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FLEET MANAGEMENT AND DRONE UTILIZATION IN AGRICULTURE: ENHANCING OPERATIONAL EFFICIENCY

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Kostyrko O. Fleet management and drone utilization in agriculture: enhancing operational efficiency

This paper explores the integration of fleet management systems and drone technology in the agricultural sector as a means to enhance operational efficiency, optimize resource utilization, and drive cost-effectiveness. The study assesses the role of fleet management technologies in improving machinery transportation, fuel efficiency, and maintenance, while also investigating the benefits of drone applications in precision agriculture, such as crop monitoring, health assessments, and automated spraying. A key focus is placed on evaluating the financial implications of these innovations, including cost reductions, profitability improvements, and return on investment.

The research primarily targets modern agricultural companies that have successfully progressed through previous technological phases, including advancements in agricultural machinery, the GMO and green revolution, and are now approaching the transition into the Digital agricultural revolution. These companies are at the forefront of adopting advanced digital solutions and are well-positioned to integrate fully automated and data-driven agricultural practices.

To support the analysis, the study employs real-world data, case studies, and financial modeling to demonstrate practical applications, challenges, and success factors in implementing these technologies. The research also identifies critical barriers to adoption, such as high initial investment costs, infrastructure requirements, and regulatory constraints, and proposes strategic solutions to mitigate these challenges. The geographical scope of this study includes regions actively embracing technological innovations, particularly in the U.S., Europe, and parts of Asia, where digital transformation in agriculture is gaining momentum.

By providing a comprehensive assessment of fleet management and drone technologies, this paper offers actionable insights for agricultural businesses to leverage digital solutions for increased efficiency, sustainability, and long-term profitability.

Keywords: operational efficiency, fleet management, drone utilization.

Костирко О. Управління автопарком та використання дронів у сільському господарстві: підвищення операційної ефективності

Досліджено інтеграцію систем управління автопарком та дронових технологій у сільському господарстві як інструмент підвищення операційної ефективності, оптимізації використання ресурсів та зниження витрат. Розглянуто роль технологій управління автопарком у покращенні транспортування техніки, підвищенні паливної ефективності та оптимізації технічного обслуговування, а також проаналізовано переваги застосування дронів, зокрема для моніторингу стану культур, оцінки їхнього здоров'я та автоматизованого обприскування.

Особливу увагу приділено фінансовим аспектам впровадження інновацій, зокрема зниженню витрат, підвищенню прибутковості та розрахунку рентабельності інвестицій. Дослідження орієнтоване на сучасні аграрні компанії, які вже пройшли попередні етапи технологічного розвитку (механізація, впровадження ГМО та «зелена революція») і нині наближаються до переходу в епоху цифрової аграрної революції. Такі компанії є лідерами у впровадженні цифрових рішень і готові до інтеграції повністю автоматизованих та керованих даними практик.

Для обґрунтування результатів використано реальні дані, кейс-стаді та фінансове моделювання, що дозволяє продемонструвати практичні приклади, виклики та фактори успіху у процесі впровадження цих технологій. Ідентифіковано ключові бар'єри для їх поширення, зокрема високі початкові інвестиції, інфраструктурні вимоги та регуляторні обмеження, й запропоновано стратегічні підходи до їх подолання. Географічні рамки дослідження охоплюють регіони з активним впровадженням технологічних інновацій – США, Європу та окремі країни Азії, де цифрова трансформація аграрного сектору набирає обертів.

Надаючи комплексну оцінку технологій управління автопарком та дронів, запропоновано практичні рекомендації для аграрного бізнесу щодо використання цифрових рішень задля підвищення ефективності, сталого розвитку та довгострокової прибутковості.

Ключові слова: операційна ефективність, управління автопарком, використання дронів.

Problem statement. The agricultural sector is undergoing a digital transformation, where technology is playing a pivotal role in enhancing operational efficiency. Fleet management systems and drone technologies are at the forefront of this revolution, offering solutions to issues such as inefficient machinery utilization, high transportation costs, and suboptimal field management. These technologies have the potential to significantly reduce operational costs and increase productivity.

However, many agricultural businesses face challenges in effectively integrating these technologies. High initial implementation costs, a lack of expertise in digital solutions, and resistance to change in traditional agricultural practices limit the widespread adoption of these advancements. Addressing these challenges is critical for improving the profitability and long-term sustainability of the agricultural sector.

This research aims to bridge the gap between the potential of these technologies and their practical implementation, with a focus on large agricultural enterprises that are on the verge of the digital agricultural revolution.

Recent researches and publications on the problem. The adoption of fleet management and drone technologies in agriculture has been extensively studied in the scientific society. Sorensen and Bochtis (2009), in their research paper *Conceptual Model of Fleet Management in Agriculture* describe the potential benefits of implementing a dedicated fleet management system in agriculture, including cost reduction and enhanced productivity. They highlight that implementing advanced fleet management practices, such as optimizing machinery allocation and scheduling, leads to decreased fuel consumption, maintenance expenses, and labor costs. Additionally, this study emphasizes the importance of using advanced information and communication technology (ICT) systems to achieve these efficiencies and improve overall productivity in farming operations [2]. Researchers from China Agricultural University in Beijing provide a detailed analysis of the development of a cloud-based fleet management system from a technological perspective. Their study examines the impact of such system on operational efficiency in agriculture, highlighting the improvements in real-time data collection, decision-making processes, and cost efficiency associated with its adoption [3]. Vanhuyse, Bailey, and Tranter from the University of Reading discuss the relationship between adopting effective management practices, including fleet management, and improved financial performance. Their research indicates that farms employing structured management strategies tend to exhibit better financial outcomes, demonstrating a positive correlation between efficient fleet management and profitability [4]. Furthermore, Costa (2019) explores the contribution of effective fleet management to financial risk management by ensuring optimal utilization of machinery and timely maintenance, thereby reducing the likelihood of unexpected expenses and operational disruptions [5]. In addition to academic studies, several reports from business consulting firms have emphasized the value of digital solutions in agriculture. McKinsey (2020) highlights the potential of advanced technologies such as fleet management systems to improve labor efficiency, reduce input costs, and optimize machinery operation and maintenance [6; 7]. Deloitte (2017) examines the rise of fleet management in Europe, emphasizing its strategic importance in a rapidly changing agricultural landscape [8]. Similarly, the Boston Consulting Group (2020) advocates for the adoption of digital solutions and automation, including fleet management, to enhance efficiency and profitability in agriculture [9].

The goal of the research. The research aims to assess the impact of fleet management systems and drone technology on agricultural efficiency, focusing on cost reduction, resource optimization, and productivity enhancement while identifying adoption barriers and strategies. The study employs quantitative analysis of financial and operational data, qualitative case studies and expert interviews to evaluate the benefits, challenges, and feasibility of implementing these technologies in agriculture.

Presenting main material. For finding best agricultural companies which can benefit most from adopting fleet management and drone technologies, it’s important to understand their classification and cost structure.

Cost structure of agricultural enterprises differs depending on size, type or other criteria, and may include labor, machinery and equipment, fuel and oil materials, seeds and fertilizers, pesticides and herbicides, irrigation, feed, veterinary services.

Table

Classification of agricultural companies based on different criteria

Category and criteria	Description	Examples
Category: Size		
Small farms	Family-owned, covering less than 50 hectares, limited mechanization.	Local organic farms, small dairy farms.
Medium-size farms	Covering 50–500 hectares, partial mechanization, some advanced technologies.	Independent crop farms, poultry farms.
Large agribusinesses	Industrial-scale operations, over 500 hectares, fully mechanized, global supply chains.	Cargill, Archer Daniels Midland (ADM), Bayer Crop Science.
Category: Type		
Crop farming	Focuses on growing crops like wheat, corn, soybeans.	John Deere-supported wheat farms, Monsanto-linked corn producers.
Livestock farming	Involves raising animals for meat, dairy, or eggs.	Tyson Foods (chicken), Dairy Farmers of America.
Mixed farming	Combination of crops and livestock to maximize efficiency.	European farms integrating wheat and cattle production.
Agroforestry	Combining agriculture and forestry for sustainability.	Rubber plantations, cocoa farms in Africa.
Category: Level of technology adoption		
Traditional farming	Manual labor-based, low-tech, minimal mechanization.	Smallholder rice farms in Southeast Asia.
Mechanized farming	Uses basic machinery like tractors and harvesters.	Eastern European wheat farms with John Deere tractors.
Digital agriculture	GPS-based fleet management, drones, precision agriculture.	US corn farms using AI-driven John Deere machinery.
Fully automated farming	Autonomous tractors, IoT sensors, AI-based monitoring.	Vertical farms in Japan, automated dairy farms in the Netherlands.
Category: Production volume		
Subsistence farming	Produces just enough for local consumption, not for sale.	Rural African and Indian villages.
Commercial farming	Produces large-scale crops/livestock for national or international markets.	US soybean farms supplying international markets.
Industrial farming	Mass-scale production using factory farming techniques.	Tyson Foods (poultry), Smithfield Foods (pork).
Other		
Supply Chain Integration	Vertical integration where a company controls multiple stages of production.	Nestlé (controls milk production to distribution).
Sustainability focus	Companies prioritizing eco-friendly and regenerative farming.	Danone (sustainable dairy practices).
Organic certification	Farms that avoid synthetic fertilizers, pesticides, and GMOs.	Whole Foods Market suppliers.
Export-oriented farms	Farms primarily producing for export markets.	Brazilian soybean farms exporting to China.

By adopting fleet management systems and drone technology, agricultural enterprises can target specific cost areas for reduction, leading to improved profitability and sustainability. Based on the two criteria – highest positive impact on cost savings and lowest effort required for implementation (Pareto approach) – the following groups of agricultural companies have the highest potential for adopting fleet management and drones:

1. Positive impact on cost savings. Crop farming company types would benefit the most from cost reduction due to high operational expenses, fuel costs, and labor-intensive processes. Labor expenses

for planting, maintenance, and harvesting can be reduced by drones monitoring and spraying, expenses on machinery and equipment can be reduced by automated maintenance checks, fuel and oil costs can be reduced by automated efficient route planning. Livestock farming enterprises can benefit from implementing fleet management which will reduce the operating cost of machinery and vehicles.

2. Less efforts required for implementation. Companies already utilizing mechanization and digital tools will find it easier to implement fleet management systems and drones: merchandized and digital farms which already use GPS and automated machinery and global export-oriented businesses with complex supply-chains.

Best candidates for fleet management and drone adoption are the ones which lie on intersection of both criteria (high savings + low effort): large agribusinesses which are already digitalized, can scale cost reductions quicky, industrial crop farms (corn, wheat, soybeans) with high logistics and machinery use, and large dairy & livestock farms with costly animal monitoring and feed transport can be automated. Projected cost efficiencies may differ, but these are indicative numbers: drones equipped with multispectral sensors provide real-time insights into crop health, enabling targeted interventions which can lead to a 25 % increase in crop yields, drones precise application of fertilizers and pesticides can lead up to a 20 % reduction in fertilizer use. Together with financial, safety and environmental benefits may be present, like performing tasks by drones in challenging environments, reduced environmental impact would be a direct result of optimized fuel reduction [13; 14].

These benefits come with related challenges: high initial costs for purchasing drones and implementing fleet management systems, technical challenges and absence of required expertise, regulatory and privacy concerns, environmental and safety risks [15]. Additionally, dependencies should be considered: infrastructure readiness (e.g., reliable internet connectivity and power sources), data management (e.g., efficient systems for data collection, storage, and analysis) and economic scale, – larger operations may realize more significant benefits from these technologies due to economies of scale.

Conclusions. The integration of fleet management systems and drone technology offers substantial opportunities for improving efficiency, reducing costs, and enhancing productivity in agriculture. As the sector faces rising operational costs, labor shortages, and pressure to meet global food demands, these technologies provide scalable solutions. Fleet management optimizes resource allocation, minimizes fuel consumption, and improves machinery uptime, while drones enable precision in crop monitoring, field assessments, and targeted interventions, reducing input costs and supporting sustainability.

However, the successful adoption of these technologies faces challenges, such as high initial costs, implementation complexity, and regulatory concerns. Smaller enterprises may struggle more with these barriers, while larger agribusinesses are better positioned to benefit from immediate returns. To facilitate adoption, it is crucial to invest in training, capacity-building, and policy support, ensuring that farms of all sizes can leverage these technologies.

Despite these challenges, the long-term benefits of fleet management and drone technology are evident. These innovations not only lead to cost reductions and efficiency gains but also enable agricultural businesses to remain competitive and sustainable in an increasingly digital landscape. As the industry embraces digital transformation, these technologies will be essential to ensuring future success in meeting global food demands while promoting environmental stewardship.

In conclusion, while the transition to a fully integrated digital agriculture system presents considerable challenges, the strategic adoption of fleet management systems and drones is a key driver of future agricultural productivity. By embracing these technologies, agricultural businesses can unlock significant improvements in efficiency, cost-effectiveness, and sustainability, ultimately positioning themselves for long-term success in an increasingly digital and data-driven agricultural landscape.

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