: The full frequency distributions for these variables are provided in the appendix (or as separate tables).
As shown in Table 1, the median responses for most of the perceived benefit variables are 4.00, indicating that, on average, farmers tend to "Agree" that IoT has provided benefits. The median response for "Rate the improvement in energy efficiency due to IoT monitoring" is 2.00, suggesting that farmers do not perceive a strong improvement in energy efficiency. The median response for "Has IoT helped improve grape quality?" is 1.00, indicating that farmers generally do not believe that IoT has improved grape quality. To further explore these perceptions, the following section presents a thematic analysis of the farmers' open-ended responses.

4.2.2 Kruskal-Wallis Test Results:

Kruskal-Wallis tests were conducted to explore potential differences in perceived benefits across different experience groups. Statistical significance was not achieved by these tests ($p > 0.05$).

4.2.3 Thematic Analysis Of Text Responses:

The thematic analysis of open-ended responses related to perceived benefits revealed several key themes. Farmers frequently mentioned improvements in grape appearance and composition, such as "चांगला रंग" (good color), "उच्च साखर अंश" (high sugar content), and "मण्याची लांबी वाढली, साकर उत्कृष्ट प्रमाणात आहे, क्रॅकिंग कमी प्रमाणात झाली" (berry length increased, sugar is excellent, cracking has reduced). Some farmers also noted a reduction in defects and damage, such as "कमी दोष" (fewer defects). Some farmers expressed a general positive sentiment towards IoT's impact on quality and quantity, such as "Good quality and quantity" and "उत्पादन क्षमता अत्यंत अधिक" (very high production capacity). One farmer also connected IoT to good management, stating, "Good management and help of IOT increase every aspect of grapes." Some farmers provided neutral responses, such as "तटस्थ" (neutral), implying that not every farmer sees a significant improvement in quality.

4.3 Implementation Challenges (Hypothesis 2)

Grape farmers in the Nashik district who have adopted IoT-based automated monitoring systems will report experiencing a range of implementation challenges, including technical difficulties, high initial costs, and difficulties with understanding and use.

4.3.2 Descriptive Statistics:

Table 2 shows the descriptive statistics for the variables related to implementation challenges.

TABLE 2 : DESCRIPTIVE STATISTICS FOR IMPLEMENTATION CHALLENGES

Variable (Question Text)	Median	IQR
Did you face any difficulties during installation?	4	0
Which technical challenges have you faced?	4	1
How significant were the initial costs?	4	1
How concerned are you about ROI?	4	1
How difficult was it to understand and use?	4	1
How would you rate internet access quality?	3	2
How often do you experience power issues?	4	1

How responsive has technical support been to your requests?	1	1
How helpful has technical support been in resolving issues?	4	1.25

Note: The full frequency distributions for these variables are provided in the appendix (or as separate tables).

As shown in Table 2, the median responses for most of the implementation challenge variables are 4.00, indicating that, on average, farmers tend to "Agree" that they faced challenges. The median response for "How responsive has the technical support been to your requests?" is 1.00, suggesting that farmers generally do not perceive technical support to be responsive. To gain a deeper understanding of these challenges, the following section presents a thematic analysis of the farmers' open-ended responses, providing specific examples of the difficulties they encountered.

4.3.3 Kruskal-Wallis Test Results:

Kruskal-Wallis tests were conducted to explore potential differences in reported challenges across different education levels. Nevertheless, $p > 0.05$ indicated that these tests were not statistically significant.

4.3.4 THEMATIC ANALYSIS OF TEXT RESPONSES:

The thematic analysis of open-ended responses related to implementation challenges revealed that farmers often mentioned technical difficulties, high initial costs, and difficulties with understanding and use. Several farmers stated that they were having issues with the sensors not working correctly, difficulty connecting to the internet, and a lack of adequate training about how to operate the system. For example, some farmers mentioned "Unexpected" challenges and "अनेक्षितपणे हवामान" (unexpected weather) which, while related to weather, also highlight the unpredictable nature of implementation. These answers imply that although farmers are willing to adopt IoT, they face practical hurdles that need to be addressed.

4.4 Adoption And Effective Application (Hypothesis 3)

Grape farmers in the Nashik district who have adopted IoT-based automated monitoring systems will report varying levels of integration of data into their practices, with a reliance on a mix of information sources, and different levels of satisfaction with training and support.

4.3.1 DESCRIPTIVE STATISTICS:

Table 3 presents the descriptive statistics for the variables related to adoption and effective application.

TABLE 3 : DESCRIPTIVE STATISTICS FOR ADOPTION AND EFFECTIVE APPLICATION

Variable (Question Text)	Median	IQR
Do you currently use any IoT devices in your grape farming?	4	1
To what extent have you integrated the data into your practices?	4	1
What were your main sources of information when you first learned about automated monitoring systems?	4	1
What kind of training did you receive?	4	1
How would you rate the quality of training provided?	4	1
If yes, how satisfied are you with the support you received?	1	1

Note: The full frequency distributions for these variables are provided in the appendix (or as separate tables).

As shown in Table 3, the median responses for most of the variables related to adoption and effective application are 4.00, indicating that, on average, farmers tend to "Agree" with the statements. However, the median response for "If yes, how satisfied are you with the support received?" is 1.00, implying that most farmers are dissatisfied with the assistance they have received. The next part provides a thematic analysis of the farmers' open-ended comments to gain a better understanding of how they are utilizing the technology and the assistance they receive.

4.3.2. KRUSKAL-WALLIS TEST RESULTS:

Kruskal-Wallis tests were conducted to explore potential differences in adoption and application across different training levels, but these tests were not statistically significant ($p > 0.05$).

4.3.3 THEMATIC ANALYSIS OF TEXT RESPONSES:

The thematic analysis of open-ended responses related to adoption and effective application showed that farmers are using IoT to improve their management practices. For example, some farmers mentioned using the data to monitor weather patterns, optimize irrigation, and make decisions about fertilizer application. The responses also highlighted a need for better support systems.

4.4 Summary

According to the descriptive analysis, farmers generally perceive benefits from IoT-based automated monitoring systems, particularly in terms of improved crop yield consistency and optimized resource use. They also face challenges during implementation, including technical difficulties, high initial costs, and difficulties with understanding and use. Farmers are utilizing the data in their operations, but many are dissatisfied with how quickly the technological assistance they have got has responded to their needs. The Kruskal-Wallis tests and Spearman's There was no statistically significant link, indicating that the variables' correlations are not sufficiently strong in this sample to be statistically significant. Thematic analysis of text responses offers valuable context and substance to these quantitative findings, emphasizing the necessity for improved support systems, specific areas of perceived benefit, and implementation challenges.

5.0 DISCUSSION

The purpose of this study was to determine the crucial elements, encompassing both perceived benefits and implementation challenges, that influence the adoption and effective application of IoT-based automated monitoring systems among grape farmers in the Nashik district. Thematic analysis and descriptive statistics were employed to assess the findings of this pilot study, which yielded valuable insights into these factors. Additionally, the complexities of technology adoption for farming were underscored.

The results of the descriptive analysis showed that farmers generally perceive benefits from IoT, particularly in terms of improved crop yield consistency and optimized resource use. These results are consistent with the broader literature on precision agriculture, which emphasizes the potential of IoT to enhance productivity and efficiency [6] [18]. According to the survey, farmers do not perceive a strong improvement in energy efficiency or grape quality, demonstrating that the benefits of IoT may be more complicated than originally imagined. The thematic analysis of open-ended responses further supports this, with farmers mentioning specific improvements in grape appearance and composition but also emphasizing the necessity of improved management techniques to properly reap the rewards of IoT.

The survey also found that farmers encounter major implementation obstacles, such as technical problems, expensive upfront expenses, and comprehension and usage issues. The obtained findings result consistent with earlier research that has identified technical and financial barriers to IoT adoption in agriculture [14] [15]. The low responsiveness of technical support, as indicated by the median response of 1.00, suggests a critical area for improvement. The thematic analysis further highlighted specific challenges such as sensor malfunctions, connectivity issues, and a lack of adequate training about how to operate the system, which are in accord with the findings of [16] Cook et al. on security vulnerabilities and privacy challenges in IoT devices.

While farmers are using the data in their practices, their satisfaction with the support they have received is low. This suggests that while the technology itself may be beneficial, the support systems are not fulfilling the needs of the farmers. This finding highlights the significance of considering the human element in technology adoption, as emphasized by Orjuela-Garzon& Quintero-Ramirez [14] in their study on technology transfer in agriculture.

The Kruskal-Wallis tests and Spearman's correlations were not statistically significant. This suggests that the relationships between the variables are too weak to be statistically significant in this sample. This may be because of the ordinal form of the data, along with the small sample size, or specific characteristics of farmers in this research.

There are numerous constraints associated with this investigation. The degree to which the results are applicable to the broader population of grape producers in the Nashik district is restricted by the small sample size (30 participants) and the use of convenience sampling. Response bias may be present when employing a self-reported questionnaire. The study's cross-sectional nature renders it impossible to establish causal relationships. The analysis' descriptive focus restricts the capacity to draw robust conclusions about the population.

6.0 CONCLUSION

This pilot study sought to determine the primary factors that influence the adoption and effective application of IoT-based automated monitoring systems among grape farmers in the Nashik district. The results show that although farmers generally perceive benefits from IoT, particularly in terms of improved crop yield consistency and optimized resource use, they also confront major implementation obstacles, such as technological ones., high initial costs, and difficulties with understanding and use. Farmers are utilizing the data in their operations, but many are dissatisfied with how quickly the technological assistance they have got has responded to their needs. These results demonstrate the necessity for extension agencies and developers of technology to solve these issues and give farmers greater assistance.

Based on these findings, we advise that future initiatives concentrate on:

1. Improving the usability and reliability of IoT systems:

- Developing more user-friendly interfaces for IoT systems.
- Improving the reliability and accuracy of sensors.
- Providing clear and concise instructions for installation and use.
- Offering troubleshooting guides and FAQs.

2. Developing more responsive and effective technical support systems:

- Establishing a dedicated helpline or online support portal.
- Providing timely assistance to farmers when they encounter technical issues.
- Offering training programs that address the specific needs of farmers.
- Creating a community forum where farmers can share experiences and support each other.

3. Conducting further research on the impact of IoT on specific farming practices and outcomes:

- Exploring the impact of IoT on energy efficiency and grape quality using objective measures.
- Investigating the long-term economic benefits of IoT adoption, including return on investment.
- Conducting comparative studies to evaluate the effectiveness of different IoT systems and implementation strategies.

Future study also addresses the variables impacting uptake and effective implementation in greater depth, employing bigger samples and more rigorous research methodologies.

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