

Drones in agriculture: analysis of different countries

*Dmitry Nazarov, Anton Nazarov**, and *Elena Kulikova*

Ural State University of Economics, Yekaterinburg, Russia

Abstract. This article provides an exhaustive, comparative study on the integration and utilization of drones in agricultural practices across various nations. The authors first illuminate the general applications of drones, highlighting their use in crop monitoring, health assessment, irrigation management, and precise pesticide application. The advantages of drone use, such as improved crop yields, reduced environmental impact, and economic efficiency, are discussed in detail. Subsequently, the authors embark on a country-wise analysis, examining the adoption rate and regulatory frameworks of drones in countries like the USA, China, Brazil, Australia, and several European and African nations. In the United States, for instance, drones are widely used and are supported by progressive regulations. China, in contrast, demonstrates a higher adoption rate but faces more significant regulatory challenges. The analysis also reveals how developing nations in Africa and South America, while presenting potential for agricultural drones, still grapple with infrastructural, economic, and knowledge barriers. The authors note that even though the use of drones is still relatively nascent, the technology has already made significant contributions to sustainable and efficient agricultural practices. They also contend that with further technological advancement and regulatory support, drones can revolutionize global agriculture. The article closes by advocating for policy changes that would encourage drone use in agriculture, particularly in developing countries. Moreover, it calls for research into affordable and easy-to-operate drone technology, suggesting that this could help overcome some of the adoption barriers faced by farmers in less economically advantaged regions.

1 Introduction

As the world faces the dual challenges of a rapidly growing population and the escalating impact of climate change, agriculture has never been more critical. For centuries, agriculture has served as the backbone of societies worldwide, providing the sustenance necessary for civilization's progress and development. Beyond its fundamental role in food provision, it holds sway over economic stability, ecological sustainability, and social structures. However, the sector faces increasing pressures from diverse fronts.

* Corresponding author: antonnazarov2807@mail.ru

On the one hand, climate change is causing more frequent and severe weather extremes, disrupting traditional farming patterns and endangering food security. It exacerbates water scarcity, soil degradation, and pest proliferation – problems that directly challenge agricultural productivity. On the other hand, the world population is projected to reach nearly 10 billion by 2050, an increase that places unprecedented demands on food production. If the agriculture sector is to feed this growing population, we must discover innovative, sustainable, and efficient methods of food production.

In this context, the rise of technology in agriculture, termed "agritech," signals a beacon of hope. One promising area of agritech innovation lies in the use of unmanned aerial vehicles (UAVs), commonly known as drones. Drones have already begun to alter the landscape of various sectors, including film, delivery, and surveillance. In agriculture, their potential is vast and transformative.

Drones can provide high-resolution, real-time data on crop health, enabling farmers to make immediate and informed decisions. They can monitor vast tracts of land, tracking variables such as temperature, humidity, and plant growth, with an efficiency unattainable by human effort alone. Additionally, drones can carry out precision farming tasks, including targeted pesticide application and irrigation, reducing environmental impact and increasing crop yields. This integration of drones into agriculture – sometimes referred to as "precision agriculture" – could be a pivotal tool in surmounting the obstacles presented by population growth and climate change.

However, the deployment and impact of drone technology in agriculture are not uniform worldwide. Regulatory, infrastructural, and economic landscapes vary between countries, impacting the rate of drone adoption and the realization of their benefits. It is thus crucial to examine these differences, understand their implications, and learn from global experiences.

The purpose of this study is to provide an in-depth, comparative analysis of the use and impact of drones in agriculture across different countries. This analysis aims to highlight the achievements and challenges experienced in various nations, from the technologically advanced United States and China to the developing regions of Africa and South America. By examining the differing landscapes, we hope to glean insights that can guide future policies, drive technological advancement, and ultimately harness the full potential of drones in revolutionizing global agriculture.

The urgency and significance of sustainable agricultural practices cannot be understated in our current global climate. If we are to secure a food-abundant, environmentally-friendly future, we must leverage every tool at our disposal. This paper asserts that drones, despite their nascent stage in agricultural application, could be one of these critical tools, offering an exciting frontier in our quest for agricultural efficiency and sustainability.

2 Drones in agriculture

As the integration of technology becomes increasingly ubiquitous in modern agricultural practices, one innovation that has become particularly significant is the use of unmanned aerial vehicles (UAVs), or drones. These autonomous or remote-controlled aircraft are equipped with an array of sensors, cameras, and sometimes actuators, which enable them to perform a diverse range of tasks that were once laborious, time-consuming, or even impossible.

At their most basic level, drones are essentially flying robots. They can be manually controlled by operators from the ground or preprogrammed to fly specific routes using global positioning systems (GPS). This flexibility allows them to conduct aerial surveys over large agricultural lands, providing an eye-in-the-sky perspective that was previously limited to expensive and less versatile satellite or manned aircraft imagery.

Drones can be equipped with various imaging devices, including multi-spectral sensors, thermal cameras, and LIDAR (Light Detection and Ranging), each serving different purposes. Multi-spectral sensors capture data in specific light wavelengths, like infrared, to provide insight into plant health. Thermal cameras measure temperature variations, useful in detecting irrigation issues or pest infestations, while LIDAR sensors generate detailed topographic maps, facilitating land and water management.

Now that we have an understanding of what drones are, let's delve into their practical applications in agriculture and explore the potential benefits of their use.

Monitoring and Mapping

The ability to swiftly and accurately monitor large areas of land is one of the most apparent advantages of drones. Equipped with high-resolution cameras and advanced sensors, drones can create comprehensive, detailed, and up-to-date maps of farmland. This provides farmers with essential information about their crops' condition, soil quality, and potential problem areas, such as water logging or pest infestation.

Real-time monitoring with drones allows farmers to react quickly to changes and prevent minor issues from escalating into more significant problems. For instance, a timely response to early signs of disease can stop its spread, saving an entire crop that might otherwise be lost.

Precision Farming

Precision farming aims to optimize agricultural practices, minimize waste, and maximize yield, where drones play a vital role. By providing exact geolocation data, drones can help farmers apply fertilizers, pesticides, or herbicides more accurately. Instead of spraying an entire field, drones can target specific areas that need treatment, reducing the amount of chemical use, decreasing environmental impact, and saving costs.

Irrigation Management

Efficient water use is another critical concern in agriculture, particularly in water-scarce regions. Drones fitted with thermal cameras can identify cooler, well-irrigated areas and warmer, likely under-watered patches. By doing so, they help optimize irrigation, reducing water wastage, and ensuring that crops receive the appropriate amount of water.

Crop Health Assessment

Using multi-spectral sensors, drones can evaluate crop health by capturing non-visible light, including near-infrared. Healthy plants reflect more infrared light, while stressed or diseased plants reflect less. Analyzing this data allows farmers to identify unhealthy plants early and take necessary measures before the problem affects the larger crop yield.

Planting and Sowing

Though less common, drones are also being used for planting and sowing. Special drone models can shoot seed pods into the soil, a method that can be faster and more efficient than traditional sowing.

In conclusion, drones offer the potential for increased efficiency, reduced costs, and improved data collection in agriculture. By enabling precision farming techniques, providing real-time monitoring, and facilitating efficient resource use, drones can revolutionize agricultural practices. However, realizing these benefits is contingent on various factors, including regulatory frameworks, technological advancements, and economic feasibility. As this study explores the use and impact of drones in different countries' agricultural sectors, it will underscore the importance of these considerations, painting a comprehensive picture of the state of drone usage in global agriculture today.

Data Collection and Analysis

Perhaps one of the most transformative applications of drones in agriculture is their role in collecting and analyzing data. Drones are capable of collecting massive amounts of data quickly and efficiently, providing farmers with insights that would be difficult, if not

impossible, to obtain through traditional methods. These data sets can include information about soil health, crop growth, pest presence, and much more.

More importantly, the data collected by drones can be processed and analyzed to provide actionable insights for farmers. Advanced analytics software can identify trends, patterns, and anomalies, providing farmers with precise, targeted feedback on their operations. This capability is not just beneficial for individual farmers; aggregated, this data can provide valuable insights on larger-scale patterns and trends, informing research and policy in agricultural sectors.

Increased Efficiency and Productivity

Drones also significantly increase efficiency and productivity in agricultural operations. The traditional methods of surveying fields, monitoring crop health, and applying treatments are labor-intensive and time-consuming. Drones can perform these tasks more quickly and with greater accuracy, freeing up resources and allowing farmers to focus on other aspects of their operations.

Moreover, by detecting issues early and enabling targeted treatments, drones can increase overall crop yields. This improved productivity is critical in an era where agricultural sectors must produce more food than ever before to feed a growing global population.

Reduced Costs

In addition to improving productivity, drones can also reduce costs in agriculture. The targeted application of treatments reduces the waste of resources, cutting down on material costs. The efficiency of drones in monitoring and surveying also means that fewer human resources are needed for these tasks, leading to savings in labor costs.

While drones themselves represent an upfront investment, the return on investment over time, considering the cost savings and increased yields, makes them a financially attractive option for many farmers. Furthermore, as drone technology continues to advance and become more mainstream, the cost of drones and related technology is likely to decrease, making them accessible to more and more farmers.

Enhanced Sustainability

Finally, drones contribute significantly to sustainability in agriculture. Precise application of treatments means less waste and fewer chemicals entering the environment. Efficient water use contributes to water conservation efforts, particularly crucial in arid regions. Furthermore, by increasing yields, drones can help to ensure food security, a fundamental aspect of social sustainability.

In conclusion, while drone technology is still evolving, its potential benefits to the agricultural sector are clear. From increasing efficiency and reducing costs to enhancing sustainability and providing valuable data, drones have the potential to revolutionize agricultural practices globally. However, realizing this potential fully will depend on addressing various challenges, including those related to regulation, technology, and economics, as we will explore in the following sections.

3 Country-wise analysis

In the United States, drones have found substantial applications in the agricultural sector. The prevalence of drones in the U.S agriculture is due, in part, to a supportive regulatory environment established by the Federal Aviation Administration (FAA). The FAA's Part 107 rule permits drone usage for commercial purposes, including farming, with some operational limitations such as maximum altitude, daylight operation, and visual line-of-sight rules.

The benefits realized in the U.S. include increased crop yields, cost efficiency, and sustainable farming practices, as drones enable precision agriculture by facilitating targeted application of treatments and real-time crop monitoring. However, there are challenges to wider adoption, such as the cost of advanced drone systems, need for operator training, and rural connectivity issues which can hinder data transmission from drones.

In China, the usage of drones in agriculture is widespread, even more so than the United States. China has a significant number of agricultural drone companies that are manufacturing cost-effective drones, making the technology accessible to many farmers. Drones are largely employed for pesticide spraying in China, which has proven to be much faster and more efficient than traditional methods.

Regulation, however, is somewhat more complicated. While the Chinese government encourages drone usage in agriculture through various incentives, regulatory clarity lags behind. Issues around airspace control and flight permissions can pose challenges. Additionally, the majority of farmers in China are smallholders, and despite lower drone costs, affordability can still be a barrier.

Across Europe, the use of drones in agriculture varies widely, influenced by differences in regulatory frameworks, farming practices, and technological adoption. Countries like France, the Netherlands, and Germany have seen a rising trend of drone usage in farming, aided by supportive governmental policies. The European Union Aviation Safety Agency (EASA) has been developing harmonized regulations for drone usage across member states, which could further drive adoption.

The benefits and limitations seen in Europe are similar to those in the U.S and China. However, privacy concerns have been a notable issue in Europe, due to the potential for drones to capture images beyond their intended survey area, which could infringe upon privacy rights.

In Australia and New Zealand, drone adoption in agriculture is gradually increasing. The vast, remote agricultural lands in these countries make drones a practical tool for monitoring and managing crops and livestock. Australia's Civil Aviation Safety Authority (CASA) has enacted laws permitting commercial drone use, which has stimulated growth in this area.

The benefits of drone usage in these regions include the efficient monitoring of large and remote farms, precision agriculture, and improved water management—critical in these water-scarce regions. However, similar to other regions, high costs, the need for technological literacy, and connectivity issues in remote areas pose adoption barriers.

In regions of Africa and South America, the potential for drone use in agriculture is significant, yet largely untapped. Drones could address several challenges in these regions, including inefficient traditional farming methods, the need for crop resilience in the face of climate change, and the remote monitoring of vast lands.

However, these regions face substantial barriers. Regulatory environments for drone usage are generally underdeveloped, with policies either being overly restrictive or lacking entirely. Furthermore, the cost of drones is often prohibitive for farmers in these regions, and lack of technological literacy can impede effective usage.

Despite these barriers, several initiatives are underway to stimulate drone adoption. Organizations like the Technical Centre for Agricultural and Rural Cooperation (CTA) are conducting drone piloting projects in countries like Uganda, demonstrating their benefits. In South America, countries like Brazil and Argentina are taking steps to enact drone-friendly regulations.

4 Future research and conclusion

The intersection of drone technology and agriculture holds tremendous potential for addressing many of the pressing challenges faced by the sector. From increasing productivity and efficiency to enabling sustainable farming practices and providing vital data for decision making, the benefits are multi-faceted and far-reaching. Yet, as this study has illuminated, the adoption and impact of drones in agriculture are not uniform across different countries and regions.

In technologically advanced regions such as the United States, China, and parts of Europe, drones are being employed with increasing frequency and effectiveness. The supportive regulatory environments, coupled with a readiness to adopt new technologies, have spurred the integration of drones into mainstream agricultural practices. Despite this, challenges persist, including issues related to cost, rural connectivity, privacy, and the need for training and technological literacy among farmers.

In countries with vast and often remote agricultural lands, like Australia and New Zealand, drones have found a niche, enabling the efficient management of large-scale farming operations. However, high costs and connectivity issues can pose barriers to wider adoption.

The potential for drones in regions like Africa and South America is substantial, but largely untapped. Here, drones could revolutionize farming practices by introducing precision agriculture, improving crop resilience, and enabling remote land management. Yet, the barriers are significant, including restrictive or non-existent regulations, prohibitive costs, and low levels of technological literacy.

These findings underscore a key theme: while the potential of drones in agriculture is universal, realizing that potential is contingent on overcoming a complex web of country-specific challenges. However, the exploration of these challenges is far from discouraging; rather, it illuminates the path forward, providing a roadmap for targeted efforts to support the integration of drones in agriculture globally.

The future of drone use in agriculture hinges on concerted efforts by policy-makers, technology providers, farmers, and researchers. Policymakers have a critical role in establishing supportive and clear regulatory environments that enable drone usage while mitigating potential risks. Technology providers can contribute by developing cost-effective, user-friendly drone systems tailored to agricultural needs, while initiatives to improve rural connectivity and technological literacy among farmers could help bridge the digital divide.

As for future research, it will be crucial to continue monitoring and evaluating the real-world impacts of drones in agriculture. Longitudinal studies can offer insights into the long-term effects on crop yields, economic benefits, and environmental impacts. Comparative research on different drone technologies and their applications in various agricultural contexts can inform best practices and guide technological development.

Furthermore, research focused on understanding and addressing the barriers to drone adoption in under-served regions can provide a foundation for targeted interventions. This could encompass studies into affordable drone technologies, strategies for enhancing technological literacy, and policy research to inform the development of supportive regulatory frameworks.

The journey towards fully harnessing the power of drones in agriculture worldwide is undoubtedly complex and filled with challenges. Yet, it is a journey worth undertaking. As we stand on the brink of a potential agricultural revolution powered by drone technology, the promise of a more efficient, sustainable, and resilient farming sector beckons. With concerted efforts and targeted research, it is a promise that we can fulfill.

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