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# Economic Analysis of Drone Technology in Agriculture: Insights from Farmer Producer Organisation in Tamil Nadu

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***Authors' contributions***

*This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.*

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## ABSTRACT

Indian agriculture makes a substantial contribution to the nation's GDP, employment, and food security. It directly employs over half of the country's workforce, supporting the livelihoods of rural communities. Historically, Indian agriculture has been labour-intensive and reliant on traditional

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practices, resulting in inefficient resource utilization. To address the numerous challenges facing the Indian agriculture sector, the adoption of emerging technologies, such as drones, is imperative. Drones have the capacity to significantly enhance agricultural practices, increasing productivity, reducing resource wastage and have the environmental advantages of drone technology, such as reduced pesticide usage and minimized runoff, would emphasize its sustainability impact. This study explores the economic dynamics of drone technology in agriculture, addressing a gap in past research amid the growing use of Artificial Intelligence in the sector. Conducted in the paddy cultivation regions of Thanjavur and Madurai districts Farmer Producer Organisations in Tamil Nadu, the study involves a sample of 80 for UAV technology and 120 for conventional methods. The findings reveal significant cost savings and higher profitability with drone-assisted farming, where total expenses decrease from ₹27,723.20 for conventional farming to ₹22,857.50 with drones, primarily due to reduced pesticide and herbicide use and improved application efficiency. While both methods yield similar gross returns of ₹39,100 for conventional and ₹40,640 for drone-assisted—the net returns are markedly higher for drones at ₹17,782.50 versus ₹11,376.80 for conventional practices. Although machine labor costs rise slightly with UAVs, overall savings enhance the financial viability of drone-assisted farming. The economic comparative analysis indicates a net profit increase of ₹7,331, underscoring the economic advantages of adopting drone technology in agriculture.

*Keywords: Unmanned aerial vehicle; agriculture; paddy; partial budgeting.*

## 1. INTRODUCTION

In India, 47 per cent of the people is dependent on agriculture. India is the largest country by population with 1.42 billion people. To sustain a growing population there is a need to improve productivity to ensure food security (Ministry of Agriculture and Farmer Welfare, 2022). Pesticides are important to kill pests and pathogens while fertilizers are needed to enhance plant growth. Manually spraying pesticides and fertilizers costs huge labor costs and affects human health which leads to cancer, hypersensitivity, asthma, and other disorders. Over the past few years, drones, often referred to as unmanned aerial vehicles (UAVs), have made impressive advancements. They have transformed agricultural practices, offering farmers substantial cost reductions, enhanced operational effectiveness, and increased profitability (Evans *et al.,* 2013). The advent of drone technology has revolutionized various industries, with agriculture being one of the most significantly impacted sectors (Mulla, 2013, Hunt & Daughtry, 2018). Drones are transforming traditional farming practices by providing innovative solutions that enhance efficiency, reduce costs, and improve crop yields. This article explores the multifaceted impact of drone technology on agricultural economics, examining its benefits, challenges, and future prospects (Malaisamy & Arun, 2024).

The integration of drones into agricultural practices contributes to environmental sustainability by promoting more efficient use of resources. Precision agriculture techniques enabled by drones minimize the overuse of fertilizers and pesticides, reducing runoff and the associated negative impacts on water bodies and ecosystems. Additionally, drones can assist in implementing conservation practices, such as monitoring cover crops and assessing soil erosion, helping farmers adopt more sustainable land management strategies. (Rathore & Wright, 2018, Barbedo, 2019). Drones also play a critical role in monitoring and managing water resources. By providing accurate data on soil moisture levels and crop water needs, drones enable farmers to implement precise irrigation practices, thereby conserving water and reducing waste. This is particularly important in regions facing water scarcity, where efficient water use is essential for maintaining agricultural productivity and economic stability. Incorporating drone technology can increase crop yields, reduce time, boost sustainable land management, and improve long-term performance. Drones have the following applications in agriculture. Remote sensing drones, equipped with electromagnetic spectrum cameras, are transforming soil and field analysis by gathering detailed ground data based on reflected wavelengths (Kachamba *et al.,* 2016). This data is processed with algorithms to monitor various farming aspects such as crop health (detecting insect damage, nutrient deficits, and pest-related color changes), vegetation (measuring leaf area, treatment efficiency, phenology, and yield), and plant growth (assessing Leaf Area Index, density, and height).

(Pathak *et al.,* 2022). This technology enables precise and informed decision-making for optimizing crop management and improving yields (Arun *et al.,* 2024).

Drones equipped with precision agriculture technology can apply fertilizers, pesticides, and water more accurately and uniformly, ensuring that crops receive the right amount of inputs precisely where needed. This targeted application minimizes waste, leading to cost savings on inputs such as chemicals and water. (Wolfert *et al.,* 2017) Additionally, drones can perform tasks that traditionally required significant manual labour, addressing the issue of labour shortages in the agricultural sector. By automating processes such as crop monitoring and spraying, drones reduce the dependency on human labour, thus decreasing labour costs and alleviating the challenges associated with labour shortages (Devi *et al.,* 2020, Malaisamy, 2024).

Another notable advantage of drones in agriculture is the reduction in the time required for various farming activities (Hafeez *et al.,* 2023). Traditional methods of field inspection, crop monitoring, and pesticide application can be time-consuming and labour-intensive. Drones can cover large areas quickly, providing real-time data and insights that enable farmers to make timely and informed decisions. Despite their benefits, drones in agriculture face challenges (IISc Bangalore, India, 2017). Pesticide drift due to wind can lead to unintended dispersal, harming non-target areas, water sources, and wildlife, while inconsistent application can damage crops (Kachamba *et al.,* 2016). Additionally, the high cost of purchasing and maintaining advanced drones makes them less accessible to small and medium-sized farms. This creates disparities between larger and smaller operations, and the need for specialized training and technical expertise further limits adoption among smaller farmers (Rejeb *et al.,* 2022).

This study is undertaken to address the notable gap in the economic analysis of Unmanned Aerial Vehicles (UAVs) in agriculture. Despite their increasing use and technological advancements, there is limited research on their economic impact, which this study aims to fill. Understanding the economic benefits of drones is crucial for several reasons (Marzuki *et al.,* 2021, Zhang & Kovacs, 2012). Drones reduce agricultural costs by precisely applying fertilizers, pesticides, and water, minimizing waste and lowering expenses. They save time and labor by quickly covering large areas and automating tasks like seed planting and crop spraying, which is especially valuable amid labor shortages. The integration of artificial intelligence (AI) with drones is set to enhance their efficiency further by improving data analysis, predicting crop health, and optimizing input use, making drones an essential tool for cost-effective and sustainable farming. The objective of this article is to analyse the cost involved in drone farming and conventional farming.

## 2. MATERIALS AND METHODS

This study was conducted in Two districts of Tamil Nadu where multistage sampling technique is used. In Thanjavur district, Ammapet and Saakottai block were chosen as study areas, in Madurai district Kulamangalam, and Kadachenendhal block were selected for the study. The sample size is 80 in UAV using farmers and 120 in conventional paddy cultivation in selected Farmer Producer Organisation (FPO's) such as Chellampatti FPO, Nanjai FPO, Rajarajacholan FPO and Orathanadu FPO.

### 2.1 Partial Budgeting

Partial budgeting is a tool used to assess the costs and benefits associated with a specific change in a farm. This tool specifically focuses on the implications of the intended change in a business operation by comparing the benefits and costs resulting from implementing the alternative with respect to the current practice. Partial budgeting is a planning and decision-making framework that is used to compare the costs and benefits of alternatives faced by a farm business. Partial budgeting is a financial tool used to assess the economic impact of small changes in a farming or business operation. The table is divided into two sections: debit and credit. The debit side captures the increased costs and reduced income resulting from the proposed change. These represent the negative financial impacts. The credit side includes the increased income and reduced costs, which represent the positive financial impacts of the change. Each section has its subtotal, and the net impact is determined by comparing the totals of the credit and debit columns. This helps in deciding whether the proposed change is economically beneficial.

**Table 1. Partial budgeting**

| Debit | Credit |
|---|---|
| Increased cost due to change | Increased income due to change |
| Subtotal | Subtotal |
| Reduced income due to change | Reduced cost due to change |
| Subtotal | Subtotal |

It focuses only on the changes in income and expenses that would result from implementing a specific alternative. Thus, all aspects of farm profits that are unchanged by the decision can be safely ignored. Nutshell allows you to get a better handle on how a decision will affect the profitability of the enterprise, and ultimately the profitability of the farm itself. However, the value of a partial budget analysis is highly dependent upon the quality of the information used in the analysis.

This budgeting approach is called partial because it does not include all production costs, but only those which change or vary between the farmer’s current production practices and the proposed one(s). PBA allows assessing the impact of a change in the production system on a farmer’s net income without knowing all costs of production.

## 3. RESULTS AND DISCUSSION

Using drone-assisted methods in agriculture reveals significant cost savings and higher profitability compared to conventional approaches. Across various stages—such as FYM application, nursery planting, seed sowing, fertilization, pest and disease management, and herbicide spraying—drone technology effectively lowers costs, particularly in labour and application resources as shown in Fig. 1. The total expenditure for conventional farming stands at ₹27,723.20, while drone methods reduce this to ₹22,857.50, primarily by minimizing herbicide and pesticide use and enhancing efficiency in application. Though both methods yield similar gross returns—₹39,100 for conventional and ₹40,640 for drone-assisted—net returns with drones reach ₹17,782.50 compared to ₹11,376.80 with conventional methods. This results from reduced input costs and slightly improved yields (2,032 kg versus 1,955 kg). Thus, the adoption of drone technology in farming demonstrates a substantial increase in net profitability and overall efficiency.

Comparing conventional farming and UAV (drone-assisted) farming on a per-acre basis reveals notable differences in costs, particularly in labour and pesticide use as shown in Table.2. Human labor costs significantly decrease with UAV farming, from ₹11,077 in conventional farming to ₹5,628 with UAVs, saving ₹5,449 per acre. Conversely, *machine labour* costs are slightly higher with UAVs at ₹4,553 per acre compared to ₹3,385 in conventional farming, resulting in a difference of ₹1,168. *Pesticide* costs drop substantially from ₹2,032 per acre in conventional methods to ₹950 with UAVs, saving ₹1,082 due to more precise and efficient application. Likewise, *herbicide* expenses decrease, with UAV farming costing ₹478 per acre compared to ₹828 in conventional methods, a difference of ₹350. These reductions reflect the cost-efficiency of UAV technology in labour and input usage, enhancing the overall financial viability of farming.

**Table 2. Major differences in input cost**

| | Conventional Farming (Rs /acre) | UAV farming (Rs /acre) | Difference (Rs /acre) |
|---|---|---|---|
| Human Labour | 11077 | 5628 | 5449 |
| Machine Labour | 3385 | 4553 | 1168 |
| Pesticide | 2032 | 950 | 1082 |
| Herbicide | 828 | 478 | 350 |

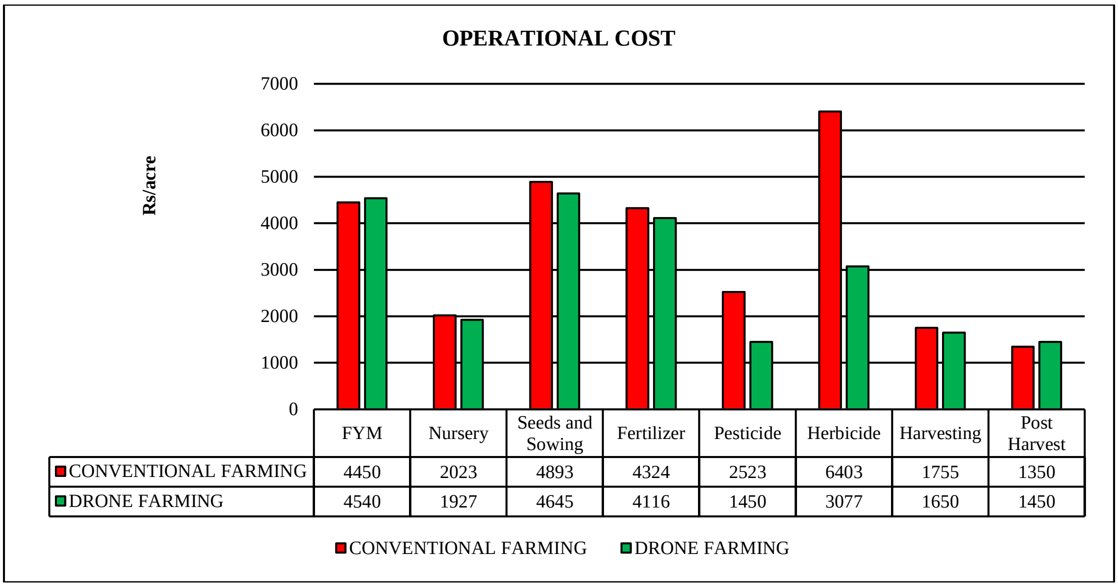


**Fig. 1. Operational Cost of Conventional and UAV farming**

**Table 3. Partial Budgeting of UAV Farming**

| Debit | Amount | Credit | Amount |
|---|---|---|---|
| Increase in cost | | Decrease in cost | |
| Machine labour | 1167 | Fertilizer | 208 |
| Seeds | 40 | Pesticide | 1082 |
| FYM | 90 | Herbicides | 350 |
| | | Human Labour | 5448 |
| Total | 1297 | Total | 7088 |
| Decrease in returns | - | Increase in returns | 1540 |
| Total debit | 1297 | Total credits | 8628 |
| Profit | 7331 | | |

This partial budget analysis highlights the financial impact of transitioning from conventional farming to drone-assisted farming by evaluating cost increases, cost savings, and changes in returns was shown in Table 3. On the debit side, which captures cost increases, we see an uptick in expenses related to machine labor (₹1,167), seeds (₹40), and FYM (₹90), leading to a total cost increase of ₹1,297. These expenses reflect the additional investment needed for UAV-specific operations and adjustments. On the credit side, which captures cost reductions and income increases, there are notable savings in labor, pesticide, and herbicide expenses (Mazur, 2016, McCarthy *et al.,* 2023). Human labor costs drop significantly by ₹5,448, with pesticide and herbicide costs reduced by ₹1,082 and ₹350, respectively. Fertilizer expenses decrease by ₹208 as well, bringing the total cost savings to ₹7,088. Additionally, the increased efficiency in UAV farming results in a higher return of ₹1,540, raising the total credits to ₹8,628. Subtracting the increased costs (₹1,297) from the combined cost reductions and returns increase (₹8,628) gives a net profit increase of ₹7,331 as shown in Table 3. This analysis illustrates the economic advantage of drone-assisted farming, showing a significant profit improvement driven primarily by reductions in human labor and input costs, alongside increased returns.

## 4. CONCLUSION

The integration of drone technology into Indian agriculture, particularly in paddy cultivation in Tamil Nadu's Thanjavur and Madurai districts, signifies a transformative shift towards more efficient and profitable farming practices. This study highlights the substantial economic advantages of adopting drone-assisted methods over conventional farming, including significant cost savings and enhanced profitability. While conventional farming incurs total expenses of ₹27,723.20, drone-assisted methods reduce costs to ₹22,857.50 by minimizing pesticide and herbicide usage and improving application efficiency. Both methods yield comparable gross returns—₹39,100 for conventional and ₹40,640 for drone-assisted—but net returns are notably higher for drones at ₹17,782.50 versus ₹11,376.80 for conventional methods. A per-acre analysis reveals marked reductions in labor costs, with human labor expenses decreasing from ₹11,077 to ₹5,628 and pesticide costs dropping from ₹2,032 to ₹950. Although machine labor costs increase slightly with UAVs, the overall savings in labor and input expenses enhance the financial viability of drone-assisted farming, resulting in a net profit increase of ₹7,331. This study underscores the importance of continued investment in drone technology and training for farmers to fully realize these benefits, as it plays a crucial role in improving agricultural productivity, ensuring food security, and enhancing the livelihoods of rural communities in India. Future research should explore the long-term impacts of drone adoption on sustainability and environmental health, reinforcing the potential of this innovative technology to foster a more sustainable and productive future in Indian agriculture.

## DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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