Advancement In Agricultural Practices with Use of Drones in The Context of Precision Farming

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Abstract

Drones have emerged as transformative tools in agriculture, revolutionizing various aspects of farming practices. This article gives an overview of how drones are used in agriculture, focusing on crop monitoring, mapping, water management, and livestock care. Drones collect real-time data, giving farmers accurate insights into crops, soil conditions, water resources, and animal health. This information helps farmers make better decisions, use resources wisely, and take targeted actions, resulting in improved yields, less waste, and better farm management. However, there are challenges to address, such as rules and regulations, costs, data management, training, and public acceptance, for drones to be widely adopted and successfully used in agriculture. By overcoming these challenges, drones can make agriculture more sustainable and efficient. They have the power to revolutionize farming practices, boost productivity, and minimize harm to the environment. With more research, collaboration, and responsible drone use, we can unlock the full potential of this technology, benefiting farmers and creating a more sustainable and productive agricultural sector.

Keywords: Drones; Agriculture; Crop monitoring; Livestock management; Sustainable practices.

Introduction

Agriculture is the backbone of our global food production system and plays a critical role in sustaining human and livestock populations [1]. However, with the challenges posed by ever-growing global population, unpredictable weather conditions, and shrinking resources, there is a pressing need for innovative and efficient agricultural practices to evolve [2,3,1]. In this scenario, drones, also known as unmanned aerial vehicles (UAVs), have emerged as a game-changer in the agricultural industry. Drones have revolutionized various sectors with their versatility and adaptability, including agriculture. These flying robots equipped with advanced sensors, cameras, and GPS technologies are transformed the way farmers approach crop management, mapping, livestock monitoring, and water management (Figure1) [4]. By providing precise and timely data, drones enable farmers to make informed decisions, optimize resource utilization and increase overall productivity. In this article, we have explored the diverse uses of drones in agriculture and how they are reshaping traditional farming practices. We will delve into the areas of crop monitoring and management, mapping and surveying, livestock management, and irrigation and water management. Additionally, we will discuss future possibilities and the challenges that come with integrating drones into agricultural operations.
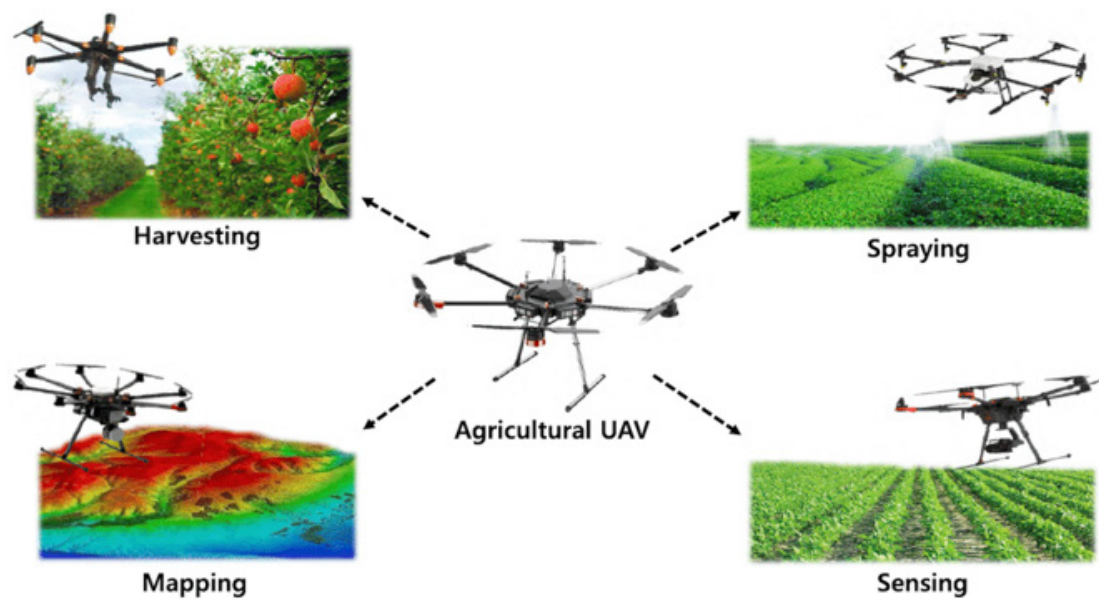
Figure 1: Different applications of drone in agriculture.

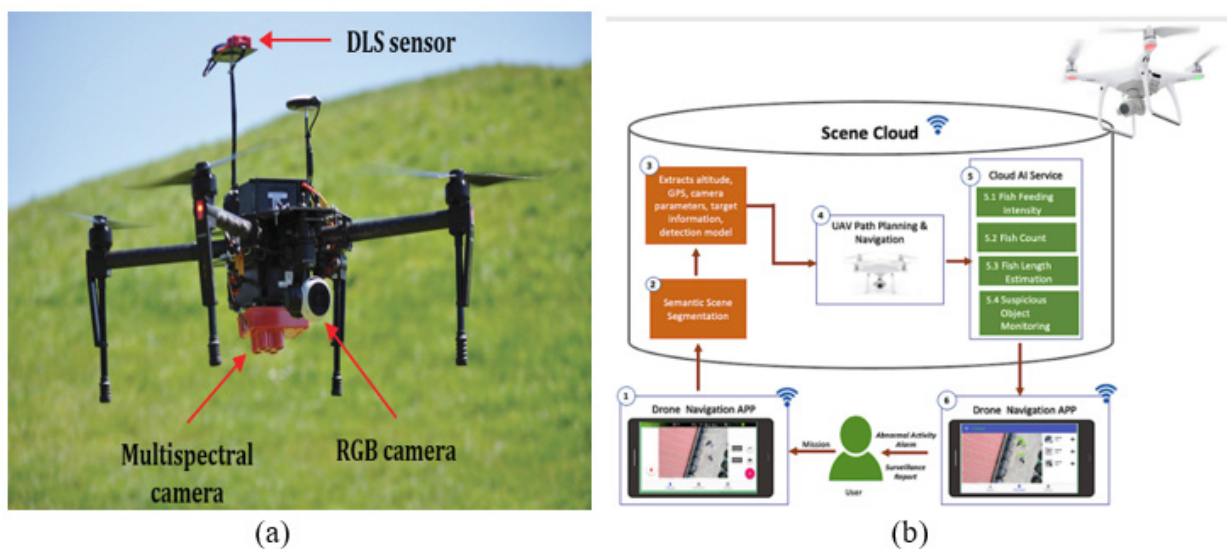## Drones with Sensors and Cameras for Data Collection

Figure 2: Crop health monitoring using (a) drone with optical sensors and (b) data analysis process.

Drones can carry a range of sensors and cameras that capture essential data about crops [Figure 2]. These sensors can include multispectral, thermal, and hyperspectral cameras, as well as LiDAR scanners (Figure 2a). Multispectral cameras, for instance, can capture images in different wavelengths, allowing farmers to analyze crop health indicators, such as chlorophyll levels and plant stress. Thermal cameras, on the other hand, can detect temperature variations, enabling the identification of irrigation issues or pest infestations. These sensors provide valuable insights that aid in timely decision-making and appropriate intervention.

Application of Drones in Agriculture

Crop Monitoring and Management

Drones have become valuable tools for crop monitoring and

management, offering farmers real-time insights and precise data on the health and condition of their crops. Equipped with sensors, cameras, and other imaging technologies, drones can capture high-resolution aerial imagery with multispectral and hyperspectral cameras even in invisible wavelengths. These capabilities have revolutionized the way farmers monitor and manage their crops [1].

Benefits of drone-based crop monitoring

One of the significant benefits of drone-based crop monitoring is early disease detection. By capturing detailed aerial imagery and using advanced algorithms, drones can identify subtle changes in plant color, texture, and growth patterns. This early detection allows farmers to take prompt action, such as targeted spraying or disease management, thereby preventing the spread of diseases and minimizing crop loss. Furthermore, drones assist in yield estimation by collecting data on plant density, biomass, and crop health indicators. This information helps farmers estimate crop yields accurately, enabling better planning for harvest and post-harvest activities. With precise yield estimation, farmers can optimize resources, plan logistics, and make informed decisions regarding storage and distribution.

Drones for Spraying and Fertilization

Drones enable precision targeted spraying and fertilization even in the condition when the conventional application equipment cannot be used in the field because of unfavorable weather and soil conditions. Traditional methods of spraying and fertilizing involve treating an entire field, regardless of specific areas that require attention. However, drones equipped with precision spraying systems can precisely treat specific areas, reducing the use of chemicals, minimizing environmental impact, and optimizing resource utilization. By analyzing crop data collected from drones, farmers can identify areas with varying nutrient requirements or pest infestations and deliver precise treatments, resulting in improved crop health at reduced cost.

Mapping and Surveying

Drones are proven to be invaluable tools for mapping and surveying agricultural land (Figure 3). With their aerial capabilities and advanced imaging technologies, drones offer farmers and landowners detailed and accurate fields maps, providing valuable insights for improved and efficient land management. Drones equipped with high-resolution cameras, LiDAR scanners, and GPS technology can generate detailed and accurate maps of agricultural land. By capturing aerial imagery and utilizing photogrammetry techniques, drones can create Orth mosaic maps, which are georeferenced and orthorectified images that provide a true-to-scale representation of the land. These maps offer precise measurements, such as field boundaries, topography, and elevation data, enabling farmers to understand their land's characteristics in a better manner.
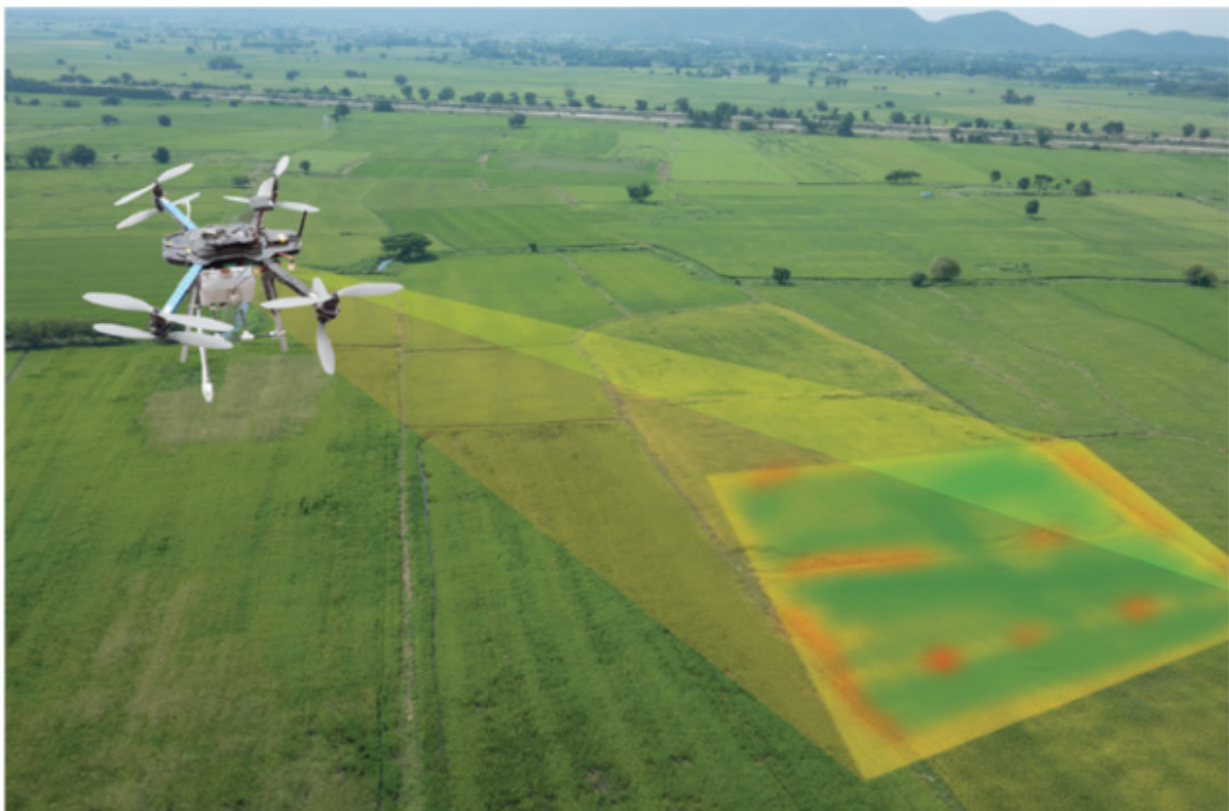

Figure 3: Field mapping using drone.

Drone for Land Surveying and Soil Analysis

Drone mapping offers several benefits in the context of agriculture. Firstly, drones can be used for land surveying, accurately measuring and marking boundaries, identifying potential obstacles, and assessing land suitability for different crops. This information helps farmers optimize land use and make informed decisions regarding field layout and crop selection [5]. Additionally, drones aid in soil analysis by capturing data on soil composition, soil moisture level, and fertility. By analyzing the collected information, farmers can identify variations in soil parameters across their fields and thereby implement suitable site-specific soil management strategy or combination of strategies. This targeted approach allows for precise fertilization, irrigation, and soil amendment, resulting in improved crop health and optimized resource utilization.

Drones for Monitoring Land Topography and for Drainage Solutions

Monitoring land topography is crucial for effective water management and identifying potential drainage issues. Drones equipped with LiDAR sensors can accurately measure the elevation of the land surface, generating detailed digital elevation models (DEMs) and contour maps. These topographic maps help farmers identify areas with uneven slopes, water accumulation, or inadequate drainage, enabling them to implement appropriate measures such as land leveling or drainage system installation. By addressing these issues, farmers can prevent waterlogging, ensure proper soil aeration, and improve overall crop productivity.

Drone for farm Planning

The integration of drone mapping and surveying techniques has already demonstrated its value in improving farm planning and efficiency. Farmers can use the detailed maps generated by drones to plan field operations more effectively, including crop planting, irrigation scheduling, and machinery routes. By optimizing these processes based on accurate spatial information, farmers can minimize overlaps, reduce input wastage, and increase operational efficiency. Furthermore, drone mapping can facilitate the identification of areas with varying soil properties or crop health, allowing farmers to implement site-specific management strategies. This targeted approach helps optimize resource allocation, improve crop quality and yield, and at the same time reduce environmental impact. Additionally, drone mapping assists in tracking changes over time, enabling farmers to monitor the effectiveness of their management strategies and make data-driven adjustments as needed.

Irrigation and Water Management

Efficient irrigation and water management are critical factors for sustainable agriculture [6], and drones have emerged as powerful tools in this domain (Figure 4). With their ability to gather real-time data and provide precise aerial insights, drones are revolutionizing how farmers monitor and optimize water usage in their fields.
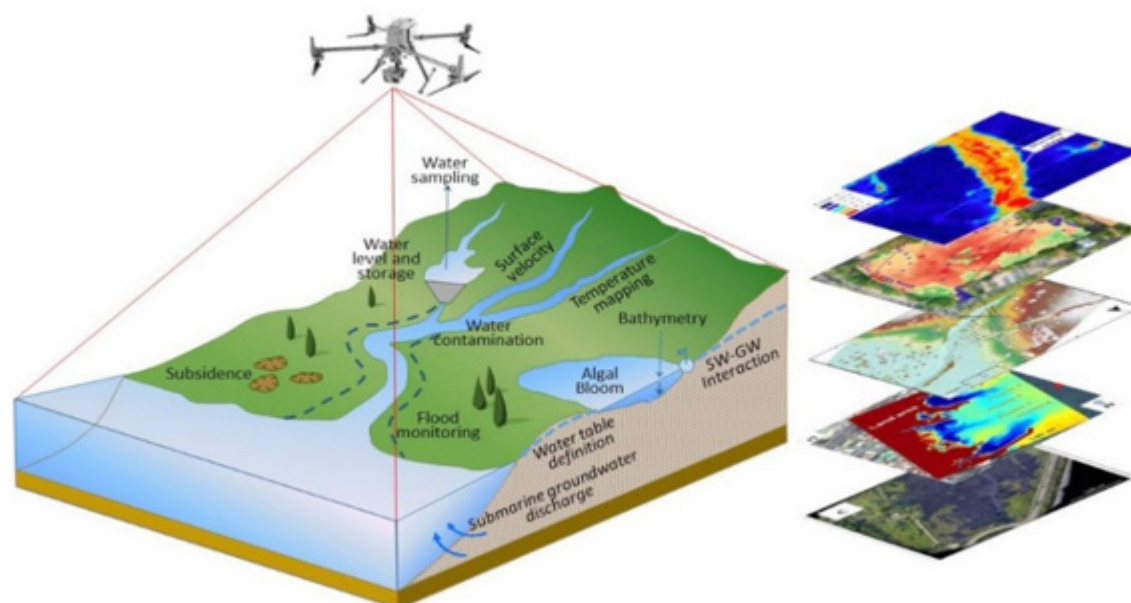

Figure 4: Use of drones for water management.

Drones to Assess Soil Moisture and Irrigation Needs

Drones equipped with advanced sensors and imaging technologies can assess soil moisture levels, a vital parameter for effective irrigation management. By utilizing sensors like thermal cameras or multispectral cameras, drones can capture data on plant stress, evapotranspiration rates, and soil moisture content. This information enables farmers to understand the water requirements of their crops accurately and make data-driven decisions regarding irrigation scheduling.

Drones to Monitor Water Sources

Drones play a crucial role in mapping and monitoring water sources within agricultural landscapes. They can capture high-resolution aerial images and create detailed maps of reservoirs, ponds, and other water bodies on the farm. These maps provide information about water levels, surface area, and potential sources of water loss, helping farmers effectively manage their water resources. By monitoring water sources, farmers can identify any issues like leaks or excessive evaporation and take corrective measures promptly.

Drone for Water Conservation and Improved Crop Health

Drone-assisted irrigation offers several benefits, including water conservation and improved crop health. By precisely identifying areas of varying moisture levels through drone data analysis, farmers can implement site-specific irrigation strategies. This targeted approach minimizes water wastage, reduces energy consumption, and ensures that crops receive the right amount of water at the right time. As a result, water resources are conserved, and the overall sustainability of agricultural practices is enhanced. Moreover, drone-assisted irrigation contributes to improved crop health. By monitoring crop stress levels and soil moisture content, drones can detect early signs of water deficiency or excess. This information enables farmers to adjust irrigation practices promptly, preventing under-irrigation or over-irrigation, which can lead to crop yield loss or disease outbreaks. Consequently, crop health is improved, leading to higher yields and better-quality produce.

Drones for Enhancing Irrigation Efficiency

Numerous examples highlight how drones enhance irrigation efficiency and reduce water wastage. For instance, drones equipped with thermal cameras can identify areas of heat stress in crops caused by inadequate irrigation. Farmers can then target those areas specifically, optimizing water application and minimizing

Drones for Livestock Monitoring and Tracking

waste. Additionally, drones can generate maps depicting soil moisture variability across a field. By integrating this information with automated irrigation systems, farmers can precisely deliver water to areas with higher water demand, improving water use efficiency and avoiding unnecessary irrigation in areas that are already adequately moist.

Livestock Management

Livestock management is a crucial aspect of modern agriculture, and drones have emerged as valuable tools in monitoring and optimizing livestock operations. With their aerial capabilities, drones offer farmers an efficient and comprehensive way to track, manage, and safeguard their livestock [7,8]. Drone-based livestock management offers several benefits for farmers and ranchers. Firstly, it reduces the need for manual labor in monitoring and herding livestock. With drones taking on these tasks, farmers can save time, reduce manpower requirements, and allocate resources more efficiently. Moreover, drones help prevent livestock theft. By providing real-time aerial surveillance and monitoring, drones act as a deterrent to potential thieves or predators. Farmers can quickly identify any unauthorized activity near their livestock and take appropriate measures to protect their animals and property (Figure 6).

Several successful drone applications have been implemented in livestock farming. For example, drones equipped with thermal imaging cameras can quickly detect abnormal body temperatures in animals, helping identify potential health issues such as fever or inflammation. This early detection allows farmers to intervene promptly and provide necessary care, reducing the risk of disease spread and minimizing economic losses. Drones have also been used to locate and count livestock, especially in expansive grazing areas. By analyzing aerial imagery captured by drones, farmers can accurately determine the number and location of animals, ensuring the entire herd is accounted for and facilitating effective resource allocation.
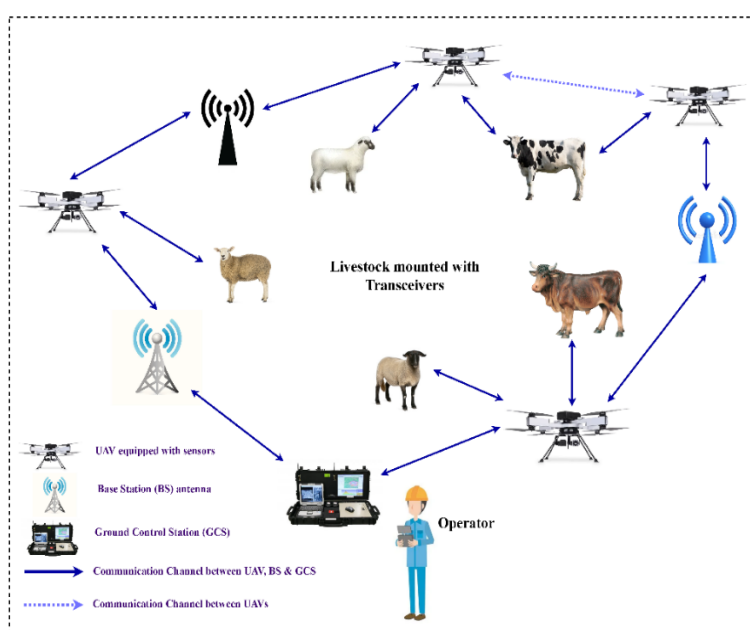

Figure 5: Use of drones for livestock management.

Drones provide a bird's-eye view of livestock operations, enabling farmers to monitor and track their animals more effectively. Equipped with cameras and thermal sensors, drones can capture aerial footage and collect data on livestock behavior, health, and movement patterns (Figure 5). This information helps farmers identify any issues or abnormalities, such as injured or missing animals, and take timely action to ensure the well-being of their livestock.

Drones for Aerial Herding and Surveillance of Grazing Animals

Figure 6: Use of drones for monitoring livestock behavior.

Drones can assist in aerial herding, which involves guiding or directing livestock from the air. With their agility and maneuverability, drones can effectively navigate and guide animals, saving time and labor compared to traditional herding methods. This is particularly useful when managing large herds or when livestock is spread over vast grazing areas. Drones can also be used for surveillance purposes, monitoring livestock as they graze and alerting farmers to any potential threats or dangers in the vicinity (Figure 6).

Future prospects and Challenges

The use of drones in agriculture has already made significant advancements, however potential for further innovation and integration is vast. As technology continues to evolve, drones hold the promise of reshaping agricultural practices even further. However, alongside the exciting possibilities, several challenges need to be addressed for widespread adoption and successful implementation.

Future Possibilities of Drones in Agriculture

• Automated and autonomous operations: Advancements in artificial intelligence and machine learning can enable drones to operate autonomously, carrying out tasks such as crop monitoring, spraying, fruit and flower harvesting and even pollination without human intervention. This can revolutionize the efficiency and scalability of agricultural operations.

• Crop health analysis and disease prediction: Drones equipped with advanced sensors and imaging technologies can provide real-time analysis of crop health, allowing for early disease detection and prevention. As technology progresses, the potential for drones to predict and mitigate disease outbreaks becomes increasingly plausible.

• Precision delivery systems: Drones have the potential to become efficient delivery systems for agricultural inputs, such as seeds, fertilizers, and even beneficial insects for pest control. Precise delivery mechanisms can optimize resource utilization and reduce the environmental impact caused by traditional delivery methods.

• Integration with other technologies: Drones can be integrated with other emerging technologies, such as satellite imagery, Internet of Things (IoT) devices, and data analytics platforms. This integration can enhance the accuracy, speed, and scope of data collection and analysis, enabling farmers to make informed decisions for improved agricultural outcomes.

Challenges in Adoption of Drone Technology

• Regulatory frameworks and safety concerns: The use of drones in agriculture is subject to various regulations and airspace restrictions. Ensuring compliance with these regulations, as well as addressing safety concerns related to flying drones near people and infrastructure, remains a challenge that needs to be overcome for widespread adoption.

• Cost considerations: While the cost of drone technology has decreased over time, it still represents a significant investment for many farmers, especially smaller-scale operations. Addressing the cost-effectiveness and return on investment aspects will be crucial to encourage broader adoption.

• Data management and analysis: Drones generate vast amounts of data, requiring robust data management and analysis systems. Farmers need user-friendly tools and platforms that can process and interpret drone-generated data efficiently, transforming it into actionable insights for decision-making.

• Skilled workforce and training: Operating drones and utilizing their full potential requires specialized knowledge and skills. Ensuring that farmers and agricultural professionals receive adequate training and education to effectively utilize drone technology is essential for its successful integration into farming practices.

• Public perception and acceptance: Public perception of drones in agriculture, including concerns related to privacy and environmental impact, can influence their widespread acceptance. Addressing these concerns through transparent communication and responsible drone use is crucial for fostering public support.

Conclusion

Drones have emerged as transformative tools in agriculture, revolutionizing various aspects of farming practices. From crop monitoring and management to mapping and surveying, irrigation and water management, livestock management, and beyond, drones offer unparalleled capabilities that enhance efficiency, productivity, and sustainability in the agricultural sector. Through their aerial perspective and advanced imaging technologies, drones provide farmers with detailed and accurate information about their crops, soil conditions, water resources, and livestock. This data enables informed decision-making, precise resource allocation, and targeted interventions, leading to optimized yields, reduced input wastage, and improved farm management practices. Furthermore, the future possibilities of drones in agriculture are vast. As technology continues to advance, drones hold the potential to automate operations, analyze crop health, facilitate precision delivery, and integrate with other emerging technologies. However, challenges such as regulatory frameworks, cost considerations, data management, skilled workforce, and public perception must be addressed for widespread adoption and successful implementation of drone technology in Indian agriculture. Overcoming these challenges requires collaboration among stakeholders, investment in research and development, and proactive measures to ensure responsible and safe drone use.

Acknowledgement

Conflict of Interest

None.

References

1. Tiwari PS, Singh KK, Sahni RK, Kumar V (2019) Farm mechanization–trends and policy for its promotion in India. Indian Journal of Agricultural Sciences 89(10): 1555-1562.

2. Sahni RK, Patel A, Kumar M, Thorat DS, Kumar V (2018) Status of farm mechanization in Indian agriculture. Biotech Articles.

3. Singh RS, Sahni RK (2019) Transformation of Indian agriculture through mechanization. Economic Affairs 64(2): 297-303.

4. Sahni RK, Kumar V, SP Kumar, NS Chandel, PS Tiwari, et al. (2018) Precision Agriculture Technologies.

5. Ghazali MHM, Azmin A, Rahiman W (2022) Drone Implementation in Precision Agriculture–A survey. International Journal of Emerging Technology and Advanced Engineering 12(4): 67-77.

6. Kumar M, Sahni RK, Waghaye AM, Nayak AK (2018) Precision Irrigation Technologies: A Present Need to Save for Future.

7. Alanezi MA, Shahriar MS, Hasan MB, Ahmed S, Shaaban YA, et al. (2022) Livestock management with unmanned aerial vehicles: A review. IEEE Access 10: 45001-45028.

8. Tiwari PS, Sahni RK, Kumar SP, Kumar V, Chandel NS, et al. (2019) Precision agriculture applications in horticulture. Pantnagar Journal of Research 17(1): 1-10.