International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

DRONE TECHNOLOGY IN ARGICULTURAL APPLICTIONS

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ABSTRACT

The integration of drone technology in agriculture is revolutionizing farming practices, offering scalable and efficient solutions for precision farming that enhance productivity, sustainability, and resource management. Drones, equipped with cutting-edge sensors, high-resolution cameras, and real-time data analytics, allow farmers to monitor crop health, detect pests and diseases, assess soil conditions, and optimize irrigation and fertilization. This data-driven approach enables precise interventions, reducing resource waste and input costs, while boosting crop yields. Beyond monitoring, drones are increasingly used for autonomous tasks such as seed planting and harvesting, further streamlining operations and reducing labour requirements. The ability to gather and analyze large volumes of data empowers farmers to make informed decisions, improving operational efficiency and mitigating risks associated with environmental factors and climate change. Furthermore, drones promote sustainable agricultural practices by minimizing chemical usage, enhancing soil health, and improving water management. As drone technology continues to evolve, its integration with artificial intelligence (AI), machine learning, and the Internet of Things (IoT) will further refine farming practices, unlocking new opportunities for precision and automation. With on-going investments in technology development, farmer training, and supportive policies, the agricultural sector can harness drones to increase food production, ensure economic viability, and promote environmental stewardship, thus securing a more resilient and sustainable food system for future generations.

Keywords: Drone technology, precision agriculture, sustainable farming, crop health monitoring, autonomous farming, data-driven decision-making, AI, IoT, resource optimization, food security, agricultural efficiency, environmental stewardship.

INTRODUCTION :

By 2050, it is anticipated that there will be nine billion people on the planet, putting an unprecedented burden on the system of food production. During the next three decades, food production will need to dramatically expand by 50% in order to keep up with the exponential population expansion. Despite the productivity of global agriculture, conventional farming practices by themselves are unable to address this issue. Urbanization's loss of arable land, water resource depletion, climate change's consequences, and growing labor costs in rural areas are some of the many stresses. Farming methods need to change drastically if the world's population is to be fed. In order to overcome these obstacles and increase agricultural productivity in a sustainable manner, innovative technologies are now crucial. Drone technology is among the most promising innovations in this shift. Unmanned aerial vehicles (drones).

Drones can monitor crops and farmland in real time because to their array of sophisticated sensors, high-resolution cameras, and other imaging technology. Because of these features, drones are essential to precision agriculture, a farming method that maximizes crop yields and optimizes agricultural inputs using data while reducing waste and environmental effect. Farmers can obtain extremely precise and detailed information regarding crop health, soil conditions, pest infestations, and irrigation needs by using drones. Previously too expensive or time-consuming to do, this degree of in-depth knowledge enables farmers to make data-driven decisions that can significantly increase the sustainability and efficiency of their operations. Additionally, drones offer data collection accuracy that is unmatched by conventional farming techniques.

Drones have also played a significant role in changing how farmers handle disease and pest control. Drones with thermal imaging and high-resolution cameras can swiftly scan fields for indications of diseases or pest damage by hovering over crops. Pesticides are frequently applied indiscriminately in conventional farming, which can result in the emergence of pesticide-resistant soil and pests [TERM PAPER-2024]. pollution, and damage to creatures that are not the intended target, such as pollinators (page 8). More focused and accurate interventions are made possible by drones. Farmers can reduce the overall chemical load on the environment by using real-time data to decide where to implement pest control techniques and, in many circumstances, to apply pesticides more precisely and in lesser quantities.

Drones are being utilized more and more for precision tasks beyond crop monitoring.

Drone technology in agriculture has significant financial advantages. The requirement for manual labour, which can be a major contributor to farm running expenses, is greatly reduced by the automation of field surveys and crop monitoring. Drones can fill the void in areas where labour shortages or rising labour costs are an issue by completing jobs fast and precisely with little assistance from humans. Drones, for instance, can survey hundreds of acres in a few hours, whereas a team of people could need several days to accomplish same task. This labour cost decrease can significantly increase a farm's [TERM PAPER-2024] Page 9 profitability, particularly when paired with the input precision that drones.

In the upcoming years, the market is anticipated to increase at a rate of 38% per year as the agricultural drone sector expands. Government backing, growing demand for sustainable farming methods, and drone technology developments are some of the causes driving this expansion. Drones are becoming more accessible, economical, and adaptable due to technological advancements in both hardware and software, which is promoting their wider use in the agriculture industry. Furthermore, farmers are adopting technologies that can lower their environmental impact while increasing yields as a result of the global push toward sustainable agriculture practices, which is being sparked by worries about food security and the environment. Governments everywhere are actively encouraging the use of drones by offering grants, subsidies, and regulatory frameworks that guarantee their efficiency and safety.

Drone use in agriculture confronts a number of obstacles despite its many advantages. The regulatory environment is one of the main issues. Numerous laws and regulations apply to drone activities, particularly those pertaining to safety requirements and the use of airspace. Although many nations have set rules regarding drone flights, these laws are frequently intricate and can differ greatly between jurisdictions. Drone use may be restricted in some countries by stringent rules, especially when flying over wide areas or at high altitudes. Furthermore, as drones gather enormous volumes of data, including private information about crop conditions and agricultural operations, concerns about data security and privacy are developing. To enable broader drone deployment in agriculture, strong frameworks that address these issues must be established.

DEFINITION, HISTORY AND BASIC COMPONENTS OF DRONE

There are different kinds of unmanned aerial vehicles available and can be categorized into the following groups are Fixed wing, Rotary wing, Tethered vehicle, Lighter-than-air (LTA).There are some differences between drone and satellite i.e., Drones can take pictures with a resolution of a few cm per pixel, whereas commercial satellites have a resolution of 50 cm per pixel. Because drones can fly below the clouds, they can capture images with higher quality and precision in real time, but the presence of cloud affect the satellite imagery. A satellite, after all, only takes photos once a week or once a month.

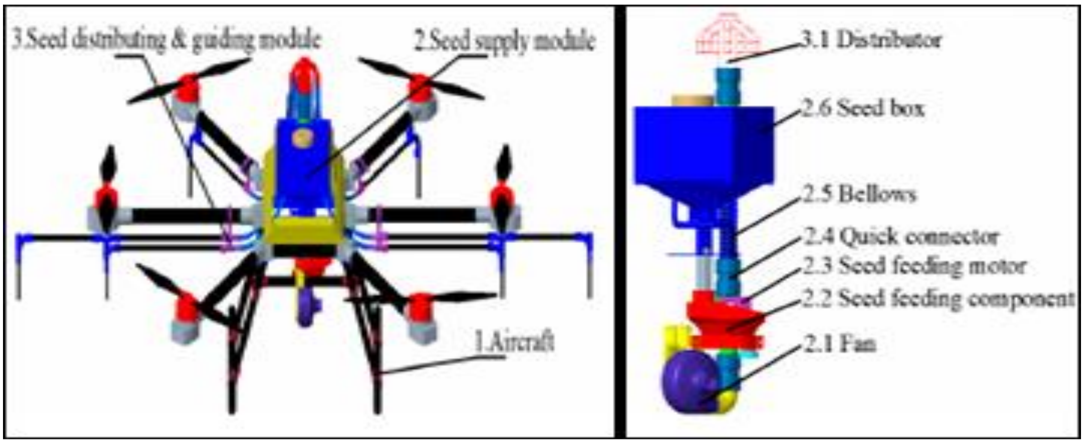

Fig.: Basic components of agricultural drone

APPLICATION OF DRONE IN AGRICULTURE

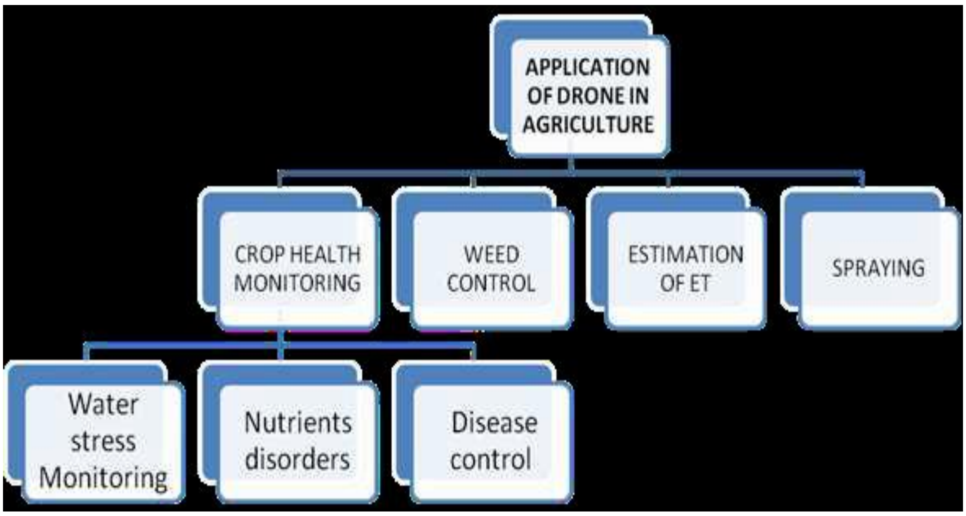

Fig.: Application of drone in agriculture

Crop Health Monitoring

Throughout the crop season, drones can be used to monitor crop conditions so that prompt, need-based action can be made. It is possible to calculate various multispectral indices based on the reflection pattern at various wavelengths by employing various types of sensors related to visible, near-infrared, and thermal infrared radiation. Crop problems like water stress, nutritional stress, insect-pest attack, illnesses, etc., can be evaluated using these indices. Even before outward symptoms manifest, the sensors on the drones can detect the prevalence of illnesses or deficiencies. As a result, they are a tool for early disease identification. Drones might be utilized in this manner as an early warning system to enable prompt action.

Water stress monitoring

Since the impacts of drought are influenced by (and can be influenced by) a number of factors, characterizing water stress on crops is a challenging issue. In order to identify stresses and other phenomena, variables obtained from thermal imaging frequently depend on extremely small temperature changes. Because of this, regression equations and thresholds that are developed under specific conditions typically do not hold under even somewhat different settings. For instance, due to intrinsic variations in stomatal conductance and transpiration rates, different genotypes of a particular crop may exhibit noticeably different canopy temperatures under the same conditions. This is illustrated in the International Journal of ChemicalStudies. To detect water stressors, researchers employed a variety of sensors and models, including:

Using the vegetation and multispectral or hyperspectral photos.

Fig.:water stress monitoring

Nutrient status and deficiencies

In order to flourish and generate a robust crop, plants require the right amounts of nutrients. Appropriate amounts of phosphorous are needed for robust root and stem growth, adequate amounts of potassium are required to increase disease resistance and guarantee higher crop quality, and adequate amounts of nitrogen will guarantee robust growth of vegetation and foliage. The plant will experience stress and find it difficult to flourish if the soil is deficient in any of these nutrients. With the help of NDVI Index mosaics, it is possible to pinpoint the precise crop areas that are under stress or having difficulty and to take direct action to address them. These control zones can be identified by the UAVs' NIR/multispectral imaging well before the UAV's monitoring.

Disease surveillance

Crop diseases, which are categorized as bacterial, viral, or fungal, can be disastrous. Infrared camera-equipped drones can look within plants, providing a clear picture of their state. A farmer can take preventative action, such as removing the plant, if they are able to identify an infection before it spreads to nearby plants. Therefore, when human evaluation is inappropriate, unreliable, or unavailable, image-based technologies can be crucial in identifying and detecting plant diseases, particularly given the increased coverage offered by UAVs. Although hyperspectral and thermal images have also been tested, RGB and multispectral images have been the most popular ways to gather data about the locations under study.

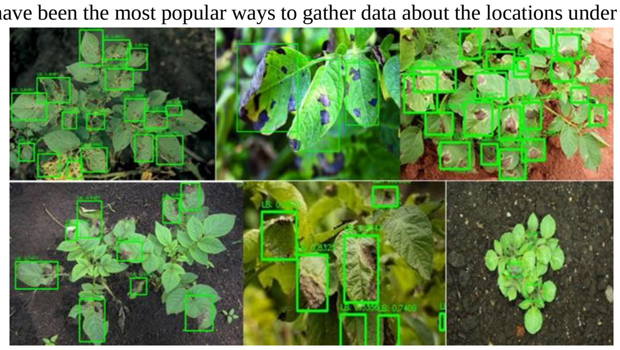

Fig.: Disease surveillance

Weedcontrol

Unwanted plants that develop in agricultural crops and can lead to a number of issues are called weeds. Crop yields and growth are suffering as a result of their competition for resources like water and even space. Rice (10–100%), wheat (10–60%), maize (30–40%), sugarcane (25–50%), vegetables (30–40%), jute (30–70%), potatoes (20–30%), and other crops all experience yield losses as a result of weeds in India [45]. The most common method for controlling weeds is the application of herbicides. The most popular method of managing weeds in conventional farming is to apply the same doses of herbicides throughout the field, even in the weed-free sections, after the weeds have post-emerged. However, excessive pesticide use can lead to the emergence of weeds that are resistant to them, which can have an impact on crops.

Evapotranspiration (ET) estimation with drone

Through transpiration from live plants and evaporation from the soil, evapotranspiration (ET) is a significant mechanism that moves water from the land to the atmosphere. Professionals in the domains of hydrology, agriculture, and water management employ estimates of potential ET. Due to climate change, population growth, and water constraint, evapotranspiration estimation has become one of the most significant agricultural research topics in recent years. Numerous unmanned aerial vehicle types are employed for ET estimate in various research projects. There are generally three types of UAV platforms: quadcopters, fixed-wings, and airplanes. Although aircraft can fly farther and carry more sensors, they are typically more costly. Fixed-wing aircraft and quadcopters are less expensive than airplanes. Usually, fixed-wing aircraft can fly.

Spraying

In order to get high output, spraying Indian agriculture required production and protection products. Chemicals and fertilizers for agriculture are commonly required to eradicate insects and promote crop development. Depending on the field's and crops' spatial heterogeneity, drones can be used to spray chemicals like insecticides and fertilizers. Depending on the crop conditions or the intensity of the insect-pest assault, the quantity of chemicals to be sprayed might be changed. The combination of UAVs and sprayers has the potential to offer a platform for vector control and pest management. This application is precise and site-specific for sizable agricultural fields. Heavy lift UAVs are needed for this purpose in order to spray a vast area. Spraying chemicals to kill pests and unwanted plants like weeds is now critical for crop health. For quicker spraying, drones can carry appropriately sized reservoirs that can be filled with fertilizers, pesticides, herbicide, plant growth regulators (PGRs) etc. Sometimes manual spraying operations are very difficult because of the crop's height, so smart farms use drones for spraying, which reduces the contact of humans with fertilizers, pesticides and other harmful chemicals (Pathak et al., 2020). Spraying capacity is up to five times faster than traditional machinery and completes a spraying in a 1 ha field in less than 40 minutes. It saves 30% pesticide.

Fig.: Spraying pesticides

METHODOLOGY

Research Design

In order to guarantee a thorough grasp of drone applications in agriculture, the study uses a mixed-methods approach, combining qualitative and quantitative data collection techniques.

Measure the effectiveness of drones in applying pesticides by conducting trials.Crop health improvement, area coverage, and pesticide use are some of the variables.operating speed, droplet size homogeneity, flight duration, and cargo capacity.Get input on usability, financial advantages, and difficulties from farmers, agricultural specialists, and drone operators.To comprehend the usefulness and practical difficulties of drone operations, observe them in various agricultural environments.Based on the ideas of Smart Agriculture, the study uses ICT, AI, and IoT technologies to enhance food production. Because of their ability to improve accuracy and productivity in agricultural chores, drones are evaluated as a crucial element within this framework.Ideal for extensive surveying and mapping.Rotary-wing drones, such as quadcopters and hexacopters, are preferred for specialised tasks like spraying pesticides.Sensors (multispectral cameras), nozzles, flight controls, and GPS systems will be among the main parts assessed.

Data Collection Methods

Use drones to carry out controlled studies in agricultural fields.Compile information on crop health, yield enhancements, and pesticide distribution.For agricultural monitoring, use drones fitted with multispectral and hyperspectral camera's.To evaluate crop health and pinpoint regions that need pesticide application, analyse photos using the Normalised Difference Vegetation Index (NDVI).Gather qualitative information from farmers and agricultural specialists to assess the economic advantages and usage of drones.Evaluate the length of the flight, the payload capacity, and the effectiveness of the spraying.To evaluate the effectiveness of drone systems, record information on pesticide usage and coverage area.

Examine the effectiveness of various droplet sizes and nozzle types in a range of scenarios.

Sample Selection

Select a variety of agricultural areas to test drones in a range of topographical and climatic circumstances.Pay attention to crops (such as rice, wheat, and maize) that are frequently impacted by pets and diseases. Incorporate farmers with fields of various sizes and degrees of technological usage.To guarantee a thorough investigation, test various drone models and setups. Include drones with varying technology and spraying capacity (e.g., fixed-wing vs. rotary-wing).

Applications of drones in agricultural sector

Drones equipped with sensors (e.g., multispectral, NIR, thermal infrared) can monitor crop conditions such as water stress, nutrient deficiencies, pests, and diseases.Thermal cameras and multispectral sensors are used to detect water stress by analyzing temperature variations and vegetation indices.Nutrient Deficiency Monitoring:Multispectral and hyperspectral imagery can identify stressed areas in crops due to nutrient deficiencies, allowing targeted interventions before yield loss occurs.

Infrared and thermal imaging helps in the early detection of crop diseases by capturing stress signals from plants, enabling timely management.Drones with hyperspectral and RGB sensors can map weeds, enabling precise herbicide application only in affected areas, reducing chemical use and environmental impact.UAVs provide high-resolution thermal and multispectral images to estimate ET rates, aiding water management in agriculture.Drones equipped with spray systems can apply fertilizers, pesticides, and herbicides accurately and efficiently, reducing human exposure to harmful chemicals and minimizing environmental impact.

CONCLUSION :

DroneshavethepotentialtorevolutionizeagricultureinIndia. Future technological developments are anticipated to make drone manufacturing more affordable. Because farming requires a lot of labour and hardship, modern youngsters are not drawn to it. Drones have the potential to captivate and inspire young people to pursue careers inagriculture. Compared to satellite imagery over agricultural areas, drones offer high-quality, real-time aerial imagery. Additionally, drones are currently being used for applications such as weed and disease localization, soil property determination, plant difference detection, and the creation of precise elevation models. Farmers will be able to learn more about their farms thanks to drones. As a result, farmers will receive support to produce more food with fewer chemicals. Almost all farmers who have used drones have benefited in some way. They can manage their land more effectively, eradicate pests before they kill entire crops, increase irrigation for plants that are stressed by heat, improve soil quality to boost growth in troubled regions, and monitor fires before theybecomeoutofhand.Drones could therefore become a commonplace aspect of agriculture in the future by assisting farmers in more sustainable and effective field and resource management.

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