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Application and development of drones in agriculture

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Abstract

India's population is expected to reach 1.64 billion by 2050 and it is required to produce up to 333 million tonnes of food grains in the near future. In addition, Indian agriculture is facing challenges such as labour shortage, arable land scarcity and increasing cost of production, environmental degradation, and rising irrigation water demand (Ahirwar *et al.*, 2019). In this context, information and communication technologies (ICT) driven tools and solutions can help people to make better decisions. Among many emerging technologies which can provide solutions, unmanned aerial vehicles (UAVs), often known as drones is one of the most recent innovations in agriculture (Kushvaha *et al.*, 2021). Drones have greatly contributed to increased productivity, precision and sustainability in farming practices. By capturing high-resolution imagery, collecting data, and delivering real-time information, drones provide farmers with valuable insights for decision-making and crop management. Additionally, their ability to spray fertilizers, herbicides, growth regulators and pesticides with precision, helps to reduce the input costs and minimizes environmental impact. The use of drones also enhances crop monitoring, pest and disease detection, and yield estimation, crop insurance, allowing farmers to make proactive interventions and optimize crop health. Moreover, drones have improved safety by minimizing human exposure to hazardous agricultural tasks. Overall, the integration of drones in modern agriculture has ushered in new possibilities for increased efficiency, reduced costs, and improved sustainability in food production (Joshi *et al.*, 2020). Therefore, drones have become an indispensable tool for farmers, potential to interest young people and inspire them to pursue agriculture and opening up a new era of smart and sustainable farming practices.

Keywords: Drones, precision farming, uses

Introduction

Global food hunger is estimated to affect 735 million people around the world (FAO, 2023) ^[10]. Farming in developing countries largely relies on the traditional knowledge of farmers, often involving unscientific agricultural practices. This results in low productivity and the depletion of resources. Additionally, mechanization is not a significant part of farming, making farm management a time-consuming and labor-intensive task (Raj *et al.*, 2020) ^[32]. Agricultural workers are increasingly moving to non-agricultural sectors (Srivastava *et al.*, 2020) ^[37], resulting in a decline of 30.7 million agricultural workers, which is a 12% reduction. This shift has led to a 9.3% increase in labor wages (Vaishnavi and Manisankar, 2022) ^[41]. Agricultural drones are employed for foliar nutrient spraying to address this issue, offering an effective solution to reduce labor demands and production costs. They improve productivity and increase the speed of application, allowing for coverage of larger areas (Nandhini *et al.*, 2022) ^[26]. In recent years, the use of UAVs in agriculture has increased significantly, especially for capturing high resolution images and videos for later analysis. AI techniques are employed to process these images for planning, navigation, geo-referencing, and other agricultural applications.

Drone

Drone is an acronym for Dynamic Remotely Operated Navigation Equipment (Rani *et al.*, 2019) ^[33]. Drones are flying robots that range from unmanned aerial vehicles (UAVs) capable of traveling thousands of kilometres to small drones designed to operate in confined spaces (Krijnen and Dekker, 2014) ^[19]. Drones are aerial vehicles that operate without a human on board, flying either remotely or autonomously, and can carry either lethal or nonlethal payloads

(Gupta *et al.*, 2013) ^[13]. The study by Mohammed *et al.* (2020) ^[25] illustrates the rapid and versatile adoption of UAV solutions in everyday situations.

In recent years, the agricultural industry has embraced innovative technologies that improve farm management strategies by enabling the precise application of inputs. One such advancement is drone technology, which has become increasingly popular (Kim *et al.*, 2018) ^[18] and is widely utilized in precision agriculture (Zhang and Kovacs, 2012) ^[46]. An agricultural drone can be equipped with various sensors depending on the specific crop characteristics that need monitoring (Yang *et al.*, 2017) ^[45]. These sensors provide valuable data at different stages of crop growth, helping to assess vegetation health, soil moisture levels, and other critical agricultural factors (Tsouros *et al.*, 2019) ^[40].

History of Drones

- 1849 - The Austrians utilized unmanned air balloons (Kennett, 1982) ^[17].
- 1916 - The first drone designed for military warfare was developed (Grossnick, 1987) ^[12].
- 1922 - French engineer Etienne Omnichen created the first quadcopter, known as the "Omnichen 2" (Miah, 2020) ^[23].
- 1946 - Meteorologists in the United States first used drones to study weather patterns and track thunderstorms and tornadoes (Theilmann, 2015) ^[39].
- 1960 - The United States was the first to develop drone technology for both military and civilian purposes (Ehrhard, 2010) ^[9].
- 1983 - A remote-controlled aerial spraying system was used to apply agrochemicals in Japan.
- 1987 - R-50, the world's first unmanned helicopter for crop dusting, was developed with the capability to carry a 15 kg payload (Miyahara, 1993) ^[24].
- 2007 - In Florida, drones are being used to monitor citrus groves for growth characteristics, weed infestations, and to detect Huanglongbing disease (Chang *et al.*, 2020) ^[7].
- The groundbreaking use of drones in agriculture became popular in 2015.

Classification of Drones

a) Based on weight (Arjomand *et al.*, 2006) ^[4]

- **Super heavy drones:** Weighing over 2 tons and capable of carrying large amounts of fuel, they fly at high altitudes for military reconnaissance missions (e.g. Global Hawk).
- **Heavy weight drones:** They have a weight range of 200 to 2,000 kg (e.g. Fire Scout).
- **Medium-weight drones:** They weigh between 50 and 200 kilograms (e.g. Raven).
- **Light-weight drones:** Weighing between 5 and 50 kilograms, they are useful in agricultural applications (e.g. RMAX, Yintong, Autocopter).
- **Microdrones:** Weighing less than 5 kilograms, these drones are more commonly used in agricultural fields and are highly portable (e.g. Precision Hawk's Lancaster, eBee, Swinglet).

b) Based on endurance (Watts *et al.*, 2012) ^[43]

- **Long-endurance drones:** They can remain airborne for 24 hours or more and cover a distance of 1,500 to 20,000 kilometers without needing a refill (e.g. Global Hawk).
- **Medium-endurance drones:** They can fly continuously for 5 to 24 hours without a break and cover long distances

based on their speed.

- **Low-endurance drones:** They can fly for an hour at a time and cover a distance of 100 kilometers.

c) Based on altitude (Bendea *et al.*, 2008) ^[5]

- **Low-altitude drones:** These drones are ideal for close-up imagery of crop fields, typically flying at altitudes of 100 to 1,000 m above the crop canopy.
- **Medium-altitude drones:** They are also used in agriculture, especially for capturing NIR and thermal images of crops, and typically fly at altitudes of 1,000 to 10,000 m above the crop height.
- **High-altitude drones:** They are frequently employed for assessing natural resources and for military reconnaissance, flying at altitudes exceeding 10,000 m above the ground.

d) Based on wing loading (Arjomand *et al.*, 2006) ^[4]

- **High wing loading types:** They are drones with a wing loading exceeding 100 kg m⁻² (e.g. Global Hawk).
- **Medium wing loading types:** They are drones with a wing loading ranging from 50 to 100 kg m⁻² (e.g. Fire Scout, X-45).
- **Low wing loading types:** They are drones with a wing loading of less than 50 kg m⁻².

e) Based on form (Chapman, 2016) ^[8]

- **Fixed-wing drones:** They feature a "two-wing design" similar to that of an airplane. They operate at speeds of up to 50 km per hour and are used for mapping larger areas. These drones can carry heavy loads over long distances but cannot take off vertically.
- **Single-rotor drones:** They have a single rotor and can take off and land vertically. They are more efficient than multi-rotor drones and are used for spraying agrochemicals.
- **Multi-rotor drones:** They are equipped with four or eight rotors and have a flight time of just 10 to 20 minutes. These drones can take off and land vertically and are primarily used for spraying agrochemicals.
- **Hybrid drones:** These drones have both wings and rotors, allowing them to take off and land vertically. They can cover much longer distances and carry heavier loads compared to multi-rotor drones.
- **Ducted fan drones:** They are capable of vertical takeoff and landing and are used for crop monitoring.

Components of a drone

a) Chassis

Every component is attached to the drone's framework. There is a trade-off in the chassis design between durability and increased weight, which requires more powerful motors and longer propellers to lift heavier items, such as cameras (Maharana, 2017) ^[22].

b) Propellers

The drone's speed and maneuverability are largely determined by its cargo-carrying capacity. Longer propellers generate more lift at lower RPMs but take more time to speed up or slow down. Shorter propellers can change direction more quickly, making them more maneuverable, but they need to spin faster to deliver the same power as longer blades, which puts extra stress on the motors and reduces their lifespan. An aggressive pitch enables faster movement but reduces hovering efficiency (Piotrowski *et al.*, 2015) ^[30].

c) Motors

Drone motors are rated in "kV" units, indicating the number of revolutions per minute a motor can achieve per volt without any load. This rating applies to each propeller. Faster motor speeds provide more flight power but consume more battery power, reducing flight time

d) Electronic Speed Controller (ESC)

It supplies each motor with a regulated current to achieve the desired spin speed and direction (Ahirwaret *et al.*, 2019) ^[2].

e) Flight Controller

It is the onboard computer that interprets data from the pilot and sends the correct signals to the ESC to control the quadcopter (Li *et al.*, 2017) ^[21].

f) Radio Receiver

It receives the control signals from the pilot (Shafiee *et al.*, 2021) ^[34].

g) Battery

Lithium polymer batteries are commonly used due to their high power density and recharging capabilities (Singh *et al.*, 2019) ^[36].

h) Others

Additionally, sensors such as barometers, GPS, gyroscopes, and accelerometers can be used to measure position. Cameras are also frequently installed for aerial photography and navigation (Maharana, 2017) ^[22].

Applications of drones in agriculture Soil Analysis

Drones can be employed to assess soil and fields for nitrogen levels, irrigation needs, and to aid in planting planning (Wu *et al.*, 2019) ^[44]. They are also valuable for generating detailed 3D maps, which can be used for soil analysis, including evaluating moisture content, soil erosion, and soil properties (Carabassa *et al.*, 2021) ^[6].

Seed planting

Although not yet widely adopted, some companies have developed an additional attachment for drone systems that enables them to shoot pods containing plant nutrients and seeds into prepared soil. This innovation is helping to reduce planting costs (Andrio, 2019) ^[3].

Crop Monitoring

Crop monitoring is a major challenge not only for farmers but also for other stakeholders in agricultural operations, especially with the rise of unpredictable weather patterns. Drones can help to address this issue by collecting multispectral, geographical and temporal data at specific scales related to crop development, allowing for the creation of effective surveillance routes.

Crop Spraying

Drones can carry appropriately sized reservoirs filled with pesticides, herbicides, or fertilizers, allowing for fast and efficient spraying over large areas. Operating autonomously based on a set schedule and route makes crop spraying safer and more cost-effective. Drones are equipped to adjust their height and speed automatically using ultrasonic echoes, TOF lasers and GNSS signals, ensuring consistent and optimal spraying results across various terrains. Smart farms use drones for spraying to reduce human exposure to harmful chemicals. Additionally,

drones excel in automated spot treatment by using stress detection technology with sensors and cameras to target unhealthy areas while avoiding healthy ones. They can enhance spraying efficiency, performing up to five times faster than traditional methods (Ahirwaret *et al.*, 2019) ^[2].

Irrigation

Drones equipped with thermal, multispectral, or hyperspectral sensors can use multispectral indices to identify moisture-deficient areas in a field. This capability helps in accurately scheduling irrigation for those specific regions (Jalajamonyet *et al.*, 2022) ^[15].

Crop health assessment

Plants reflect both visible and near-infrared light, with the amount of reflection indicating their health and stress levels. Drones equipped with sensors to scan for visible and near-infrared light can monitor crop health over time and track the effectiveness of corrective actions (Abbas *et al.*, 2023) ^[1].

Crop surveillance

In large fields, assessing the overall condition of crops can be challenging. Drone-based agriculture mapping helps farmers stay informed about their plants' health and identify areas needing attention. By using infrared cameras to scan the field and measure light absorption rates, drones provide precise and current data on crop condition. This information enables farmers to make informed decisions to improve plant health in specific field areas. Additionally, drone technology is enhancing agricultural insurance tools by cross-verifying insurance claims with crop surveillance and health assessments. The future effectiveness of this application will depend on practical feasibility and the financial aspects of the insurance plans (Shah *et al.*, 2023) ^[35].

Controlling weed, pests and diseases

Drones can detect and alert farmers to areas of the field affected by diseases, weeds and insect pests, as well as soil-related issues. This information allows farmers to address infestations more effectively, reduce the quantity of insecticides needed, save on costs and enhance overall field health (Stroppiana *et al.*, 2018) ^[38].

Tree/crop biomass estimation

Drones equipped with ultra-small LiDAR sensors can measure the distance from the ground surface and assess the density of crop and tree canopies. This capability allows for the evaluation of changes in biomass by comparing height measurements, which is essential for estimating the yield of crops such as sugarcane and timber in forests (Navarro *et al.*, 2020) ^[27].

Scaring birds

After sowing seeds for various crops, birds often become a major problem, requiring a workforce to protect the field. A few drone flights can help scare the birds away from the area (Wang *et al.*, 2019) ^[42].

Benefits of using drones in agriculture (Puri *et al.*, 2017) ^[31]

- Drones can reduce the time needed to spray agrochemicals.
- The need for labour can be decreased.
- Once learned, it is easy to operate.
- It can be combined with GIS mapping.
- Drones can be used for imaging crop health.
- Work efficiency is improved.

- Crop damage can be detected accurately.
- It helps to reduce pollution.
- Productivity can be boosted.
- The wastage of agrochemicals is minimized.

Problems associated with the usage of drones in agriculture (Hardin and Jensen, 2011) ^[14]

- Drones used in agriculture have a short flight duration, typically ranging from 20 to 60 minutes. This limits the amount of land that can be covered per charge.
- Some drones are more expensive due to the costs of imaging sensors, software, hardware and tools. The initial cost also correlates with the payload and flight duration capacities, in addition to the sensors and features included.
- It is not suitable for very small areas.
- Safety precautions must be observed when operating drones.
- Several federal laws regulate the use of drones.
- Interference in the airspace is a serious issue.
- Weather-dependent and therefore not operable in adverse conditions.
- An average farmer may struggle to analyze drone images, as it requires specialized skills and knowledge to convert them into useful information. In such cases, the farmer would need to either learn image processing software or hire a skilled individual.
- There is a risk of misuse that could lead to privacy violations and illegal information transfer.

Rules and regulations for using drones in India (Pathak *et al.*, 2020) ^[29]

- Densely populated areas and large crowds should be avoided.
- Avoid infringing on others' privacy.
- UAVs are prohibited within 5 km of airports or in areas where aircraft are in operation. Operate during daylight hours and in favorable weather conditions
- The use of drones or camera drones is restricted in sensitive areas, such as government or military facilities.
- The drone operator must be a trained pilot and at least 18 years old.
- A license plate with the operator's details and contact information must be attached to the drone.
- The visual line of sight must be maintained when operating an RPAS.
- A single person cannot operate more than one UAV simultaneously.
- Drone flying is prohibited within 50 km of the country's border.
- Flying a drone more than 500 m from the coastline into the sea is prohibited.
- Similarly, drone flights are not permitted within 5 km of Vijay Chowk in Delhi.
- Flying over national parks or wildlife sanctuaries is also prohibited.
- All drones must be covered by a valid third-party insurance policy to address any liabilities that may arise from accidents.
- Basic drone regulations must be adhered to when operating a drone weighing over 250 grams.

Conclusion

Originally, drones were designed solely for military use. However, over the past decade, they have been making significant impacts in the agricultural sector. With rising demands for agricultural labor, the need to boost food production and enhance food security, drones are poised to drive the next revolution in agriculture. As a result, Research Institutions, Agricultural Universities and State Agricultural Departments can utilize drones to facilitate future advancements.

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