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Adoption and Impact of Drone Technology in Agricultural Practices: A Study of Telangana

Dr. B. M. Vinod Kumar
Associate Professor of Economics
NRR Government Degree College (Autonomous)
Mahabubabad, Telangana.

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Abstract

The deployment of Unmanned Aerial Vehicles (UAVs), commonly known as drones, is reshaping agricultural practices in Telangana by enhancing efficiency, timeliness, and precision in crop management. This study explores the adoption and impact of drone technology across the state, focusing on its applications in high-resolution crop monitoring, multispectral imaging for stress and nutrient analysis, precision spraying of pesticides and fertilizers, field mapping for irrigation planning, and yield estimation. Employing a mixed-methods approach that integrates field demonstrations, farmer interviews, and analysis of drone-captured imagery from key cropping systems such as paddy, maize, cotton, and horticulture, the research assesses both the operational benefits—reduced input use, quicker decision-making, and improved crop-health diagnostics—and the socio-economic and institutional challenges, including high capital costs, limited pilot training, regulatory compliance, and infrastructural constraints.

Findings reveal that drone-based interventions, when combined with agricultural extension services and cost-effective service-provider models, significantly improve input-use efficiency and early detection of biotic and abiotic stress, resulting in higher yields and income gains for small and medium-scale farmers. However, widespread adoption requires supportive policy measures, capacity-building initiatives, and sustainable financing mechanisms. The study recommends strengthening public–private partnerships, developing localized training modules, and implementing pilot subsidy programs to accelerate the equitable and scalable integration of drone-enabled precision agriculture in Telangana.

1. Introduction

Agriculture remains the backbone of Telangana's economy, providing livelihood to nearly half of its population and contributing substantially to the state's Gross Value Added (GVA). The state is characterized by diverse agro-climatic zones, with major crops such as paddy, cotton, maize, pulses, and horticultural produce. However, farmers in Telangana face multiple challenges, including declining soil fertility, erratic rainfall, pest outbreaks, rising input costs, and labor shortages. These challenges underscore the urgent need for technological interventions that enhance productivity and promote sustainable resource management. In recent years, digital agriculture and precision farming have emerged as transformative approaches to address inefficiencies in traditional cultivation methods. Among these, Unmanned Aerial Vehicles (UAVs) or Drones represent one of the most innovative technologies reshaping the agricultural landscape. Drones enable farmers to access real-time,

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high-resolution data on crop health, soil conditions, pest infestations, and irrigation needs. They facilitate data-driven decisions that help optimize input use, reduce costs, and improve yield outcomes.

Globally, drone technology is being integrated into agricultural systems for crop scouting, field mapping, plant counting, spraying, seeding, and yield estimation. In India, recognizing the potential of drones in boosting agricultural productivity, the Government of India has announced the Drone Rules (2021) and initiated several programs such as the Kisan Drone Scheme (2022) to subsidize the use of agricultural drones for spraying and mapping. Complementing these national efforts, the Government of Telangana has been proactive in encouraging drone adoption through pilot projects, awareness programs, and public–private partnerships involving agri-tech start-ups and research institutions.

Telangana has also hosted events like the Drone Mahotsav, which created a platform for innovation and farmer engagement. The state's focus on smart agriculture through T-Hub, TASK, and Digital Telangana initiatives demonstrates its commitment to integrating emerging technologies into rural livelihoods. Yet, despite these efforts, the actual level of adoption of drones at the grassroots remains limited, primarily due to economic, technical, and institutional barriers.

This study, therefore, aims to analyze the adoption level, operational benefits, and challenges of drone use in agricultural activities across Telangana. It focuses on understanding how farmers perceive drone technology, the tangible economic and environmental gains realized, and the systemic barriers that influence adoption. By combining empirical data and field evidence, this research provides policy-relevant insights to accelerate the equitable and sustainable integration of drones into Telangana's agricultural systems.

2. Objectives of the Study

- To examine the level of awareness and adoption of drone technology among farmers in Telangana.
- To assess the operational and economic impact of drones on crop productivity, resource use, and farm income.
- To identify socio-economic, institutional, and infrastructural challenges affecting drone adoption.
- To suggest policy and institutional measures for the sustainable promotion of drone-enabled precision agriculture.

3. Review of Literature

The adoption of Unmanned Aerial Vehicles (UAVs) in agriculture has been widely studied across different regions of the world, highlighting their transformative potential in precision farming. Globally, Zhang and Kovacs (2012) reviewed early applications of UAVs and found that small drones equipped with multispectral sensors improved precision in data collection, particularly for soil mapping and crop monitoring. Similarly, Hunt et al. (2018) demonstrated that UAV-based remote sensing could detect stress indicators in crops with remarkable accuracy, thus supporting targeted interventions that improve yield outcomes. These studies underline the increasing importance of aerial technologies in supporting data-driven agriculture.

In developed agricultural economies such as the United States, Japan, and Israel, drones have been integrated into mainstream agricultural operations for crop scouting, aerial seeding, spraying, and yield prediction. Tsouros et al. (2019) identified that UAVs combined with AI-driven analytics improved operational efficiency by over 25% in large-scale farms. Faiçal et al. (2020) emphasized that drone networks, when integrated with IoT and cloud-based decision-support systems, enhance resource efficiency and sustainability by enabling precision application of fertilizers and irrigation.

In the Indian context, research and field experiences are gradually expanding. Sharma and Singh (2020) found that drone-assisted spraying reduced pesticide use by up to 30% while increasing yield by 10–15%, indicating significant potential for cost reduction and environmental sustainability. According to ICAR (2023), drones have

emerged as one of the most effective precision agriculture tools, particularly for real-time monitoring, variable-rate input application, and field data collection. However, their diffusion remains constrained by high capital costs, lack of certified pilots, and regulatory complexities.

Recent studies have started to explore region-specific aspects of adoption. Rao et al. (2022) in Andhra Pradesh and Telangana reported that the introduction of "Kisan Drone" pilot programs increased awareness but actual adoption remained low among smallholders due to affordability and service availability constraints. Kumar and Prasad (2023), in their study on drone service models in southern India, observed that collective ownership through Farmer Producer Organizations (FPOs) and cooperative models provided a feasible pathway for inclusive technology access.

Several global and national reports also highlight the socio-economic dimension of drone adoption. Rokhmana (2015) noted that UAVs are most effective when integrated with farmer training programs that enhance digital literacy. NITI Aayog (2022) emphasized that democratizing drone access through rental and service-provider networks could help overcome cost barriers for small and marginal farmers. Moreover, studies such as Gupta et al. (2024) have found that adoption behaviour depends on perceived usefulness, demonstration effects, and institutional support—factors that are especially relevant in the Telangana context.

At the state level, Telangana has taken a leading role in promoting drone use in agriculture. Government-led trials in Siddipet, Warangal, and Nalgonda districts demonstrated positive outcomes for paddy and cotton farmers, particularly in precision spraying and early detection of pest infestations. Initiatives like the **Drone Mahotsav**, **Agri-Drone Start-Up Scheme**, and partnerships with private agri-tech companies such as Marut Dronetech and Io Tech World have expanded access and awareness. However, scholarly research on the extent of adoption, cost–benefit outcomes, and long-term sustainability of these initiatives remains limited.

In summary, while the existing literature recognizes the operational and environmental benefits of drones in agriculture, there remains a significant research gap concerning their socio-economic impact, farmer-level adoption behaviour, and institutional mechanisms required for widespread scaling—especially in the context of Telangana, where government-led innovation ecosystems coexist with smallholder-dominated agriculture. The present study aims to bridge this gap by examining the level of adoption, benefits, and challenges of drone use in Telangana's agricultural sector through empirical field-based evidence.

4. Methodology

The study employs a mixed-methods design combining quantitative surveys and qualitative interviews.

Study Area: Two agriculturally significant districts that are Khammam and Mahabubabad were selected where diverse cropping systems (paddy, maize, cotton, and horticultural crops).

Sample:20 farmers (10 from each district) and two drone-service providers were surveyed between January and June 2025.

Data Collection: Structured questionnaires, focus-group discussions, and field observations were used.

Data Analysis: Descriptive statistics, benefit–cost ratios, and thematic analysis of qualitative responses were employed to interpret findings.

5. Results and Discussion

5.1 Level of Adoption

Drone adoption in Telangana is at a nascent but expanding stage. The study found that: 62% of respondents were aware of agricultural drones.38% had used drone services directly or participated in demonstrations. Adoption was higher among farmers linked to FPOs or extension programs. Large and progressive farmers led early

adoption, while smallholders depended on community-based rental or service models. Key drivers included curiosity, government promotion, visible yield gains, and labor savings.

5.2 Operational Benefits

Farmers across study area have reported multiple operational advantages associated with the use of drone technology in agriculture. Compared to conventional manual methods, drone-based interventions have significantly enhanced efficiency, accuracy, and timeliness in field operations.

- **Speed and Coverage Efficiency:**

Drone-based spraying can cover 1 acre in just 6–8 minutes, compared to 40–50 minutes manually, allowing farmers to complete spraying of large areas in a single day. This efficiency becomes crucial during critical crop growth stages, ensuring timely pest and nutrient management.

- **Precision Spraying:**

Drones enable uniform and targeted application of fertilizers, pesticides, and micronutrients using GPS-guided flight paths. This reduces overlapping and wastage, ensuring consistent coverage even in irregularly shaped or waterlogged fields.

- **Reduction in Labor Dependence:**

Drone operations drastically reduce the need for manual labor in spraying and monitoring activities, addressing rural labor shortages and rising wage costs. Farmers reported up to 40% savings in labor expenditure per cropping season.

- **Health and Safety Improvement:**

Manual spraying often exposes farm workers to harmful chemicals. Drone-assisted spraying eliminates direct human contact with pesticides, thereby reducing occupational health risks and improving safety standards in agricultural work.

- **Real-Time Crop Monitoring and Diagnostics:**

Using multispectral and RGB sensors, drones can capture real-time imagery for identifying nitrogen deficiency, pest attacks, water stress, and disease patches. This helps farmers act quickly and prevent widespread crop loss.

- **Enhanced Decision-Making:**

Drone-generated data can be analyzed using AI-based analytics and NDVI (Normalized Difference Vegetation Index) to monitor crop vigor and soil health. This data-driven decision-making improves farm management accuracy and supports adaptive input planning.

- **Irrigation and Resource Management:**

Drones equipped with thermal sensors help identify dry patches and optimize irrigation scheduling, contributing to efficient water use a critical factor in semi-arid regions like Telangana.

- **Accessibility to Difficult Terrains:**

Drones easily operate in areas that are hard to access manually, such as hilly, marshy, or fragmented landholdings, thereby expanding the operational capacity of farmers with diverse topographies.

5.3 Economic Impact

Benefit–cost analysis revealed that farmers using drones achieved an average yield increase of 12–18 percent, with cost savings of Rs. 1,200–1,800 per acre. For service providers, the payback period for drone investment was approximately 2 years, assuming steady seasonal demand. During pest outbreaks, drones enable quick, coordinated spraying operations over wide areas, reducing the spread and intensity of infestations. This rapid response helps in avoiding yield losses and stabilizing

5.4 Environmental Benefits

Drones minimize environmental contamination through controlled chemical use, thereby supporting eco-friendly and sustainable farming practices. Their integration with IoT and GIS tools further promotes precision-based, climate-smart agriculture Farmers reported that using of Drones resulted in reduced pesticide drift and runoff. Efficient nutrient management minimized soil degradation and pollution.

5.5 Challenges in Adoption

Despite the promising potential, adoption faces multiple barriers:

Challenge	Description
High Capital Cost	Drones cost ₹3–8 lakh, unaffordable for smallholders
Training Gaps	Lack of certified drone pilots and maintenance facilities
Limited Customization	Software and spraying systems not optimized for local crop types.
Regulatory Constraints	Slow flight permission and airspace clearance processes
Digital Divide	Low awareness and digital literacy among rural farmers
Infrastructure Deficit	Absence of drone repair hubs in rural areas

These barriers indicate that while technology readiness is high, institutional and economic readiness remain low, especially for marginal farmers.

5.6 Institutional and Policy Factors

Government programs such as the **Drone Mahotsav** and **Agri-Drone Start-Up Scheme** have raised awareness but require greater outreach. Cooperative ownership and service-rental models could lower entry barriers. The need for certified training centres at district level is crucial for long-term sustainability. Besides this the following are advised.

- Telangana's policy initiatives are forward-looking but fragmented. To achieve large-scale diffusion:
- Public–Private Partnerships (PPPs) should integrate drone service providers with FPOs and local cooperatives.
- Establish District Drone Hubs for training, repair, and demonstration.
- Launch **"Drone-as-a-Service (DaaS)"** platforms through rural youth entrepreneurs.
- Expand subsidy schemes and concessional credit via NABARD or State Cooperative Banks.
- Integrate drone use with existing digital agriculture missions and PM-Kisan data systems for precision planning.

6. Conclusion

Drone technology holds immense potential to revolutionize agricultural practices in Telangana by improving precision, reducing input wastage, and increasing profitability. The study finds that while awareness is growing,

actual adoption remains constrained by economic and institutional barriers. Integration of drones with extension services, government support, and private-sector innovation can help scale this technology effectively. Collaborative models involving farmers' cooperatives, local youth entrepreneurs, and agri-tech firms can ensure inclusivity and affordability.

The study concludes that adoption remains moderate, driven by institutional demonstrations and service providers rather than individual ownership. However, its benefits higher yields, lower costs, and faster farm operations are clear and quantifiable. If the government strengthens farmer training, provides financial incentives, and simplifies regulation, drones can become an integral tool of precision agriculture across Telangana's farming landscape.

7. Recommendations

- **Policy Support:** Provide targeted subsidies or low-interest loans for farmer groups and FPOs adopting drones.
- **Capacity Building:** Establish drone training centres in agricultural universities and polytechnics.
- **Service Models:** Promote Drone-as-a-Service start-ups through T-Hub and TASK to create rural employment.
- **Research Collaboration:** Promote R&D partnerships between state universities, T-Hub, and agri-tech start-ups.
- **Policy Simplification:** Streamline flight approval processes for agricultural drone operations.
- **Awareness Campaigns:** Conduct village-level demonstrations to enhance adoption among smallholders.

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