Research Proposal: Identifying and Overcoming Barriers to the Adoption of Drone-Based Pesticide Systems for Small and Medium-Sized Farms

1. Introduction

The agricultural industry is evolving with the introduction of advanced technologies aimed at increasing efficiency, sustainability, and productivity. Among these technologies, drone-based pesticide application systems have emerged as a game-changing tool [1]. These systems ensure precision in spraying, optimize resource usage, reduce human exposure to harmful chemicals, and minimize environmental impact [5]. Drone-based pesticide systems promise to revolutionize traditional farming methods by enhancing accuracy, reducing pesticide waste, and improving overall crop yield.

However, despite the clear benefits, small and medium-sized farms face significant challenges in adopting drone technology. High costs, technical complexity, and regulatory issues make it difficult for these farms to integrate drones into their daily operations. As a result, adoption rates remain low, leaving many farmers unable to benefit from the efficiency gains and environmental improvements that drone technology offers. This research aims to investigate ways to address the barriers that prevent small and medium-sized farms from adopting drone-based pesticide systems, offering practical solutions to increase accessibility and improve adoption rates.

2. Background

Drones, also known as unmanned aerial vehicles (UAVs), are transforming agricultural practices globally with their advanced precision farming capabilities. Initially, drones were used for non-spraying purposes like monitoring field conditions, but now they are primarily employed to gather comprehensive data such as crop nutrient stress, weed presence, pest outbreaks, and soil characteristics. This data collection, facilitated by drones equipped with sophisticated GPS, high-resolution cameras, and customizable flight paths, allows farmers to closely monitor plant development from seeding to harvest. These tools provide detailed, actionable insights into every square inch of the crop and soil, significantly improving crop management and optimizing resource use. Although the adoption of drones in Bangladesh has been limited, their global usage is rapidly expanding. According to Fortune Business Insights (2024), the agricultural drone market is projected to grow from $6.11 billion in 2024 to $23.78 billion by 2032, with a compound annual growth rate of 18.5% [1].

Drone-based pesticide systems, in particular, are becoming crucial for modern farming due to their precision, efficiency, and ability to reduce overall pesticide use. Qin et al. (2019) found that UAVs deliver superior droplet deposition and are highly efficient in controlling pests, such as wheat powdery mildew, leading to reduced chemical usage and environmental impact [12]. Furthermore, Tsouros et al. (2019) emphasize that UAVs equipped with intelligent data processing and high-resolution imaging offer real-time monitoring, enabling data-driven decisions that maximize crop health and resource efficiency [11].

Future advancements in drone technology, including autonomous flight, AI-powered analytics, and improved sensor technologies, will further streamline farm management. These innovations will help minimize operating costs and environmental damage, ensuring drones remain a key tool in sustainable farming and global food security [11].

3. Problem Statement

Small and medium-sized farms often lack the resources and knowledge to adopt advanced technologies like drone-based pesticide systems. Despite the clear benefits, the upfront costs, lack of technical skills, and regulatory challenges have created a significant barrier. The question arises: how can these barriers be mitigated to help small and medium-sized farms take advantage of drone-based pesticide systems? This research seeks to address this issue by examining the economic, technical, and regulatory challenges faced by farmers and identifying solutions that can ease the adoption process.

4. Objectives

General Objective

The general objective of this study is to explore methods and strategies to make it easier for small and medium-sized farms to adopt drone-based pesticide systems.

Specific Objectives

1. To understand the economic barriers that small and medium-sized farmers face in adopting drone-based pesticide systems.
2. To describe the challenges associated with the use of UAVs in agriculture and propose potential solutions.
3. To investigate the effectiveness of training programs in enhancing the skills required for operating drone-based pesticide systems.

5. Contribution of the Study

This research will contribute significantly to the field of precision agriculture by providing practical insights into the adoption of drone-based pesticide systems. By addressing the specific challenges that small and medium-sized farmers face, the study will offer targeted solutions that can increase the accessibility and usability of this technology. Furthermore, the findings of this study may influence policymakers and agricultural organizations to develop support mechanisms such as subsidies, training programs, and regulatory frameworks to facilitate the adoption of drones in farming. Successful implementation of these mechanisms could lead to broader adoption of drone-based pesticide systems, ultimately reducing pesticide waste in the environment and promoting more sustainable farming practices.

6. Literature review

Drone-based pesticide systems are gaining prominence in modern agriculture for their precision and efficiency. Qin et al. (2018) note that small unmanned aerial vehicles (UAVs) achieve better droplet deposition and higher efficiency in pest control, such as managing wheat powdery mildew, reducing pesticide use and promoting sustainability [12]. Tsouros et al. (2019) emphasize that UAVs, equipped with high-resolution imagery, enable precise and quick pesticide applications, reducing chemical usage while maintaining effectiveness [11].

UAVs also play a vital role in early pest detection. Iost Filho et al. (2020) demonstrate that drones with multispectral sensors can detect pest-induced stress in cotton plants with 74% to 95% classification accuracy, leading to targeted interventions and reduced pesticide use [9]. Feng et al. (2020) further highlight the value of UAV-based multi-sensor imagery for monitoring crop health and optimizing input usage [10].

However, small and medium-sized farms face economic and regulatory challenges. Hanif et al. (2022) stress that high initial costs and complex regulatory frameworks hinder widespread adoption. Varying national regulations also complicate UAV use in agriculture [4]. Additionally, Rathnayake et al. (2022) emphasizes the need for standardized training programs to ensure that farmers can effectively and safely operate UAVs, as a lack of training can limit the technology's potential [5].

Integrating UAVs with other smart farming technologies can enhance farm management. De Castro et al. (2018) discuss the benefits of integrating UAVs with IoT devices, which improve real-time monitoring and resource management [13]. Shafiq and Choi (2022) also argue that

UAVs equipped with remote sensing technologies enable early pest detection and contribute to more sustainable agricultural practices [7].

Future advancements in drone technology, such as improved data processing and multi-spectral remote sensing, could expand the potential of UAVs in agriculture. Hafeez et al. (2022) suggest that such innovations could lead to more precise pesticide applications, though further research is needed to address the current limitations of cost, regulation, and training [6].

Overall, while drone-based pesticide systems offer significant potential, addressing economic, regulatory, and training barriers is essential for broader adoption. Continued research and technological advancements can further improve UAV efficacy and contribute to more sustainable farming practices.

7. Research Methodology

A mixed-methods research design will be applied to this study. The justification for using a mixed-methods approach is that it combines the advantages of both quantitative and qualitative research to provide a comprehensive understanding of the variables influencing the adoption of drone-based pesticide systems by small to medium-sized farms. This approach is beneficial because it not only reveals trends and statistical relationships through quantitative data but also explores the underlying reasons behind those trends through qualitative insights. For example, surveys and questionnaires will be distributed to farm owners to gather data on the specific challenges related to drone technology adoption, including costs and technical skills. These tools will provide measurable, generalizable insights into key barriers. On the other hand, qualitative methods, such as semi-structured interviews, will be used to gain a deeper understanding of the personal experiences and obstacles encountered by farmers, agricultural experts, and drone technology providers. This combination ensures that not only numerical data, but also personal experiences are considered, resulting in more actionable findings. This method ensures the practical applicability of the results to real-world scenarios. Puppala (2023) employed similar mixed-methods approaches in his research and achieved satisfactory results, further validating the effectiveness of this design for addressing complex, multifaceted problems [2].

7.1 Flowchart of Research Methodology

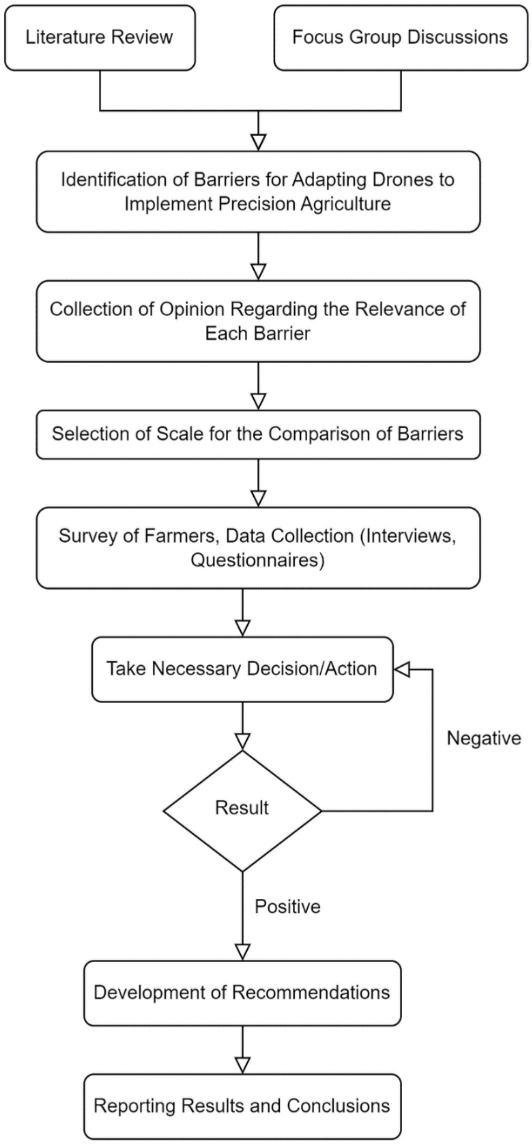

Figure 1. Flowchart of Proposed Research Methodology

8. System Development Methodology

This research adopts the **Agile methodology**, known for its flexibility and iterative nature, aligning well with the dynamic field of precision agriculture. Agile promotes collaboration, adaptability, and responsiveness to user feedback, making it ideal for addressing challenges in adopting drone-based pesticide systems on small and medium-sized farms. The methodology will involve stages of requirements gathering, iteration planning, prototyping, testing, and continuous improvement. Similar methodologies were successfully employed by L. R. Campuzano (2023) in tackling related agricultural technology adoption barriers, yielding satisfactory results [3].

The Agile methodology stages include:

1. **Requirements Gathering:** The research will involve collaborating with farmers to understand their needs and the challenges they face in adopting drone technology.
2. **Iteration Planning:** The team will define specific objectives and deliverables for each iteration based on the gathered requirements.
3. **Development:** The research will prototype potential solutions, such as training programs and technical support mechanisms, in short cycles.
4. **Testing and Feedback:** Proposed solutions will be implemented in real farm settings, allowing for the gathering of feedback from farmers and necessary adjustments.
5. **Review and Retrospective:** The effectiveness of the solutions will be evaluated, and the approach will be refined based on user experiences and outcomes.

9. Schedule and Budget

<u>Schedule:</u>

The study will be conducted over a 12-month period, illustrated by the following Gantt chart:

Duration (Month)												
Phase	1	2	3	4	5	6	7	8	9	10	11	12
Literature Review												
Problem Identification												
Survey Design												
Data Collection												
Data Analysis												
First Report Submission												
Development and Recommendation												
Final Report Submission												

<u>Budget:</u>

The proposing budget for this research is as follows:

Budget Type	Description	Cost (USD)
Survey Distribution	Costs for designing, distributing, and collecting survey responses from small and medium-sized farms. Includes digital and physical formats.	2,500

Interview Transcription and Analysis	Recording, transcription, and analysis of interviews with stakeholders, such as farmers, agricultural experts, and drone technology providers.	3,500
Case Study Visits	Travel, accommodation, and meal expenses for on-site farm visits to observe drone technology implementation and adoption.	2,500
Data Analysis Software	Purchase of software licenses for specialized data analysis tools.	1,300
Miscellaneous Expenses	Unforeseen costs, including printing, administrative fees, and additional travel expenses.	1,800

This budget breaks down the anticipated costs over a one-year period, with a total of $11,600 which is about 14 lack Bangladeshi TK.

10. Data Collection Methods

As discussed earlier, we will use mixed method for our research design as it has several benefits for our research and Puppala (2023) also used this method to collect data and got satisfactory result [2].

Data collection emphasizes mixed method is summarized below:

- **Surveys and Questionnaires**: These will be distributed to small and medium-sized farm owners to gather quantitative data on their experiences and challenges with drone technology. This data will include statistics on adoption rates, perceived barriers, and the effectiveness of training programs, allowing for a robust analysis of trends and correlations.
- **Interviews**: Semi-structured interviews with farmers, agricultural experts, and drone technology providers will provide qualitative insights into the economic, technical, and regulatory challenges.
- **Case Studies**: Selected farms that have successfully adopted drone-based pesticide systems will be studied in-depth to extract lessons that can be applied more broadly.

11. Significance of the Study

This study is significant because it addresses the practical challenges that hinder the adoption of drone technology in agriculture. By focusing on small and medium-sized farms, which make up the majority of agricultural operations worldwide, this research can have a far-reaching impact on improving farm productivity, reducing environmental harm, and promoting sustainable agricultural practices. The research will contribute to the growing body of knowledge in precision agriculture and may serve as a guide for policymakers, agricultural organizations, and technology providers in making drone-based pesticide systems more accessible to farmers. Moreover, by developing effective training programs, this research will empower farmers to adopt new technologies with confidence, thereby enhancing agricultural productivity and sustainability.

References:

[1] Fortune Business Insights. (2024, June). Agriculture Drone Market Size, Share & Industry Analysis, By Type (Fixed Wing, Rotary Wing, and Hybrid), By Component (Hardware [Frames, Control Systems, Propulsion System, Navigation System, Payload, Avionics, and Others] and Software [Imaging Software, Data Management Software, Data Analytics Software, and Others]), By Application (Field Mapping & Monitoring, Crop Spraying, Crop Scouting, Variable Rate Application, Livestock Monitoring, and Others), and Regional Forecast, 2024-2032. Retrieved from https://www.fortunebusinessinsights.com/agriculture-drones-market-102589

[2] H. Puppala, P. R. Peddinti, J. P. Tamvada, J. Ahuja, and B. Kim, "Barriers to the adoption of new technologies in rural areas: The case of unmanned aerial vehicles for precision agriculture in India," *Technology in Society*, vol. 74, p. 102335, 2023.

[3] L. R. Campuzano, G. A. H. Llanos, J. W. Z. Sossa, G. L. O. Mendoza, J. C. Palacio, and M. Herrera, "Barriers to the Adoption of Innovations for Sustainable Development in the Agricultural Sector—Systematic Literature Review (SLR)," *Sustainability*, vol. 15, no. 5, p. 4374, Mar. 2023.

[4] A. S. Hanif, X. Han, and S. H. Yu, "Independent control spraying system for UAV-based precise variable sprayer: A review," *Drones*, vol. 6, no. 12, p. 383, 2022.

[5] A. P. Rathnayake, R. K. Sahni, L. R. Khot, G. A. Hoheisel, and H. Zhu, "Intelligent sprayer spray rates optimization to efficiently apply chemicals in modern apple orchards," *Journal of the American Society of Agricultural and Biological Engineers*, vol. 65, no. 6, pp. 1411–1420, 2022.

[6] A. Hafeez, M. A. Husain, S. P. Singh, A. Chauhan, M. T. Khan, N. Kumar, and S. K. Soni, "Implementation of drone technology for farm monitoring & pesticide spraying: A review," *Information Processing in Agriculture*, vol. 10, no. 2, pp. 192–203, 2022.

[7] M. Shafiq and J. G. Choi, "Unmanned Aerial Vehicles (UAV) in precision agriculture: Applications and challenges," *Energies*, vol. 15, no. 1, p. 217, 2022.

[8] N. Falco, H. M. Wainwright, B. Dafflon, C. Ulrich, F. Soom, J. E. Peterson, J. B. Brown, K. B. Schaettle, M. Williamson, J. D. Cothren, and R. G. Ham, "Influence of soil heterogeneity on soybean plant development and crop yield evaluated using time-series of UAV and ground-based geophysical imagery," *Scientific Reports*, vol. 11, no. 1, p. 7046, 2021.

[9] F. H. Iost Filho, W. B. Heldens, Z. Kong, and E. S. de Lange, "Drones: Innovative technology for use in precision pest management," *Journal of Economic Entomology*, vol. 113, no. 1, pp. 1–25, 2020.

[10] A. Feng, J. Zhou, E. D. Vories, K. A. Sudduth, and M. Zhang, "Yield estimation in cotton using UAV-based multi-sensor imagery," *Biosystems Engineering*, vol. 193, pp. 101–114, 2020.

[11] D. C. Tsouros, S. Bibi, and P. G. Sarigiannidis, "A review on UAV-based applications for precision agriculture," *Information*, vol. 10, no. 11, p. 349, 2019.

[12] W. C. Qin, X. Y. Xue, S. M. Zhang, W. Gu, and B. K. Wang, "Droplet deposition and efficiency of fungicides sprayed with small UAV against wheat powdery mildew," *International Journal of Agricultural and Biological Engineering*, vol. 11, no. 2, pp. 27–32, 2018.

[13] A. I. de Castro, J. Torres-Sánchez, J. M. Peña, F. M. Jiménez-Brenes, O. Csillik, and F. López-Granados, "An automatic random forest-OBIA algorithm for early weed mapping between and within crop rows using UAV imagery," *Remote Sensing*, vol. 10, no. 2, p. 285, 2018.