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# DRONE-BASED CROP MONITORING AND PEST DETECTION: THE MODERATING ROLE OF TECHNOLOGY ADOPTION READINESS AMONG FARMERS

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**Abstract**
*Agricultural productivity is increasingly threatened by pest infestations, diseases, and inefficient crop management practices. Drone-based crop monitoring systems provide a technological solution, enabling high-resolution aerial imaging, real-time data collection, and early pest detection. By integrating remote sensing, multispectral imaging, and artificial intelligence, drones allow precise assessment of crop health, facilitating timely interventions and resource optimization. This study investigates the impact of drone-based crop monitoring on pest detection and overall crop management, with a focus on the moderating role of farmers' technology adoption readiness (TAR). TAR encompasses farmers' willingness, skills, and preparedness to adopt and effectively utilize innovative technologies. High TAR is expected to enhance the effectiveness of drone-based monitoring by enabling accurate interpretation of data and timely implementation of pest management strategies. A quantitative research design was adopted, targeting farmers, agronomists, and agricultural extension officers using or familiar with drone technologies. Structured questionnaires assessed drone usage, pest detection efficiency, crop monitoring practices, and farmers' technology adoption readiness. Data were analyzed using Smart PLS structural equation modeling to evaluate direct effects of drone-based crop monitoring and the moderating role of TAR on pest detection and crop management outcomes. Results indicate that drone-based crop monitoring significantly improves pest detection and crop management. Technology adoption readiness positively moderates this relationship, emphasizing that farmers who are more prepared and skilled in technology adoption derive greater benefits from drone-based systems. These findings highlight the importance of combining innovative technologies with human readiness and capacity-building initiatives to optimize agricultural productivity and pest management. Policymakers, extension services, and technology developers can leverage these insights to design effective adoption strategies and enhance sustainable farming practices.*

**Keywords:** *Drone-Based Crop Monitoring, Pest Detection, Technology Adoption Readiness, Precision Agriculture, Sustainable Crop Management*

## Introduction

Agriculture faces increasing challenges due to pest infestations, crop diseases, and climate variability, which compromise food security and farm profitability. Traditional crop monitoring and pest detection methods rely on manual inspection, which is time-consuming, labor-intensive, and prone to errors (Zhang et al., 2019). Recent advancements in drone technology provide an innovative solution, enabling high-resolution aerial imaging, multispectral sensing, and real-time data collection. Drone-based crop monitoring allows precise assessment of crop health, identification of pest hotspots, and early detection of diseases, enabling timely and targeted interventions (Huang et al., 2018).

Drone-based systems collect data on vegetation indices, canopy temperature, moisture levels, and pest presence, which can be integrated with AI-based analytical tools to produce actionable insights for farm management. The application of drones enhances resource efficiency, reduces pesticide usage, and improves crop yield quality (Tsouros et al., 2019). However, the effectiveness of drone technology is

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contingent on farmers' capacity to adopt and utilize these tools effectively.

Technology adoption readiness (TAR) reflects farmers' willingness, skills, and preparedness to incorporate innovative technologies into their agricultural practices. High TAR enables farmers to interpret drone data accurately, implement timely pest control measures, and optimize crop management strategies. Conversely, low TAR can limit the benefits of drone-based monitoring, even when advanced technologies are available (Liakos et al., 2018).

The Technology Acceptance Model (TAM) and Diffusion of Innovations (DOI) framework provide theoretical guidance for understanding technology adoption. TAM emphasizes perceived usefulness and ease of use as determinants of adoption, while DOI highlights innovation attributes, communication channels, social systems, and time as key factors influencing adoption (Rogers, 2003; Davis, 1989). In the context of drone-based agriculture, TAR mediates the ability to derive maximum benefits from advanced monitoring systems.

Empirical evidence suggests that drone-based crop monitoring improves pest detection and supports precision agriculture. Huang et al. (2018) demonstrated that drones equipped with multispectral cameras identified pest outbreaks earlier than conventional methods. Tsouros et al. (2019) reported increased resource efficiency and yield quality through drone-based monitoring. However, these benefits were contingent upon farmers' readiness and skill levels in using drone technology.

This study investigates the impact of drone-based crop monitoring on pest detection and crop management, emphasizing the moderating role of technology adoption readiness. Using Smart PLS structural equation modeling, the study evaluates direct and moderated effects, providing evidence for policies, extension programs, and training initiatives to enhance the adoption of drone technology in agriculture.

## Literature Review

Drone technology has emerged as a critical tool for precision agriculture, enabling efficient crop monitoring and early pest detection. Drones, also known as unmanned aerial vehicles (UAVs), collect high-resolution imagery, multispectral data, and thermal information, which can be processed using AI algorithms to detect pest infestations, plant stress, and disease presence (Zhang et al., 2019). These systems allow targeted pesticide application, optimized irrigation, and efficient farm management, enhancing crop productivity and sustainability.

Precision agriculture relies not only on technological tools but also on human factors, such as farmers' technological skills and readiness to adopt innovations. Technology adoption readiness encompasses familiarity with technology, confidence in its use, and willingness to implement it in daily operations (Liakos et al., 2018). High TAR ensures that drone-collected data are correctly interpreted, enabling timely interventions that prevent crop loss and improve resource use efficiency.

The Technology Acceptance Model (TAM) and Diffusion of Innovations (DOI) theory explain the adoption and effectiveness of drone technologies in agriculture. TAM emphasizes that perceived usefulness and perceived ease of use influence adoption decisions (Davis, 1989). DOI highlights innovation characteristics, communication channels, social influence, and readiness as key factors driving technology uptake (Rogers, 2003). Empirical studies indicate that TAR moderates the effectiveness of drone-based systems, ensuring that farmers with higher readiness achieve superior pest detection and crop management outcomes.

Studies demonstrate that drone-based monitoring significantly enhances pest detection. Huang et al. (2018) found that drones identified pest hotspots with higher accuracy and earlier than traditional field scouting. Tsouros et al. (2019) reported improved water and nutrient management when drones were integrated into farm management. However, adoption barriers, including cost, lack of digital literacy, and insufficient training, limit the effectiveness of drone systems in many regions.

Integrating TAR into drone adoption strategies addresses these barriers. Farmers with higher TAR can efficiently operate drones, process data, and apply pest control measures promptly. Training programs, extension services, and participatory technology adoption approaches can enhance TAR, ensuring sustainable implementation of drone-based crop monitoring (Liakos et al., 2018).

This study empirically examines the direct impact of drone-based crop monitoring on pest detection and crop management, with technology adoption readiness as a moderator. By evaluating the interaction between technological tools and human readiness, the study provides insights for enhancing precision agriculture adoption and improving farm productivity sustainably.

**Conceptual Model and Theoretical Framework**

**Conceptual Model:**

- Drone-Based Crop Monitoring (DCM) → Pest Detection & Crop Management (PDCM)
- Moderator: Technology Adoption Readiness (TAR)

**Theoretical Framework:**

- Technology Acceptance Model (TAM)
- Diffusion of Innovations (DOI)

**Hypotheses:**

H1: Drone-based crop monitoring positively influences pest detection and crop management
H2: Technology adoption readiness moderates the relationship between drone-based crop monitoring and pest detection/crop management

**Methodology**

A quantitative research design was employed to examine the effect of drone-based crop monitoring on pest detection and crop management, with technology adoption readiness as a moderator. The target population included farmers, agronomists, and agricultural extension officers in regions implementing drone technologies. A structured questionnaire measured drone usage, pest detection efficiency, crop management practices, and TAR on a five-point Likert scale.

Data collection was conducted through field visits, online surveys, and extension service networks. Out of 400 distributed questionnaires, 355 valid responses were obtained. Demographic variables, including farm size, crop type, education level, and prior experience with technology, were recorded.

Data analysis employed Smart PLS structural equation modeling. Reliability and validity of constructs were assessed using Cronbach alpha, composite reliability, and average variance extracted. The structural model tested direct effects of drone-based crop monitoring on pest detection and crop management and evaluated the moderating effect of TAR using interaction terms. Bootstrapping with 5000 resamples was employed to assess significance.

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## Results and Interpretation

### Measurement Model Results

| Construct | Cronbach Alpha | Composite Reliability | AVE |
|---|---|---|---|
| Drone-Based Crop Monitoring | 0.91 | 0.93 | 0.72 |
| Pest Detection & Crop Management | 0.90 | 0.92 | 0.71 |
| Technology Adoption Readiness | 0.88 | 0.90 | 0.68 |

### Structural Model Results

| Hypothesis | Relationship | Path Coefficient | T value | P value | Result |
|---|---|---|---|---|---|
| H1 | DCM → PDCM | 0.56 | 9.12 | 0.000 | Supported |
| H2 | DCM × TAR → PDCM | 0.29 | 5.45 | 0.000 | Supported |

### Interpretation

The structural model indicates that drone-based crop monitoring has a significant positive effect on pest detection and crop management (H1, 0.56). Technology adoption readiness significantly moderates this relationship (H2, 0.29), suggesting that farmers who are more prepared and skilled in technology adoption benefit more from drone-based systems. The findings highlight that technological tools alone are insufficient; human readiness and capacity are critical for maximizing the effectiveness of drone interventions. Farmers with high TAR are able to interpret drone-generated data accurately, implement timely pest control measures, and optimize crop management strategies, resulting in enhanced productivity and sustainability. Extension programs and training initiatives should focus on enhancing TAR to facilitate efficient use of drone technology in agriculture.

## Conclusion and Discussion

This study demonstrates that drone-based crop monitoring significantly improves pest detection and crop management. The effectiveness of these systems is moderated by farmers' technology adoption readiness, emphasizing the importance of human capacity in leveraging technological innovations. Farmers with high TAR can efficiently interpret drone data, apply timely interventions, and optimize farm practices, resulting in increased crop productivity and sustainable resource use.

Policy implications include developing targeted training programs, promoting awareness campaigns, and providing technical support to enhance farmers' technology adoption readiness. Technology developers should design user-friendly and cost-effective drone systems to facilitate adoption among smallholder farmers. Integrating drone-based monitoring with capacity-building initiatives ensures sustainable and effective adoption of precision agriculture technologies.

## Future Recommendations

Future research should examine long-term impacts of drone adoption on crop yields, cost-benefit analyses for smallholder farmers, and the integration of drones with AI-based decision support systems. Policymakers should provide incentives, digital literacy training, and technical assistance to maximize adoption and effectiveness. Comparative studies across crop types and geographic regions can further inform targeted drone deployment strategies.

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