Original Research Article

Drone Technology in Agricultural Practices: A SWOC Analysis

Abstract

Drone technology, also known as Unmanned Aerial Systems (UAS), is transforming modern agriculture by introducing precision farming techniques that enhance crop monitoring, resource management, and sustainability. By providing real-time data on plant health, soil conditions, and irrigation needs, drones enable farmers to make informed decisions that optimize yields while reducing input costs. In India, the rapid growth of the drone sector highlights its increasing importance in addressing challenges such as labor shortages, water scarcity, and the need for more sustainable farming practices.This case study explores the adoption and impacts of drone technology in agricultural practices within Coimbatore District, Tamil Nadu, India. The purposive sampling method was used to chosen the farmers.Data were collected through a structured questionnaire and interviews with farmers who had adopted in drone technology.The study investigates the profile characteristics of farmers and evaluates the Strengths, Weaknesses, Opportunities, and Challenges (SWOC) related to the adoption of drones in agriculture.Findings revealed that drone usage significantly improved farm efficiency, reduced labor dependency, and optimized the application of fertilizers and pesticides, resulting in lower input costs and more sustainable practices. However, challenges such as high upfront costs, fragmented land holdings, technical expertise gaps, and limited drone availability constrained wider adoption.This research concludes that while drones offer substantial potential to modernize agriculture and address labor and environmental challenges, further government support and farmer training are crucial to overcome adoption barriers. The study underscores the role of drones in promoting climate-resilient and sustainable farming practices.

Keywords: Drone Technology, SWOC Analysis, Coimbatore District.

Introduction

Drone technology, also known as Unmanned Aerial Systems (UAS), is rapidly transforming agriculture by enabling farmers to adopt precision farming techniques that improve crop yields, resource management, and sustainability (Inoue,2020).The drone industry in India is experiencing rapid growth, with the market expected to reach an impressive USD 13 billion by 2030, a significant increase from USD 2.71 billion in 2022 (Statista,2023). This expansion reflects a robust compound annual growth rate (CAGR) of 21%. As of March 2024, the country boasts over 200 drone technology startups, highlighting the sector's innovative momentum. Additionally, more than 13,000 drones have been officially registered, demonstrating the increasing adoption of this technology (India Brand Equity Foundation,2024). From January 2016 to November 2023, the drone sector attracted investments exceeding USD 83 million, further underscoring its potential for future development and impact across various industries.The integration of drone technology into agricultural practices leads to more informed

decision-making, reduces resource wastage, and improves overall farm efficiency. In countries where agricultural productivity is vital for economic growth and food security, such as India, drone technology has become an essential tool for overcoming challenges like labor shortages, environmental degradation, and climate change impacts.

Drone technology has a wide range of applications in agriculture, revolutionizing traditional farming practices with precision and efficiency. Drones are used for crop monitoring, allowing farmers to assess plant health, detect diseases, and spot nutrient deficiencies in real time, leading to timely interventions (Abbas*et.al*,2023). They also aid in soil and field analysis, providing detailed maps of soil health (Soman*et.al*.,2024), moisture levels, and topography (Brent,2021) which helps in precision irrigation and optimizing planting patterns. Additionally, drones are employed for precise application of fertilizers and pesticides, reducing the overuse of chemicals and minimizing environmental impact (Taseer and Han,2024). Irrigation management is another crucial application, where drones help monitor water distribution and detect water-stressed areas, ensuring efficient water usage (Nhamo *et.al*.,2020). Overall, drones enhance productivity, reduce input costs, and support sustainable farming practices, making them a game-changer in modern agriculture (Balyan *et.al*.,2024).

Despite the growing global interest in drone technology and its potential benefits for agriculture, there is a significant lack of localized studies that address its practical implementation, awareness, and adoption among farmers, particularly in regions with diverse agricultural practices, such as India. Many existing studies focus on drone capabilities, technical advancements, and case studies from developed nations, but there is a limited understanding of how these technologies are received and integrated into the farming practices of smallholder farmers in developing countries. Furthermore, the specific challenges, constraints, and benefits experienced by farmers in adopting drone technology have not been sufficiently explored.This research seeks to contribute insights into how drone technology can be better integrated into existing agricultural practices, enhancing productivity and sustainability. The research objectives are to identify the profile characteristics of the farmer and to conduct the SWOC Analysis of the farmers with the respect to drone technology in agriculture.

Research Methodology:

The study utilizes a case study approach to investigate the adoption and effects of drone technology in agricultural practices.This approach is chosen for its ability to provide in-depth insights into the lived experiences of farmers, their decision-making processes, and the context-specific challenges and benefits of using drone technology (Flyvbjerg,2011). The study focuses on Coimbatore District in Tamil Nadu, which is known for its diverse agricultural practices and growing interest in the use of modern technology in farming. The district is known for its agricultural diversity, with crops such as paddy, coconut, sugarcane, and various horticultural products being cultivated. This diversity makes Coimbatore an ideal site for studying the adoption of drone technology, as it allows the exploration of how drones are being utilized across different types of farming systems. A purposive sampling technique was used to select the farmers for the study.This non-random method targeted farmers who had already adopted or shown interest in drone technology, ensuring the study focused on individuals with relevant

experiences (Campbell *et.al.,*2020). A structured questionnaire was administered to collect information on farmers' profiles, their use of drones, adoption factors, and the perceived benefits and challenges of drone technology. A SWOC analysis framework was used to evaluate the strengths, weaknesses, opportunities, and challenges associated with the adoption of drone technology in agriculture, based on the data from surveys and interviews.

Results and Discussion:

Case Study 1

Chart 1 : Profile Characteristics of the Farmer

Name of the Farmer	**:**	Farmer 1
Name of the Village	**:**	Kembanur
Name of the Block	**:**	Thondamuthur
Name of the District	**:**	Coimbatore
Age	**:**	47
Education	**:**	Primary Education
Gender	**:**	Male
Farming Experience	**:**	30 years
Occupation	**:**	Farming and Livestock Management
Total Land Area (in Acres)	**:**	6 acres
Land Area under Drone Application (in Acres)	**:**	1.5 acres
Crops cultivated in the field	**:**	Coconut, Brinjal, Onion, Coriander, Broad Bean, Cowpea, Horse gram, Cabbage
Crops preferred in using the drone	**:**	Brinjal, Onion
Time preference for using the drone	**:**	Morning (Before 9.00 am) Evening (After 4.00pm)
Task preferred for Drone Usage	**:**	Spraying of Agrochemicals and Fertilizers
Average Time spent for fertilizer application	**:**	**Before** Drone Usage: 1 hr – 1.5 hr / acre **After** Drone Usage : 20 mins – 25 mins / acre
Cost of fertilizer application (in rupees per day)	**:**	**Before** Drone Usage: ➢ Labour cost for spraying and weeding Rs. 1150/ day (Male – 800/day, Female – 350/day) **After** Drone Usage: ➢ Spraying charge only – Rs.400/ day

Fertilizer Usage (in acre)	**:**	**Before** Drone Usage: 100 litres/ ac **After** Drone Usage: 10 litres/ac

Factors Influencing the adoption of Drones for Fertilizer Application

The farmer explained that the decision to adopt drone technology for agricultural practices was primarily driven by several key factors. One of the most pressing challenges was the scarcity of labor, which had become a significant issue in recent years. Additionally, the high wages demanded by the available labor force made it increasingly difficult to maintain cost-effective farming operations. Another major concern was water scarcity, which impacted irrigation and crop management. By using drones, the farmer was able to optimize water usage, ensuring better irrigation management (Zuo *et.al.*,2021). Lastly, drones allowed for reduced pesticide usage, making farming practices more efficient and environmentally friendly (Zhang & Kamargianni,2023).

Impact of Drone Based Fertilizer Application

The farmer highlighted several positive impacts of using drones for fertilizer application. One of the major benefits was the effective utilization of inputs, as drones ensure precise application of fertilizers, minimizing the chances of overuse or underuse (Raza et.al.,2023). This precision also contributed to the minimization of waste, making the process more efficient and environmentally sustainable. Additionally, the use of drones resulted in significant water savings, optimizing irrigation practices. By ensuring timely fertilizer application, the farmer was able to achieve timely harvests, improving overall productivity. Moreover, drones helped in the reduction of cultivation costs, particularly by reducing the reliance on manual labor and other traditional methods (Wang *et.al.*,2021). As a result, there was a noticeable increment in income. Lastly, drones effectively addressed labor scarcity, filling a critical gap in agricultural operations and enhancing the farm's efficiency**.**

Constraints faced on Drone Based Fertilizer Application

The farmer encountered several constraints in adopting drone technology for fertilizer application. One major challenge was the non-availability of drones at all times. Since the farmer relied on renting drones rather than owning one, access to the technology was limited, especially during peak agricultural seasons when demand was high. Additionally, drones were found to be unsuitable for spraying on fragmented land. In areas where land was divided into smaller, irregular plots, the effectiveness and efficiency of drone spraying were reduced, making it difficult to cover the entire area uniformly. Another significant barrier was the insufficient knowledge about operating the drones. Many farmers lacked the technical expertise required to use this advanced technology effectively, leading to a heavy dependence on external service providers for drone rental and usage.

Case Study 2

Chart 2 : Profile Characteristics of the Farmer

Name of the Farmer	**:**	Farmer 2
Name of the Village	**:**	Kulathupalayam
Name of the Block	**:**	Thondamuthur
Name of the District	**:**	Coimbatore
Age	**:**	40
Education	**:**	Secondary Education
Gender	**:**	Male
Farming Experience	**:**	22 years
Occupation	**:**	Farming and Livestock Management
Total Land Area (in Acres)	**:**	4 acres
Land Area under Drone Application (in Acres)	**:**	2 acres
Crops cultivated in the field	**:**	Coconut, Onion, Chilli, Areca Palm and Banana
Crops preferred in using the drone	**:**	Banana, Areca Palm and Chilli
Time preference for using the drone	**:**	Morning (Before 9.00 am) Evening (After 4.00 pm)
Task preferred for Drone Usage	**:**	Spraying of Agrochemicals and Fertilizers
Average Time spent for fertilizer application	**:**	**Before** Drone Usage : 1 hr – 1.5 hr / acre **After** Drone Usage : 10 – 15 mins / acre
Cost of fertilizer application (in rupees per day)	**:**	**Before** Drone Usage: ➢ Labour cost for spraying and weeding Rs. 1600/ day ➢ Fuel Cost for power Spraying Rs.100 ➢ Total Cost (Rs.1700/Spraying) **After** Drone Usage: ➢ Spraying charge only – Rs.500/ day
Fertilizer Usage (in acre)	**:**	**Before** Drone Usage: 150 litres/ ac (Banana) **After** Drone Usage: 10 - 20 litres/ac

Factors Influencing the adoption of Drones for Fertilizer Application

The farmer shared that labor scarcity and the high wages required for available labor have made it difficult to manage farm operations efficiently. He noted that using drones has been a

game-changer, especially in reducing the reliance on manual labor. The drone technology has also contributed to a reduced usage of pesticides, as it allows for more precise spraying, ensuring only the necessary amount is applied. Additionally, he highlighted how drones can cover more area in a much shorter span compared to traditional methods, making farming more efficient. With the ongoing issue of water scarcity, he believes drones can optimize water distribution, further conserving this vital resource (Sabino*et.al.*,2022).

Impact of Drone usage for Fertilizer Application

A farmer highlighted the impact of drone-based fertilizer application, emphasizing its effectiveness in utilizing inputs more efficiently. He mentioned that drones help in saving water by ensuring targeted application, reducing wastage (Dutta,2020). This method has also led to a significant reduction in the overall cost of cultivation, as precise application minimizes the amount of fertilizer needed. Moreover, by using drones, the farmer has been able to meet the challenge of labor scarcity, as the technology reduces dependency on manual labor while increasing productivity (

Constraints faced by farmer Drone Based Fertilizer Application

The farmer shared the challenges he faced while using agricultural drones. He explained that the speed of the drone sometimes damages the delicate inflorescence of his chili plants, negatively affecting the crop (Degieter*et.al.*,2023). In his areca palm fields, he noticed significant pesticide wastage, as the drone does not target the plants efficiently. Similarly, when spraying pesticides on his banana crops, the farmer observed that the penetration is not evenly distributed, leaving some parts under protected. He also emphasized the lack of awareness among farmers about the proper use and benefits of agricultural drones, which further limits their effectiveness.

The farmer suggested that crops like onion, cauliflower, and cabbage could be more suitable for drone applications. He believes that these crops, due to their structure and growing patterns, would benefit from the precision and efficiency that drones offer. The controlled spraying could help these crops receive the right amount of inputs without the risk of damage or wastage, making drone technology a viable solution for improving productivity and reducing labor dependency in these types of cultivation.

Case Study 3

Chart 3 : Profile Characteristics of the Farmer

Name of the Farmer	**:**	Farmer 3
Name of the Village	**:**	Pulliagoundaputhur
Name of the Block	**:**	Thondamuthur
Name of the District	**:**	Coimbatore
Age	**:**	53
Education	**:**	Primary Education

Gender	**:**	Male
Farming Experience	**:**	35 years
Occupation	**:**	Farming and Livestock Management
Total Land Area (in Acres)	**:**	4.5 acres
Land Area under Drone Application (in Acres)	**:**	2 acres
Crops cultivated in the field	**:**	Coconut, Bhendi, Tapioca, Onion
Crops preferred in using the drone	**:**	Tapioca
Time preference for using the drone	**:**	Morning (Before 10.00 am) Evening (After 4.00 pm)
Task preferred for Drone Usage	**:**	Spraying of Agrochemicals and Fertilizers
Average Time spent for fertilizer application	**:**	**Before** Drone Usage: 1 hr – 1.5 hr / acre **After** Drone Usage: 10 – 15 mins / acre
Cost of fertilizer application (in rupees per day)	**:**	**Before** Drone Usage: ➢ Labour cost for power spraying and weeding Rs. 1400 / day ➢ Chemical cost: Rs.200 ➢ Fuel cost for Power sprayer: Rs.100 ➢ Total cost: Rs.1700 / spraying **After** Drone Usage: ➢ Labour cost: Rs. 300 ➢ Spraying charge only – Rs.400/ day
Fertilizer Usage (in acre)	**:**	**Before** Drone Usage: 8 -10 tank/ ac **After** Drone Usage: 1 tank/ac

Factors influencing the Adoption of Drone Technology

A farmer shared his insights on the factors influencing the adoption of drones in agriculture. He explained that labor scarcity and the high cost of wages have made it necessary to explore alternatives, with drones offering an efficient solution by reducing the need for manual labor. He also pointed out that drones help cut costs by optimizing the use of inputs like pesticides and fertilizers, leading to lower cultivation expenses. Water scarcity and the need for precise water management have made drones even more appealing, as they improve irrigation efficiency. According to him, farm size matters too, as larger farms benefit greatly from the ability of drones to cover extensive areas quickly. However, he emphasized that many farmers, including himself, are hesitant to adopt this technology due to a lack of awareness and technical

knowledge. He also believes that government policies and subsidies play a crucial role in promoting drone use, making it more accessible and affordable for farmers like him.

Impact of Drone Based Fertilizer Application

The impact of drone-based fertilizer application has been transformative for many farmers. By using drones, fertilizers can be applied with greater precision, ensuring that the right amount is distributed evenly across the field, which significantly reduces waste. This precise application leads to more effective nutrient management, resulting in healthier crops and increased yields. Additionally, drone-based fertilization helps save time and labor, as drones can cover large areas much faster than traditional methods. The cost of cultivation is also reduced, as farmers use less fertilizer and require fewer workers for the application process. Furthermore, it supports better environmental sustainability by minimizing the risk of over-fertilization and reducing runoff into nearby water sources. Overall, the use of drones for fertilizer application enhances farm efficiency, productivity, and cost-effectiveness.

Constraints faced by farmer Drone Based Fertilizer Application

One major challenge faced by farmers is the issue of small and fragmented land holdings, which makes the adoption of advanced technologies like drones less practical for individual use. In such cases, farmers often cannot justify the cost of purchasing or maintaining drones due to the limited area they cultivate. Additionally, the non-availability of service centers at all times poses another significant constraint. Farmers may struggle to access timely maintenance or technical support for their drones, leading to delays in their operations and reducing the overall effectiveness of the technology. This lack of readily available services further discourages many farmers from adopting drone technology.

SWOCAnalysis

A SWOC analysis is a strategic planning tool used to evaluate the Strengths, Weaknesses, Opportunities and Challenges related to a project, business, or organization. It helps in identifying internal and external factors that can affect the achievement of objectives (Gurl,2017). With the above case studies, SWOC Analysis which is represented in the Figure 1. which provides the comprehensive view for the adoption of drone technology.

Strength

Drones have brought significant advancements to the agricultural sector by offering efficient monitoring and data collection capabilities, allowing farmers to manage larger areas more effectively and in less time compared to traditional methods. With their ability to capture high-resolution images, drones enable the detection of issues such as crop health problems, nutrient deficiencies, and disease outbreaks at an early stage. This early detection empowers farmers to make informed, timely decisions that lead to higher productivity and better crop management. In addition to their monitoring benefits, drones offer substantial cost savings. The reduction in manual labor and the ability to automate tasks like fertilizer application and crop monitoring leads to more efficient resource use. Over time, this can significantly reduce operational costs, especially for large-scale farming operations. The precision offered by drones

in applying fertilizers or pesticides ensures that these resources are used optimally, which not only cuts costs but also contributes to environmental sustainability by reducing chemical runoff and preventing overuse of agricultural inputs. The reduced dependency on labor and the time-saving nature of drones further enhance their appeal, making them an integral part of modern precision agriculture.

Weakness

Despite their numerous benefits, the use of drones in agriculture comes with certain drawbacks. One of the most significant challenges is their vulnerability to adverse weather conditions. Drones may not be able to operate during heavy rain, strong winds, or extreme temperatures, which can disrupt important agricultural operations, particularly during critical periods like planting or harvesting. Another key weakness is the technical expertise required to operate drones effectively. Many farmers, especially in rural or less-developed regions, may lack the necessary skills to pilot drones or to interpret the data they collect. This creates a dependency on external service providers, which can add to the costs and complexity of adopting drone technology. Additionally, small and fragmented landholdings is the common issue in many agricultural regions which limit the full potential of drone technology. Drones are most effective when used over large, contiguous areas where they can cover more ground efficiently. In areas with small or divided plots, the cost-effectiveness and benefits of drones are diminished. Finally, the high upfront cost of purchasing drones, along with the expenses associated with maintaining the equipment and acquiring the necessary software, makes it difficult for many small and medium-scale farmers to adopt this technology. While the long-term benefits are clear, the initial investment can be a prohibitive barrier.

Opportunities

The potential opportunities for drones in agriculture are vast, especially as technological advancements continue to make drones more affordable and adaptable to a wide range of agricultural applications. As drone technology evolves, we are seeing more customizable solutions tailored to specific farming needs, from mapping and soil analysis to fertilizer application and pest management. These advancements make drones more accessible and valuable for farmers in diverse regions and cropping systems. Moreover, government initiatives aimed at promoting modern farming techniques, including precision agriculture, present a significant opportunity for widespread drone adoption. Many governments are implementing policies and subsidies that support the use of drones to boost agricultural productivity, ensure food security, and promote sustainable practices. Drones can also be instrumental in bridging connectivity gaps in remote agricultural areas, where access to real-time data is often limited. By enhancing precision farming techniques in these areas, drones can significantly improve farm management and decision-making. Drones also align with global movements toward climate-resilient farming. By allowing farmers to optimize water usage, minimize the environmental impact of chemical inputs, and respond quickly to climate-related challenges, drones are helping build more resilient agricultural systems. The potential for increased crop yields and income through better management of resources, combined with water conservation efforts, makes drone technology a powerful tool in the fight against climate change and food insecurity.

Challenges

While drones offer great potential, several challenges hinder their widespread adoption. One of the most critical barriers is the high initial cost of acquiring the technology. Although long-term cost savings can be achieved, the significant upfront investment along with ongoing expenses related to drone maintenance, software updates, and specialized training poses a challenge, particularly for small-scale farmers who operate with limited budgets. In addition, the need for specialized training presents a hurdle. Farmers must learn not only how to operate the drones but also how to interpret the data they generate. Without adequate training, the benefits of drone technology could be underutilized, leading to suboptimal results. Moreover, the challenge of technological failures whether due to equipment malfunction, software issues, or pilot errors—can result in poor fertilizer application, crop damage, or even financial losses, which could deter farmers from adopting the technology. Economic volatility in the agricultural sector further complicates the adoption of drones. Fluctuating crop prices, unpredictable weather patterns, and market instability can make farmers hesitant to invest in expensive technology. Finally, there is a certain level of resistance to change among some farmers who are more comfortable with traditional farming practices.

Figure 1. SWOC Analysis on Adoption of Drone Technology

Conclusion

The adoption of drone technology in agricultural practices, as highlighted through various case studies, demonstrates significant benefits in terms of efficiency, cost reduction, and sustainability. Farmers who have integrated drones into their farming practices have experienced precise and timely application of inputs like fertilizers, resulting in reduced labor costs and optimized resource management. Drones have proven particularly effective in addressing challenges such as labor scarcity and water conservation, offering a practical solution to modern agricultural demands.However, the technology is not without its challenges. Fragmented land holdings, high initial investment costs, and the need for specialized knowledge have limited its wider adoption, particularly among small-scale farmers. Additionally, drone efficacy can be hindered by adverse weather conditions and technical malfunctions.Despite these challenges, the potential for drones to revolutionize agriculture is vast. With the continued advancement of technology, along with government support and subsidies, drone usage can become more accessible to a broader range of farmers, enhancing productivity and sustainability. Ultimately, drones represent a transformative tool for modernizing agriculture, improving precision farming, and supporting the global push toward environmentally conscious farming practices.

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