**Revolutionizing Indian Agriculture with Drones: A Comprehensive Review of Applications, Challenges and Future Prospects**

**Abstract**

Indian agriculture contributes to the GDP, but our nation still needs to improve productivity and efficiency to the fullest extent possible. Numerous aspects and concerns need to be identified, supported, and equipped with solutions. Now agriculture sector is the fastest-growing sector, which is faced with several issues, one of which is the lack of labour for farming. Some additional issues or challenges are extreme weather conditions, inadequate and ineffective fertilizer application, infection, illnesses, allergies, and other health issues brought on by chemical applications (fungicide, pesticide, insecticide, etc.). Drones, also called Unmanned Aerial Vehicles (UAV), have developed remarkably in recent years. Common applications of drones are Pesticide application, soil sampling and fertilizing, farm animal observation, real-time aerial imagery, sensor data collection, etc. These drones have been primarily created to speed up, boost productivity, and effectively utilize agricultural resources. The government is working toward a liberalized policy to encourage drones and also provide institutions, individual farmers, and businesses with significant financial incentives to buy and utilize or build drones. If farmers start to trust drones for spray-related tasks, there's a strong chance their use will be expanded to other revolutionary use cases as well, which will be beneficial for Indian agriculture.

**Keywords:** Drone,Agriculture**,** Irrigation, Crop Monitoring

**1. Introduction**

The agricultural sector is increasingly leveraging technological advancements to enhance productivity and sustainability. Among these innovations, drone technology, a crucial component of precision agriculture, is gaining global recognition (Murugan et al., 2024). Traditional manual agriculture methods might be completely transformed by drone technology, which is an enormous advance (Pathak et al., 2020). Globally, agricultural companies are increasingly using drone technology to modernise farming (Duncan et al., 2021). In addition to having a satellite navigation system, programmable controller, propulsion system, automated flight planning capabilities, and the capacity to carry payloads such as cameras, spraying systems, etc., drones are remotely piloted aircraft systems (RPAS). (Gupta et al., 2013Other acronyms that are often used interchangeably include unmanned aerial vehicle/systems (UAV/UAVs) and unmanned aircraft systems (UAS); nonetheless, RPAS is the most official and widely used method to refer to such a system (Pathak et al., 2020). Drones, which stand for "Dynamic Remotely Operated Navigation Equipment," are flying machines that can fly themselves along a predefined path utilising GPS coordinates and autopilot control (Ajmera et al., 2022). As an alternative, it may be manually controlled via radio signals via smartphone apps or remote control (Maddikunta et al., 2021). Drones can locate items that are undetectable to the human eye because they have access to so many sensors. Drones can, therefore deliver real-time, more accurate, reliable, and objective information with greater detail and fewer errors (Molina et al., 2012). Drones can fly autonomously with dedicated software which allows making a flight plan and deploying the system with GPS and feed in various parameters such as speed, altitude, ROI (Region of Interest), geo-fence and fail-safe modes. Drones are preferred over full size aircrafts due to major factors like combination of high spatial resolution and fast turnaround capabilities together with low operation cost and easy to trigger. These features are required in precision agriculture where large areas are monitored and analyses are carried out in minimum time (Dutta & Goswami, 2020; Singh et al., 2024; Meivel and Maheswari, 2021).

A drone used for agricultural purposes is referred to as an agriculture drone. Particularly in difficult terrain like hills, drones might be utilised to spray pesticides more efficiently than time-consuming, conventional approaches (Yinka-Banjo & Ajayi, 2019). Artificial intelligence and machine learning may be used to analyse soil conditions and forecast crop output using high-resolution drone photographs taken using NDVI (Normalised Difference Vegetation Index) imaging technology (Saini et al., nd). Using image processing techniques, a stressed plant may be independently discovered and inspected (Du & Sun, 2004). Using this discovery as a guide, farmers may take preventive measures to limit diseases from spreading to other crops (Reinecke & Prinsloo, 2017). Timely measures can be taken to minimise the effects of climate change and unpredictable weather, optimise fertilisation, rationalise irrigation, and stop losses from biotic stresses like insects, pests, and disease by using the insights analysed from data collected by drones and satellite-based remote sensing (Pathak et al., 2020). Farmers can make informed decisions regarding irrigation, fertiliser, and pesticide application by using real-time data gathered by drones. In addition to improving crop quality, this data-driven approach reduces resource waste and its negative effects on the environment. Drone technology and Geographic Information Systems (GIS) allow farmers to create detailed maps of their land (Anusha and Padhy, 2024).

**2. Drone Operations in Indian Agriculture**

Drones are presently promoted in India as typical automatic spray devices that may be used for pesticides and other tasks (Beriya, 2022). Using a sprayer to cover plants reduces the health risks associated with hand spraying and saves time, resources, and labour (Chaitanya et al., 2020). According to the Indian Agriculture Ministry, each acre will cost between Rs 350 and Rs 450 for the use of a drone with a 10 km payload capacity (Zeliang et al., 2017). The figure is entirely predicated on the assumption that a drone equipped with several batteries will be used for at least six hours every afternoon to cover about 30 acres of agriculture (Shi et al., 2016). These were extracted from a fact-sharing webinar held by the company IFFCO Kisan, in which Dr. Shankar Goenka, a professional, gave information on drone operations based on their reports on the rollout of drone income in addition to spray services (on a rent-per-acre basis).

According to Dr. Goenka, even for vegetation with higher heights like sugarcane, mango orchards, and other similar flora, equal depth/unfold of spray is carried out using drones (Yadav et al., 2023). Due to automated processes, a reduction in the input prices of spray equipment (pesticides/weedicides) is predicted to be in the range of 25–30%). Using nano urea as an example, if the farmer can save 25% on the price of the input while spraying it on an acre for Rs. 240 per bottle, the price is reduced to that level (KATEKAR et al., 2022). Due to the tiny droplet sizes of about 50 microns compared to the manual spray's droplet length of about 500 microns, a similar around eighty-nine per cent reduction in water is also achieved (CARLSON et al., 1979). Drone sprays save time because each spray takes about 5-7 minutes per acre, but a person can normally only cover three to four acres manually in one afternoon. A 10-litre capacity drone has an 11-litre tank capacity, among other drone features (Beriya, 2022). The integration of drone technology has the potential to revolutionise the agricultural industry and pave the way for more effective, sustainable, and productive farming practices (Anusha and Padhy, 2024).

**3.** **Drones in agriculture applications**

Drones can be used in a variety of agricultural applications, some of which are briefly covered below:

**3.1. Field and Soil analysis:** Sensors that can measure the soil's moisture content, nutrients, fertility, and topography can be mounted on drones. The regional variability of crop growth and field conditions may therefore be taken into consideration when planning the pattern of planting various crops, scheduling irrigation, and managing fertiliser applications using these sensors (Nahry et al., 2011).

**3.2. Planting of Seed Pods:** Several companies have created additional drone system attachments that can fire pods containing seed and plant nutrients into already prepared soil, even though they were invented but rarely used. Lower planting expenses result from this (KATEKAR et al., 2022).

**3.3. Crop Health monitoring:** Throughout the agricultural season, drones may be used to monitor crop conditions, enabling timely and need-based management. Yield loss can be prevented with a timely and appropriate reaction (Anghelache et al., 2021). This technology will eliminate the need for farmers to visually inspect their crops. The combination of large regions and ineffective crop monitoring is the primary farming problem (Tian et al., 2020). Unpredictable weather conditions make monitoring more difficult and raise risk and field maintenance expenses (Elijah et al., 2018).

**3.4. Identification of weeds:** Drones may be used to detect the presence of weeds in the field. These weeds might be quickly removed from the field so they don't compete with the main crop for resources (Herwitz et al., 2004).

**3.5. Crop Spraying:** In order to achieve consistent coverage, drones can precisely distribute liquid while changing their distance from the ground and spraying in real-time. Improved efficacy and reduced chemical penetration into groundwater were the final results (Delavarpour et al., 2021). Experts claim that drones can actually carry out aerial spraying up to five times faster than traditional equipment (Klauser & Pauschunger, 2021).

**3.6. Irrigation:** Drones using thermal, multispectral, or hyperspectral sensors can employ multispectral indices to identify deficient moisture locations in the field. This facilitates the accurate and timely scheduling of irrigation for the assigned areas (Abrahams et al., 2023).

**3.7. Crop health monitoring:** Depending on their health and stress level, plants reflect different amounts of visible and near-infrared light (Zahir et al., 2022). Crop health can be tracked over time and remedial measures can be more successful when drones are fitted with sensors that can scan crops using visible and near-infrared light (Hafeez et al., 2022).

**3.8. Weed, insect, pest, and disease control:** Drones may identify and alert farmers to field regions affected by weeds, disease, and insect pests in addition to soil conditions (Sinha & Dhanalakshmi, 2022). Based on this knowledge, farmers can reduce costs and improve the health of their fields by maximizing the use of chemicals needed to combat pests (Brodt et al., 2011).

**3.9. Protecting the field from animal damage:** The thermal cameras that are put on drones may find people or animals in the dark. Therefore, it can be used to safeguard fields from animal damage that would otherwise be impossible to notice at night in huge fields (Patel et al., 2022). It will therefore function more effectively than human guards.

**3.10. Scaring birds:** After planting the seeds of various crops, birds pose the biggest challenge. To keep the field protected, labour is required. Birds in fields can be scared off with a few drone flights (Cheke & Sidatt, 2019).

**4. General drone laws in India**

India allows the usage of drones, however, there are a number of drone regulations that must be followed when flying there (Ahirwar et al., 2019). A remote pilot licence issued by DGCA is mandatory for operating any drone, except for drones up to 2 kg weight (used for non-commercial purposes) and drones weighing less than 250 grams (DRONE RULES, 2021). When operating a drone in India that weighs more than 250 grams, operators need to make sure they abide by the following drone legislation (Jain & Saxena, 2020).

* Avoid flying your drone over crowded places or regions with a lot of people (Whitlock, 2014).
* When using your drone, respect the privacy of others (Finn & Wright, 2016).
* • Do not fly your drone within 5 km of airports or in areas where aeroplanes are operating (Pathak et al., 2020).
* You may only fly in excellent weather and during the hours of daylight (Ahirwar et al., 2019).
* Flying a drone in sensitive regions, such as inside military or government buildings, is prohibited (Yaacoub et al., 2020).
* You have to have finished a training program and be no less than 18 years old.
* • Each drone has to have a license plate with the operator's name and contact details (Ahirwar et al., 2019).
* A single UAV can be flown at once (Merkert et al., 2021).
* Drones are not allowed to fly within 50 km of a border.
* Never take your drone within 500 meters out to sea from the shore (Darack, 2012).
* Flying is prohibited in Delhi within 5 km of Vijay Chowk.
* Flying above national parks and wildlife sanctuaries is not advised.
* Every drone needs liability insurance (Ahirwar et al., 2019).).

**5. Conclusion**

Drones have great potential to transform Indian agriculture. The production of drones is projected to become less expensive in the future as technology advances. Young people nowadays are not interested in farming because of the hard work and boredom required. Young people may be interested in and inspired to seek jobs in agriculture by drones. Drones provide superior and more precise aerial images over agricultural regions compared to satellite imagery. Programs for identifying weeds and diseases, assessing soil characteristics, identifying vegetation variations, and producing precise elevation models may now also make use of drones. Farmers will be able to better understand their farms due to drones. As a consequence, farmers may use less pesticides and produce healthier food. Nearly every farmer who has utilised drones has benefited in some way. By getting rid of pests before they destroy entire harvests, optimising irrigation for plants that are stressed by heat, modifying the soil to promote development in areas of trouble, and putting out fires before they get out of control, they may make better use of their land. Therefore, by assisting farmers in more efficient and sustainable land and resource management, drones may potentially play a significant role in agriculture in the future.

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Details of the AI usage are given below:

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