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Advancing Precision Agriculture: The Role of UAVs and Drones in Sustainable Farming

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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

Modern sustainable agricultural production trends pose a need to change production technology processes with the application of techniques, and tools that cause less environmental pollution and contribute to ensuring health safety in general. Precision agriculture can be defined as an agricultural production process that includes the application of information technology and various

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types of sensors, satellite positioning, and monitoring of farming machinery. Aerial remote sensing is regarded as one of the most crucial technologies for smart and precision agriculture. This mini-review aims to summarize the applications of drones in precision agriculture with special reference to crop monitoring and pest management. Drone equipped with modern capabilities like Artificial Intelligence integrated systems with multispectral cameras help the farmers to observe aerial images of crops in real time. Camera-equipped drones use advanced image data analysis tools to identify diseased or defective plants which assists the farmer in crop monitoring. Also, the fully automatic pesticide spraying system analyzes real-time data and is capable of spot spraying. The use of drone-borne sprayers in the field increases coverage, chemical effectiveness, and make spraying operations easier and faster. Each type of drone has its performance drawbacks, such as high operating and maintenance costs, limited flight range, time, and payload capacity, but with accelerating technology development and the systems integrated into drones, they offer a promising role in advancing precision agriculture.

Keywords: Drone; UAV; crop monitoring; pest management; precision agriculture; digital technologies; smart agriculture.

1. INTRODUCTION

As agricultural scale and production reach new world records, society's environmental consciousness fortunately also increases [1]. The demand for producing high-quality food free of pesticide residues and other harmful substances is rising in contemporary, environmentally conscious societies. Ecological concerns drive the use of renewable energy sources and the preservation of natural resources. Current trends in sustainable agricultural production necessitate a shift in production technology procedures through the use of methods and instruments that reduce environmental contamination and help to ensure overall health and safety [1]. Many studies and social initiatives call for a transition to more sustainable agricultural methods due to their favourable impacts on ecosystems, biodiversity and human health [2]. The idea of precision agriculture, or agricultural management based on the use of information technology in agriculture, is one strategy that backs such initiatives [3]. An agricultural production process that incorporates the use of information technology, different kinds of sensors, satellite positioning, and farming machinery monitoring is known as precision agriculture.

Aerial remote sensing is regarded as one of the most crucial technologies for smart and precision agriculture. Drones are used in aerial remote sensing, which measure vegetation indices and uses images of various wavelengths to identify various crop conditions to assess the crop health [4]. In recent decades, manned aircraft or satellites have also been used to capture desired images for precision agriculture [5]. The cost of taking pictures with manned aircraft is high, and the issue with satellite imagery is that, in most cases, the spatial resolution is not as good as one would like. Additionally, weather conditions affect image quality and availability [6,7]. Advances in unmanned aerial vehicle (UAV) technology and the reduction in weight of payloads have transformed the use of remote sensing of crops using this technology. This technology is less expensive, saves time, and obtains high-resolution images without destruction [8,9]. Drone surveillance systems help farmers observe aerial images of crops. This provides information regarding water systems, soil varieties, pests and fungal infestations. Images collected by drones contain information in the infrared and visual spectrum ranges. Various features from these images can be extracted, providing information about plant health in a way that is invisible to the naked eye. Another important feature of this technology is the ability to monitor performance regularly, i.e. weekly or even hourly. Regularly available crop information helps farmers take corrective measures for better crop management [10,11].

Applications of drones in precision agriculture can be studied based on payloads. The actual payload is the weight that the drone can carry [12]. Concerning the payloads two main applications of drones in precision agriculture are described in this review *viz.* crop health monitoring and pest management.

2. UAVs AND DRONES

Nowadays, the application of small unmanned aerial vehicles (UAVs) is growing at a very fast pace in the agricultural industry [13-15]. Drones are semi-autonomous devices that are continuously evolving into fully automated devices. These devices have great potential for agricultural planning and the collection of related spatial information. Despite some inherent barriers, this technology can be used for effective data analysis [16].

Drones were originally radio-controlled aircraft that pilots operated from the ground. Modern drones, on the other hand, are GPS-based, self-governing aircraft. The drone's intended use determines the kinds of cameras, sensors, and control systems that are used. Fixed wings, helicopters or VTOL, and multicopters are the three primary categories of UAVs. The size of different payloads has decreased as a result of advancements in drone technology, leading to more compact and effective drones. These drones can now carry out tasks like applying pesticides thanks to AI integration, which gives them the ability to make wise decisions.

However, the complexities in laying the regulations for the use of drones, high initial costs as well as the adverse impact of drone batteries coupled with noise pollution and impact on sensitive ecosystems prove to be hurdles in its large scale adoption. Also, a typical farmer must either recruit knowledgeable staff to operate the drones and analyze the resultant data or learn and develop the necessary skills [17].

2.1 Drones for crop monitoring

For small installations, there are limitations to using satellite imagery for data analysis. Additionally, weather and lighting conditions affect the availability of satellite imagery. Because unmanned aerial vehicles (UAVs) can automatically take pictures of the desired location at the desired altitude and frequency, they offer a better option for gathering image data. Furthermore, drone-based technologies can be used as a fully automated tool for weed and pesticide analysis and can analyze data instantly. Camera-equipped drones use advanced image data analysis tools to identify diseased or defective plants [18,19]. Drones are primarily used in agriculture to map fields and monitor crops.

Drones in the agriculture perform many activities that assist in crop monitoring, some of which are:-

1. Crop scouting
2. Crop health monitoring
3. Yield monitoring
4. Biotic and abiotic stress assessment
5. Disease classification
6. Plant height, canopy estimation

In 2012, Jacopo Primicerio et al., developed an unmanned aerial vehicle (UAV) called VIPtero. [20]. This allowed them to manage the vineyards appropriately depending on their location. This was an autonomous hexacopter that could operate based on location using a multi-spectral camera. In 2015, Hassan-Esfahani et al. [21] proposed a remote sensing technology called “AggieAir” for agricultural applications. They were able to capture images in the RGB (red, green, blue), near-infrared (NIR), and thermal spectra. It provided high-quality multispectral imaging data for monitoring plant health. In 2016, Santesteban et al. used a drone system to investigate water conditions in vineyards [22]. Aerial thermal images taken by drones were used to estimate current and seasonal water status of crops. In 2018, Arnab Kumar Saha et al., proposed an IOT-based real-time drone system for crop data monitoring [23]. Real-time data analysis was done using intelligent sensors and modules. In 2019, Jack et al., used a Raspberry Pi 3B module to incorporate a method for estimating soil properties that used the visible atmospheric resistance index (VARI) [24]. In 2020, Su et al., proposed an automatic yellow rust monitoring system using UAV [25].

2.2 Drones for Pest Management

Manual mechanical sprayers are the most common tools for traditional pesticide application. Manual pesticide application can affect the human body and cause diseases such as cancer, hypersensitivity, asthma, and other disorders [26]. In addition, traditional methods also have other drawbacks, such as: additional use of chemicals, shortage of agricultural labour, less uniform application, environmental pollution, and reduced land coverage. These traditional methods have high pesticide application costs and are less effective in controlling pests and diseases. To address these drawbacks, drone-borne sprayers are used. The use of drone-borne sprayers in the field has increased coverage, increased chemical effectiveness, and made spraying operations easier and faster. Currently, drones carry pesticide tanks with a capacity of up to 40 litres and can spray crops according to requirements according to premapped routes. Drones have shown great potential in covering fields that are difficult to access with tractors or aircraft. The first UAV (unmanned helicopter) for pesticide spraying was developed in 1983 by Yamaha Motor Co., Ltd. in Shizuoka Prefecture, Japan. The stability and controllability of this helicopter was not suitable for use in the field.

Recent years have seen many changes in both drone flight controls and spray systems. The spray system has been upgraded from a semi-controlled device to an AI-based fully automated system. The fully automatic pesticide spraying system analyzes real-time data and is capable of spot spraying. Chemical spraying requires no human effort, making it a safer and more economical system of choice. However, spraying with drones is subject to interference by weather conditions, calibration of spray nozzles, and the maintenance of the drone and spraying payloads. Malfunction in calibration can lead to an increased application of the pesticide than required leading to phytotoxicity.

It is crucial to stress that there is no direct human activity present when using a drone for spraying. The impact of pesticides on people is greatly lessened in practice since the drone pilot is safely away from the surface to be sprayed [27]. Current research focuses on improving the spray coverage to enable the large-scale use of drones for pesticide spraying [28]. The drone industry needs more path-breaking reforms by taking into account the rapid increase in population, dire needs of the farmers, operational policies and shrinking farm fields [29]. When used in conjunction with precise monitoring, pesticides can be applied less frequently, which may lead to decreased pesticide use and resistance development as well as a rise in natural enemies [30]. The use of drones in agriculture heralds a new era of efficiency and precision in crop protection. The use of drones, especially for supplementary biological control, requires the large-scale release of natural enemies to immediately combat pests [31]. Natural enemies can be distributed precisely where they are needed, potentially increasing the effectiveness of biological control agents and reducing distribution costs.

3. CONCLUSION

Since 2017, the application of drones in precision agriculture has rapidly increased. This is due to the reduced weight, reduced cost, and increased payload capacity of UAVs. By using drone surveillance technology, the data collected is processed instantly, allowing for active processing and decision-making in real-time. Currently, the practical use of drones in agriculture is spreading faster than in other industries. There are several reports highlighting the successful use of drones in agriculture, both in the areas of crop monitoring and use of pesticides.

The (UAV) market is constantly changing, with improved technology now shifting the use of fixed-wing drones and helicopters to smaller multicopter-based drones, accounting for almost 50% of the UAV models currently available. Each type of UAV has its performance drawbacks, such as high operating and maintenance costs, limited flight range, time, and payload capacity, but with accelerating technology development and the systems integrated into drones, the drones offer a promising solution in addressing the needs of sustainable farming through precision 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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