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# The Precision Agriculture Revolution in the United States: The Utilization of Drone Technology and Big Data

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**ABSTRACT**
Precision agriculture is an innovative approach that is increasingly being applied in the United States to increase agricultural productivity through the use of cutting-edge technology. The background of this research focuses on the importance of adopting modern technologies, such as drones and big data, in addressing global challenges such as climate change, resource limitations, and increasing food needs. The purpose of this study is to explore how the integration of drone technology and big data can revolutionize the agricultural sector in the United States, specifically in improving efficiency, reducing waste, and increasing crop yields. This study uses a qualitative method with a case study approach to several agricultural companies that have adopted drone technology and big data. Data collection was carried out through in-depth interviews with farmers, document analysis, and field observations regarding the implementation of the technology. The data collected was then analyzed using thematic analysis methods to identify patterns and impacts that arise from the adoption of this technology. The results show that the use of drones allows for real-time monitoring of land, early detection of plant diseases, and more efficient resource management, while big data helps in more accurate data-driven decision-making. These two technologies significantly improve the productivity and sustainability of agriculture in the study area. The conclusion of this study confirms that the integration of drone technology and big data can make a great contribution in facing the challenges of modern agriculture. Precision agriculture, with the support of technology, has the potential to be a long-term solution to improve the efficiency and yield of agricultural production.

**Keywords:** *Big Data, Precision Agriculture, United States*

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## INTRODUCTION

Precision agriculture has become a global trend in recent decades, especially in developed countries such as the United States (Shahmoradi dkk., 2020). This approach integrates advanced technologies to improve efficiency in food production (Wadhe dkk., 2023). Drone technology and big data are the two main elements supporting this development, giving farmers the tools to manage their land more accurately and effectively (Abdulai, 2022). These technological advances create great potential to improve agricultural yields, reduce waste, and improve environmental sustainability.

The use of drones in agriculture allows for more efficient land monitoring than traditional methods (Day & Sigrimis, 2020). With the help of drones, farmers can map the land in detail, monitor crop health, and identify problems that are invisible from the ground level (Jurn dkk., 2021). This technology can also be used to precisely spread fertilizers or pesticides in areas that require intervention, thereby reducing the use of unnecessary chemicals.

Big data is also playing an important role in the precision agriculture revolution. Data collected from a variety of sources, including drones, satellites, and sensors in the field, can be processed to provide deeper insights into soil conditions, weather, and plant needs (Sibanda dkk., 2021). Big data analysis allows farmers to make better decisions based on accurate and real-time information, thereby significantly improving crop yields.

In the United States, the adoption of drone technology and big data is becoming more widespread, especially among large farmers and agribusiness companies (Rashidzadeh dkk., 2021). Research shows that the application of this technology can increase productivity by up to 25%, which is a significant achievement in the agricultural industry. In addition, this technology helps farmers respond to the challenges of climate change more adaptively, predict weather patterns, and adjust the right farming methods.

Challenges in the implementation of precision agriculture technology still exist, especially related to high initial costs and the need for technical training (Bhat & Huang, 2021). However, with the support of the government and the private sector, more and more farmers are turning to this method (Guo & Lin, 2021). Technology continues to evolve, and adoption costs are expected to decrease as technology improves and the scale of use increases.

The use of drone technology and big data is a revolutionary step in changing the way agriculture is done in the United States (Lykou dkk., 2020). This innovation opens up great opportunities to increase agricultural yields sustainably, while reducing negative impacts on the environment.

Although precision agriculture with the use of drone technology and big data has shown great potential, there are still many things that are not fully understood or properly measured (Miyauchi, 2022). Many studies have focused on the benefits of these technologies in improving agricultural yields, but few have delved into their impact on smallholders, especially in terms of the cost of implementation, training, and technology adoption (Hossen dkk., 2022). A deeper understanding of these barriers is important to ensure that this technology is accessible to all levels of farmers, not just those with large resources.

Knowledge of how drone technology and big data contribute to environmental sustainability is also limited (Munawar dkk., 2022). While these technologies can help reduce the use of water, pesticides, and fertilizers, their long-term impact on agricultural ecosystems has not been comprehensively measured (Bollard dkk., 2022). Many aspects related to environmental sustainability still need further research, including how these technologies can be optimized without putting additional pressure on natural resources.

There has not been an adequate study of how drone technology and big data can be adapted to diverse geographical and climatic conditions in different regions of the United States (Sliusar dkk., 2022). Each region has different agricultural characteristics, so further understanding is needed on how best to integrate these technologies in local contexts (Kweera, 2023). The adaptation of this technology to areas with small land areas or extreme climatic conditions is also a challenge that has not been widely explored.

In the context of policy, there has not been much discussion about how government regulations can support the wider adoption of this technology (Iost Filho dkk., 2020). Questions about financial incentives, regulations on the use of drones in agricultural areas, and farmer data protection are still areas that need to be studied more deeply (Yaman dkk., 2021). Filling this gap is important to ensure that the precision agriculture revolution can truly provide broad and sustainable benefits to the agricultural industry in the United States.

Filling the gap in understanding the utilization of drone technology and big data in precision agriculture is essential to ensure more equitable and optimal adoption. By understanding the barriers smallholders face, more affordable and accessible solutions can be developed (Serrano dkk., 2024). This technology has great potential to improve agricultural yields and environmental sustainability, but its benefits can only be widely felt if all levels of farmers have equal access (Hamdan dkk., 2022).

The importance of researching the long-term environmental impacts of the use of drones and big data cannot be ignored (Hafeez dkk., 2023). These technologies can help reduce the use of natural resources, but without a more comprehensive understanding, there is a risk of potential unforeseen negative impacts (Baldantoni dkk., 2021). An in-depth study will help ensure that this technology not only increases productivity, but also maintains the balance of the agricultural ecosystem in the long term.

The formulation of supportive policies is also the main reason why this gap needs to be filled (Do dkk., 2024). Without proper regulation and adequate incentives, the adoption of these technologies may be hampered (Sara dkk., 2024). By studying how policies can facilitate the use of drone technology and big data, it is hoped that a more innovative, efficient, and sustainable agricultural ecosystem can be created in the United States (P. Kaur dkk., 2020).

## RESEARCH METHODS

This study uses a qualitative research design with a case study approach to explore the use of drone technology and big data in precision agriculture in the United States (Shepherd dkk., 2020). The case study was chosen because this approach allows for in-depth analysis of complex and contextual phenomena, thus providing richer insights into the impact of these technologies in the field. A qualitative approach was also chosen to understand the perspectives of farmers and stakeholders regarding the implementation of this technology.

The population in this study includes farmers and agribusiness companies that have adopted drone technology and big data in the United States (Singh dkk., 2023). The sample was taken purposively, focusing on five large agribusiness companies as well as ten farmers representing various scales of agricultural businesses (Ismil dkk., 2024). The selection of this sample aims to obtain a wider representation of the various challenges and benefits faced in the use of the technology.

The research instruments are in the form of structured and semi-structured in-depth interviews, as well as field observations to see firsthand the application of drone technology and big data. In addition, related documents such as company internal reports, technology usage data, and related articles are also used as analysis materials (Gautam, 2020). This instrument was chosen to obtain more detailed and accurate information about the experience and results of the adoption of this technology.

The research procedure begins with primary data collection through interviews with selected farmers and agribusiness companies, followed by field observations of ongoing precision farming processes (Durgun & Durgun, 2024). Secondary data such as reports and other documentation are collected to supplement the information obtained from interviews and observations. Data analysis was carried out using thematic analysis methods to identify patterns, challenges, and benefits arising from the use of drone technology and big data in agriculture.

## RESULTS AND DISCUSSION

Data collected from five major agribusiness companies in the United States showed an average increase in crop yields of 20-25% after the adoption of drone technology and big data. Based on the company's internal reports, the reduction in water and pesticide use reached 15% and 10%, respectively. The average decrease in operating costs ranges from 12-18%, depending on the scale of the business. This data also shows an increase in accuracy in monitoring plant health through real-time analysis of big data combined with drone imagery.

| Company | Increase in Crop Yield (%) | Water Reduction (%) | Pesticide Reduction (%) | Decrease in Operating Costs (%) |
|---|---|---|---|---|
| Company A | 25 | 18 | 12 | 15 |
| Company B | 23 | 15 | 10 | 18 |
| Company C | 20 | 12 | 8 | 12 |
| Company D | 25 | 17 | 11 | 16 |
| Company E | 22 | 14 | 9 | 14 |

**Table. 1 The** application of drone technology and big data has a positive impact on agricultural products

The above data shows that the application of drone technology and big data has a significant positive impact on agricultural yields and operational efficiency. A 20-25% increase in crop yields shows that this technology allows for more effective land use. The reduction in water and pesticide use also indicates that these technologies are able to make resource management more efficient, reducing waste and negative environmental impacts. The recorded operational cost savings also show that despite the initial investment in high technology, there are clear economic benefits for farmers in the long run.

The use of drones allows for more accurate monitoring of land and plant conditions. Real-time data from drone imagery allows farmers to detect problems such as diseases or nutritional deficiencies more quickly. Big data facilitates deeper analysis, so that agricultural decisions can be made based on clear evidence. As a result, the actions taken by farmers become more targeted, both in terms of the use of agricultural inputs and in planning harvest timing.

The reduction in water and pesticide use is proof that these technologies also contribute to environmental sustainability. Drone technology helps identify areas that need intervention more precisely, so water and pesticides are only used on the parts of land that need it (A dkk., 2024). This not only reduces costs, but also reduces negative impacts on the surrounding environment, such as groundwater pollution or damage to local ecosystems.

Recorded operational cost efficiencies show that while there are initial costs to adopting drone and big data technology, in the long run the benefits outweigh the initial investment. Farmers can allocate resources more effectively and reduce waste (Dai dkk., 2023). It also reduces reliance on expensive agricultural inputs, such as fertilizers and pesticides, while also increasing crop yields.

In one case study involving smallholder farmers in Iowa, the application of drone technology and big data proved to provide significant benefits even on a smaller scale. The farmers reported an 18% increase in crop yields, with a reduction in water use by up to 10%. In addition, the time spent monitoring land conditions has been drastically reduced, from an average of 10 hours per week to just 2 hours thanks to automated monitoring using drones. This case shows that this technology can be applied effectively not only by large companies, but also by farmers with small and medium-sized enterprises.

Farmers in this case study also reported a decrease in the cost of agricultural inputs, such as fertilizers and pesticides, by 8%. This is due to the ability of drones to identify areas that require special treatment, so the use of chemicals can be limited to only those areas that really need them. The direct impact is increased efficiency and reduced operating costs, as well as a reduction in environmental impact due to excessive use of chemicals.

The use of big data in this case study allows farmers to make better data-driven decisions. Weather, soil condition, and plant health data collected from various sources are integrated and analyzed to provide more accurate recommendations for land management

(Liu dkk., 2021). Thus, the decisions taken by farmers are more on target, both in terms of scheduling planting, fertilizing, and pest control.

This case study shows that the adoption of drone technology and big data can be a viable solution for smallholders who want to increase agricultural yields without having to spend a fortune (Toguzaev dkk., 2022). With the support of training and access to more affordable technology, the benefits of this technology can be felt by more farmers of all business scales. The relationship between increased productivity, cost reduction, and environmental sustainability is very close in this case.

This study shows that the use of drone technology and big data in precision agriculture in the United States has a significant impact on increasing productivity and efficiency. The results of the study revealed that the use of this technology was able to increase crop yields by up to 25% and reduce the use of water and pesticides by 10-15%. In addition, farmers also felt a decrease in operating costs of between 12-18%, which indicates that despite the high initial investment, the long-term economic benefits can be felt. This data also indicates that the adoption of these technologies supports environmental sustainability by reducing resource waste.

Case studies conducted on small farmers in Iowa show that the benefits of this technology can be felt not only by large agribusiness companies, but also by smallholder farmers with smaller business scales. Increased crop yields, efficient use of resources, and cost savings also occur on a small scale. The study also highlights that the adoption of these technologies requires access to affordable training and technology, but with the right support, the benefits can be felt widely.

The use of big data provides advantages in the form of more accurate analysis in decision-making related to land management (Elghaish dkk., 2021). This technology allows farmers to plan agricultural activities more precisely based on real-time data on weather, soil conditions, and plant health. The results of the study show that this data-based land management is more effective than traditional methods that rely on experience and manual observation.

Overall, the results of this study confirm that the adoption of drone technology and big data is a promising solution in facing global challenges in the agricultural sector. This technology is able to increase efficiency, reduce environmental impact, and provide significant economic benefits for farmers.

This research is in line with previous studies that highlighted the benefits of drone technology in improving efficiency and agricultural yields. Some previous studies have also noted that the use of precision technology can reduce the use of water and pesticides, as shown in this study. These results are consistent with studies showing that precision technology helps farmers increase crop yields and reduce agricultural input costs.

However, there are differences in terms of the impact of this technology on small-scale farmers. Several previous studies have stated that the adoption of advanced technologies such as drones and big data is more difficult for smallholders to access due to costs and technical limitations. This study, through case studies, found that smallholders can benefit similarly to large farmers, provided they get training support and access to affordable technology.

Other research also highlights the challenges in big data management in the agricultural sector. In this study, the use of big data showed positive results in data-driven decision-making, but there are other studies that indicate that data complexity and lack of technological infrastructure in some regions are obstacles (Paul, 2023). The results of this study are different because they cover areas that have better access to technological infrastructure.

In the context of environmental sustainability, this study supports the finding that precision agriculture technology can reduce environmental impact through more efficient use of resources. Previous research has shown concerns about the impact of these technologies on ecosystems, but the results of this study have found no indication of significant negative impacts on the environment in the short term.

The results of this study show that precision agriculture technology, especially drones and big data, can be an effective solution to overcome the challenges facing the agricultural sector today. This research indicates that this technology not only has the potential to increase productivity, but also encourages more sustainable and efficient land management. Farmers can respond more quickly to climate change, weather fluctuations, and market uncertainty through this technology.

The adoption of drone technology and big data signals a paradigm shift in the agricultural sector. Manual traditions and experiences that have been the backbone of farming methods are beginning to be replaced by more accurate data-driven decisions. This technology allows farmers to minimize risks and optimize resources, which can ultimately improve food security in the United States.

From a policy perspective, these results are a sign that greater support is needed for smallholders to access these technologies. Governments and the private sector need to work together to provide the necessary training and infrastructure for the wider adoption of these technologies (Clay & Zimmerer, 2020). Otherwise, the gap between large and small farmers could widen further, which will have an impact on inequities in access to technology.

In addition, the results of this study also indicate that further research is needed to explore the long-term impact of the use of this technology on the environment. Although short-term results show a reduction in resource waste, the long-term impacts on ecosystems and biodiversity still need to be studied further.

The implication of this study is that precision agriculture technology can be a strategic solution in facing global challenges such as climate change, population increase, and limited natural resources. Drone technology and big data have proven to be able to increase agricultural productivity while reducing resource waste, which is important in maintaining the sustainability of the agricultural sector in the future.

The adoption of this technology by small farmers shows that precision technology is not only exclusive to large agribusiness companies. With policy support and wider access, smallholders can also benefit from this technology. This has implications that the government and stakeholders need to encourage programs that support access to technology for all levels of society.

The results of the study also imply that the agricultural sector needs to rely more on data in decision-making. The use of big data allows for more precise management of land and crops, resulting in greater profits with less risk. This is changing the way farmers manage land, from an experience-based approach to an evidence-based one.

Environmental sustainability is also an important aspect highlighted in this study. Drone technology and big data allow for more economical use of water and pesticides, which has the potential to reduce negative impacts on the environment (Birner dkk., 2021). However, there needs to be further oversight to ensure that these technologies truly contribute to sustainability in the long run.

The results of this study occur because drone technology allows for more accurate and real-time monitoring of land and plant conditions. Visual monitoring powered by drones provides detailed information that cannot be obtained through traditional methods, such as early detection of plant diseases and more precise irrigation management. This helps farmers manage their land more effectively and increase crop yields.

Big data plays a crucial role in analyzing information gathered from various sources. Integrated weather, soil condition, and plant health data helps farmers make more timely and accurate decisions (Ali dkk., 2024). This technology is changing the approach to agriculture from reactive to proactive, allowing farmers to respond to challenges more quickly and effectively.

The results of this research are also due to the increased support of technological infrastructure in the United States, which allows precision agriculture technology to be applied more easily. Farmers, especially in regions with good access to technology, can quickly adopt and integrate drone and big data technologies in their agricultural practices.

In addition, these results also reflect the important role of government policies and incentives in encouraging technology adoption (J. Kaur & Pandove, 2023). Supportive policies, such as technology subsidies and training programs, allow farmers, especially those operating on a small scale, to access these advanced technologies at a more affordable cost.

The next step is to ensure that the adoption of drone technology and big data is accessible to all farmers, both large and small. Governments and the private sector must work together to provide the necessary training programs, subsidies, and technology infrastructure so that these technologies can be applied more widely. It is important to ensure that all farmers, regardless of the size of their ventures, can benefit from this technology.

More research needs to be done to explore the long-term impact of the use of this technology on the environment. Although short-term results show reductions in water and pesticide use, the long-term impacts on ecosystems and biodiversity still need to be studied (Elghaish dkk., 2021). This research will help ensure that the adoption of precision technology is not only economically beneficial but also ecologically sustainable.

In terms of policy, clearer regulations regarding the use of drones in agriculture need to be developed. This policy should include aspects of security, privacy, and data protection, given that drones collect sensitive data about land and agricultural activities. In addition, these regulations must ensure that drone technology can be used in a way that does not harm the surrounding community.

In the future, technological innovation in precision agriculture needs to continue to be encouraged. Further development of drones and big data, including the integration of artificial intelligence, could provide more advanced solutions to improve agricultural efficiency and productivity.

## CONCLUSION

The study found that the adoption of drone technology and big data in precision agriculture in the United States is able to have a significant impact not only on large agribusiness companies, but also on smallholder farmers. Increased productivity, efficient use of resources, and cost savings are the key findings that mark a shift in the way agriculture is managed. The study also shows that the technology can be accessed by all sizes of agricultural businesses if supported by the right training and infrastructure, something that has not been revealed much in previous research.

The main contribution of this research is to a case study approach that shows how precision technology can be widely applied, even to small-scale farmers, providing solutions to challenges in the agricultural sector. The study also highlights the importance of integrating big data in agricultural decision-making, which has the potential to become a new standard in data-driven land management. However, this study has limitations on the limited scope of the study area and has not fully explored the long-term impact on the environment. Further research needs to focus on testing long-term environmental impacts as well as how these technologies can be adapted in regions with limited access to technology.

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