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Review paper

Application of Modern Techniques, Drones and IoT in Indian Agriculture

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ABSTRACT

India's vast agricultural sector is on the cusp of a transformation. Modern techniques like drones and the Internet of Things (IoT) are poised to revolutionize the way farmers manage their land, optimize resources, and boost yields. This fusion of technology and traditional practices holds immense potential to address longstanding challenges in Indian agriculture, ensuring food security for a growing population and empowering farmers toward a more sustainable and profitable future. Drones are being used to collect data on crop health, soil conditions, and water levels. This data can be used to create detailed maps of farms, which can help farmers to identify areas that need attention. Drones can also be used to spray pesticides and fertilizers, which can save farmers time and money. IoT devices are being used to track the movement of livestock and to monitor their health. This data can help farmers to identify sick animals early on, so that they can be treated promptly, IoT devices can also be used to monitor the temperature and humidity of greenhouses, which can help farmers to create optimal growing conditions for their crops.

1. Introduction

Drones and the Internet of Things (IoT) are rapidly transforming the Indian agricultural sector. These technologies are enabling farmers to monitor their crops and livestock more effectively, make informed decisions about irrigation and fertilization, and improve their overall efficiency (Van Der Merwe et al., 2020). Drones are being used to collect data on crop health, soil conditions, and water levels. This data can be used to create detailed maps of farms, which can help farmers to identify areas that need attention. Drones can also be used to spray pesticides and fertilizers, which can save farmers time and money (Aghababyan, K., 2016). IoT devices are being used to track the movement of livestock and to monitor their health. This data can help farmers to identify sick animals early on, so that they can be treated promptly. IoT devices can also be used to monitor the temperature and humidity of greenhouses, which can help farmers to create optimal growing conditions for their crops (Drones in agriculture, n.d. [3]). The use of drones and IoT in Indian agriculture is still in its early stages, but the potential benefits of these technologies are enormous. By using these technologies, farmers can improve their yields, reduce their costs, and make their operations more sustainable. Drones are being

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used to monitor the health of crops and to identify areas that need irrigation or fertilization (Drones in agriculture, n.d. [4]). Drones are being used to spray pesticides and fertilizers, which can save farmers time and money. IoT devices are being used to track the movement of livestock and to monitor their health. IoT devices are being used to monitor the temperature and humidity of greenhouses. The use of drones and IoT in Indian agriculture is still in its early stages, but the potential benefits of these technologies are enormous (Drones, n.d. [5]). By using these technologies, farmers can improve their yields, reduce their costs, and make their operations more sustainable.

India's vast agricultural sector is on the cusp of a transformation (Fish culture, n.d.). Modern techniques like drones and the Internet of Things (IoT) are poised to revolutionize the way farmers manage their land, optimize resources, and boost yields. This fusion of technology and traditional practices holds immense potential to address longstanding challenges in Indian agriculture, ensuring food security for a growing population and empowering farmers toward a more sustainable and profitable future (Hafeez, A., et al., 2023). This introduction sets the stage for your exploration of how drones and IoT are being implemented in Indian agriculture (Joseph, et al., 2021). It highlights the key challenges the technology aims to address and the potential benefits for both farmers and the nation as a whole (Krishna et al., 2018).

2. What is Drone?

A drone is an unmanned aerial vehicle (UAV) that can fly autonomously or be remotely controlled by a human operator (Krishna et al., 2018). They come in different sizes, shapes, and configurations, and can be equipped with various sensors, cameras, and other types of equipment depending on their intended use (Nations, F. A. A. O. O. T. U., 2018). They are commonly powered by electric motors and rechargeable batteries, and they can fly at different speeds and altitudes, depending on their design and purpose. Moreover, they work by using a combination of hardware and software components that allow them to take off, fly, and land safely. They typically have a flight controller that regulates their movements and behavior, as well as GPS sensors that provide location data for navigation (Rejeb, A., et al., 2022). Sometimes, they also have cameras, obstacle avoidance sensors, and other types of sensors that allow them to capture images, detect obstacles, and avoid collisions (Shah, 2023).

2.1 Drones in Agriculture

Drones are increasing productivity and crop yield in the agricultural industry. From real-time data to healthier plants, UAS are literally growing more plants.There are numerous ways drones are assisting the agriculture industry. That's important for a few reasons. The current population of the world is over 7.6 billion. And, by 2050, most experts believe food production will need to double, to meet growing demand. Unfortunately, food distribution is not evenly spread across the globe. However, there is technically enough food to feed all 7.6 billion people. Though, that won't be the case once an additional two billion people require sustenance. By some estimates, global food production will need to increase by between 60-100%. The Earth's entire surface area is around 51.01 billion hectares. To put that into perspective, one hectare equals 2.471 acres. Without updating current agricultural practices, doubling the world's food production would require the clearing of approximately one billion hectares of land… mostly rainforests and savannas. Obviously, clearing more land is not a viable solution. The removal of such an enormous amount of forest would certainly have a significant negative impact on climate change. The only hope for meeting the world's future demands for food is precision agriculture.

2.2 Drones are at the fore front of that movement

Precision agriculture uses technology to accurately measure and study crop production. The data gained in these observations allows for better crop and farm management. As a result, production yields increase without the need to consume more land.

2.3 The Role of Drones in Agriculture:

Some of the more common agricultural applications for UAVs include pest control, plant health monitoring, livestock management, soil analysis, and aerial survey. One of the best examples to illustrate successful drones usage in agriculture is plant health monitoring. The health of a farmer's crops is of critical importance to achieving the highest yields. There

exists a wide range of circumstances that can adversely affect crop yield. Crops are susceptible to pathogens, fungus, and insects. Improper levels of carbon and nitrates in the soil also impact a plant's productivity. Even a lack of proper water levels can cause an otherwise fertile field to produce lackluster results. Traditionally, farmers monitored all these conditions through visual observations and soil analysis. Visual inspections are very time consuming, and they depend on the observer's skills at detecting the signs of potential problems. This method is extraordinarily inefficient for large-scale farming operations. Soil analysis can take even more time than visual inspections.

Trained professionals must take samples, which are often analyzed in a laboratory. Inevitably, the time required by this process creates a lag in data. Thus, there is no real-time information available to the farmer as it pertains to the crops on a given day. UAVs can perform all the above tasks in real-time, utilizing a combination of RBG cameras, thermal imaging, and multi-spectral imaging. With the proper equipment, a drone operator can fly over a field and present the farmer with a full report covering everything from plant count to health conditions Drones provide real-time and accurate data that farmers can act on immediately. They are truly a disruptive technology that is at the beginning of revolutionizing precision agriculture as we know it.

2.4 The Future of drones

Research and innovation create pathways for drones to assist in agriculture all of the time. In Japan, scientists created insect-size drones capable of pollinating flowers in the same manner as bees. The drones use GPS to select the optimal flight path for pollinating all plants in a given area. As the world faces a crisis in dwindling bee populations, drones may very well become a replacement pollinator. Only a few years ago, in early 2020, a team in Canada announced the development of a drone used for planting trees. Using a pressurized air cannon, the team successfully fired small pods of seeds into the ground. The group estimates a single drone operator would be capable of planting 100,000 seed pods per day, with the goal of planting one billion trees by 2028.

The agricultural community is just scratching the surface of what drone technology can provide to the industry. As research continues and engineers find new ways to integrate aerial data collection into farming operations, we are likely to see significant jumps in crop production. Now is the ideal time for stakeholders and decision makers involved in agriculture to consider the integration of UAS technology into their operations. With low barriers to entry, and the promise of greater efficiencies, it will soon be difficult to imagine successful operations without drones.

2.5 Mapping and surveying in farm by drone

Drone mapping and surveying are revolutionizing farm management by offering a quicker, more affordable, and data-rich alternative to traditional methods.

2.5.1 Data Collection

High-resolution Images: Drones equipped with high-resolution cameras capture detailed images of your entire farm. These images are then stitched together using photogrammetry software to create high- resolution orthomosaics, which are essentially precise maps from aerial photographs. 3D Modeling:
Detailed Terrain Maps: Drones can also capture data to generate 3D models of your fields. This allows you to visualize elevation changes, slope variations, and other topographical features that may not be apparent in traditional 2D maps.

2.5.2 Field Boundaries and Area Measurement

Accurate Field Mapping: Drone-captured data can be used to create highly accurate maps of your field boundaries. This is crucial for farm management purposes, such as calculating field area for planting purposes or complying with land use regulations.

2.5.3 Benefits of Drone Mapping and Surveying

Increased Efficiency: Compared to traditional ground surveying methods, drones can collect data over large areas much faster and with less manpower.

Improved your farm's topography, soil variability, and potential problem areas. This information can be used to make informed decisions about planting strategies, resource allocation, and irrigation management.

Precision Agriculture: Drone-derived maps can be used to implement precision agriculture practices. By identifying areas with Decision Making: The detailed data obtained from drone mapping provides valuable insights into different soil characteristics or crop health, farmers can apply fertilizers, pesticides, and water more precisely, reducing waste and optimizing resource use.

2.6 Additional Applications

Volume Measurements: Drone-derived 3D models can be used to calculate stockpile volumes, such as grain or silage heaps, quickly and accurately.

Drainage Analysis: By analyzing elevation data, drone surveys can help identify areas with potential drainage problems, allowing for better irrigation management. Overall, drone mapping and surveying offer a powerful tool for farmers to gain a deeper understanding of their land, optimize resource use, and improve farm management practices.

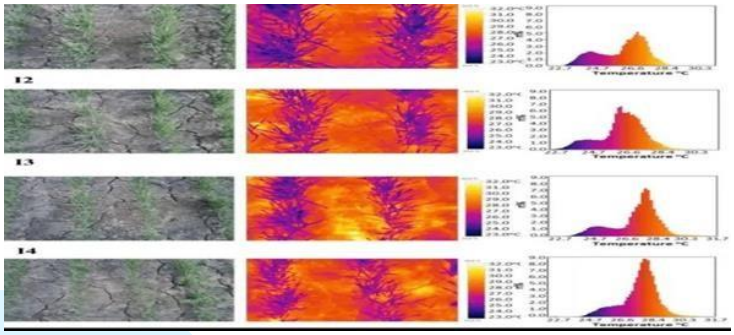
2.7 What is drone mapping and How does drone surveying work?

Drone mapping is the use of a drone to create a 3D representation of an area. It is also the use of unmanned aerial vehicles (UAVs) to capture high-quality imagery and data. Drone imaging are often used for surveying and mapping construction sites, but they can also be used to capture images of other areas, such as farmland, forests, or even cities.The drone uses various sensors to create a more accurate image than a satellite or aerial survey would be able to create. The images are then analyzed and processed by software to create the 3D model.

2.8 Drone imaging can be used for a variety of purposes

- Landscape architecture – Drone imaging is often used in landscape architecture to design public parks and gardens.
- Urban planning – Drones can take aerial photographs and video footage of cities to help urban planners plan future developments.
- Architecture – Architects can capture detailed 3D models of buildings before they go up using this technology.
- The use of drones for mapping offers several advantages over traditional methods such as satellite images or ground surveys.
- Drone imaging provide high-resolution data which can be used to create accurate maps. This technology is

2.9 Soil analysis by thermal image to captured by drones



Thermal imaging with drones can be a useful tool for soil analysis, but it provides information on specific aspects of soil health rather than a complete picture (Spraying pesticides, n.d.).

Temperature detection: Drones equipped with thermal cameras capture images based on the temperature variations of the ground below. Since temperature is influenced by several factors, including soil properties, this data can be indirectly linked to soil health.

Moisture content: One of the primary applications of thermal imaging in soil analysis is estimating soil moisture. Moist soil retains heat better than dry soil, so areas with higher temperatures in the thermal image likely indicate higher moisture content.

Drainage issues: Thermal images can help identify areas with poor drainage. Wet areas will retain heat longer and show as warmer spots on the image.

2.10 Limitations

Indirect measurement: Thermal imaging provides an indirect measurement of soil properties. Other factors like surface composition and sun exposure can also affect the temperature captured.

Data interpretation: Analyzing thermal data requires expertise and often needs to be combined with other data sources, like trade.

Crop health assessment: Drones equipped with multispectral or thermal cameras can capture data on crop health. This allows farmers to identify areas with nutrient deficiencies, diseases, or pest infestations early on, enabling them to take targeted action (Van Der Merwe et al., 2020).

Field scouting: Drones can quickly cover large areas, providing farmers with a bird's-eye view of their fields. This helps them identify potential problems and assess crop growth and development.

Irrigation monitoring: Drones can be used to monitor irrigation systems for leaks or uneven water distribution. This helps farmers optimize water usage, a crucial factor in areas with water scarcity.

Field mapping and analysis: Drones can create detailed maps of fields, including data on elevation and soil composition. This information can be used for precision agriculture practices, such as variable-rate fertilization, where fertilizers are applied based on the specific needs of different areas of the field.

Planting: Some drones are being developed for planting seeds. This can be particularly useful for uneven terrain or hard-to-reach areas.

Livestock management: Drones can be used to monitor livestock herds, check on the health of animals, and ensure their safety and security.

Spraying: Drones can be equipped to spray pesticides, herbicides, and fungicides. This can be a more targeted and efficient way to apply these chemicals compared to traditional methods, reducing waste and environmental impact (Yokoyama, 2010).

Overall, drones are transforming agriculture by providing farmers with new tools to improve efficiency, increase yields, and make more informed decisions.

3. Use of drones for spraying pesticides in the field

Drones are becoming a game-changer in terms of spraying pesticides in fields.

Targeted Spraying: Unlike traditional methods that broadcast pesticides over entire fields, drones can apply them directly to targeted areas. This minimizes waste and reduces the risk of harming beneficial insects or contaminating surrounding areas.

Variable Rate Application: Drones equipped with advanced sensors can adjust the amount of pesticide applied based on real-time data on crop health and pest infestation levels. This ensures that only the necessary amount of pesticide is used, further reducing waste and environmental impact.

Increased Efficiency and Safety: Faster Coverage: Drones can cover large fields quickly and efficiently, saving farmers time and labor compared to ground-based spraying methods.

Difficult Terrain Accessibility: Drones can easily navigate uneven terrain or reach areas inaccessible to tractors or other machinery, ensuring complete coverage of the field.

Reduced Worker Exposure: By eliminating the need for workers to directly handle and apply pesticides, drones significantly reduce their exposure to potentially harmful chemicals.

3.1 Additional Advantages

Reduced Drift: Drones can fly closer to the crop canopy compared to airplanes, minimizing the risk of pesticide drift to nearby areas or bodies of water.

Improved Crop Health: Targeted and precise application of pesticides can lead to improved crop health and potentially higher yields.

3.2 Challenges and Considerations:

Regulations: Drone use for pesticide application is a relatively new technology, and regulations are still evolving in many regions. Farmers need to be aware of and comply with all applicable regulations.

Battery Life: Current battery technology limits the flight time of drones, so they may not be suitable for very large fields.

Weather Conditions: Wind and rain can affect the accuracy and effectiveness of drone spraying**.** Overall, drone spraying offers a promising approach for precise, efficient, and safe pesticide application in agriculture. As technology advances and regulations become more established, drone use is likely to become even more widespread in the farming industry.

4. The fertilizer by drone to interrupt in field

Fertilizer application by drone is a growing trend in precision agriculture, offering several advantages over traditional methods:

4.1 Targeted Application

Precision Dosing: Drones can be equipped with specialized spreading mechanisms that allow for

controlled release of fertilizers. This ensures that fertilizers are applied only where needed, at the desired rate, minimizing waste and environmental impact.

Reduced Soil Compaction: Traditional methods often involve heavy machinery driving through fields, which can compact the soil. Drones eliminate the need for this, promoting healthier soil structure and potentially improving crop yields.

Difficult Terrain Accessibility: Drones can easily navigate uneven terrain or reach areas inaccessible to ground machinery, ensuring uniform fertilizer application across the entire field.

4.2 Efficiency and Cost Savings

Faster Application: Drones can cover large areas quickly and efficiently, significantly reducing the time and labor required for fertilizer application compared to traditional methods.

Reduced Labor Costs: The use of drones can minimize the need for manual labor, potentially leading to cost savings for farmers.

Fuel Efficiency: Drones are generally more fuel-efficient than tractors or other ground-based application equipment.

4.3 Safety Benefits

Reduced Worker Exposure: By eliminating the need for workers to be directly involved in fertilizer application, drone technology reduces their exposure to potentially harmful chemicals. It's important to note that intercepting fertilizer application by drone on another farm is illegal and unethical. Fertilizers are essential for crop growth, and interfering with their application could harm the farmer's livelihood. However, if you're concerned about fertilizer drift from a neighboring farm landing on your property, here are some legitimate courses of action:

Talk to the Farmer: A friendly conversation with your neighbor about your concerns is often the best first step. They may be unaware of the drift and willing to adjust their application methods to minimize the impact on your property.

Contact Local Authorities: If you have concerns about the type of fertilizer being used or believe the application violates local regulations, you can contact your local agricultural extension office or environmental protection agency. Overall, drone technology offers a promising approach for precise and efficient fertilizer application in agriculture. However, it's crucial to use this technology responsibly and ethically.

5. To controlled fish culture by drones

Drones offer several exciting possibilities for monitoring and managing fish farms, but they can't directly control fish culture in the way a human might.

5.1 Monitoring and Data Collection

Fish Health: Drones equipped with multispectral or thermal cameras can monitor water quality and temperature, which are crucial factors for fish health. They can also identify areas with low oxygen levels or potential algal blooms.

Growth Tracking: Advanced drones with AI-powered image analysis can track fish size and growth patterns over time. This data helps fish farmers optimize feeding strategies and predict harvest times.

Inventory Management: Drones can be used to count fish stock quickly and accurately, reducing the need for manual counting methods that can be stressful for the fish.

Enhanced Management Techniques:

Feeding Management: While direct drone feeding of fish isn't yet common, some systems are being developed for automated feeding based on drone data on fish health and growth.

Disease Detection: Early detection of disease outbreaks is critical in fish farming. Drones can monitor fish behavior and water quality to identify potential problems early on, allowing for prompt intervention.

Security and Predator Deterrence: Drones can be used to patrol aquaculture sites, deterring predators like birds or other animals.

5.2 Limitations to consider

Direct Fish Control: Drones cannot directly control fish movement or behavior. They are primarily data collection and monitoring tools.

Environmental Factors: Wind, rain, and other weather conditions can affect drone operation and data collection.

Regulations: Drone use in aquaculture may be subject to specific regulations regarding airspace restrictions and data privacy.

Overall, drones are a valuable tool for fish farmers, providing a new level of insight into fish health, water quality, and overall farm management. As drone technology and data analysis techniques continue to develop, we can expect even more innovative applications for aquaculture in the future.

Drones, also known as Unmanned Aerial Vehicles (UAVs), can be used to collect data on crop health monitoring systems by providing real-time insights into crop health and growth patterns. Drones can:

Detect pests and diseases: Drones can cover large areas quickly, providing a comprehensive overview of crop health.

Manage water: Drones can assess soil moisture levels with remote sensing technologies. This data can help farmers identify areas that may need more or less irrigation.

Apply targeted pesticides

- Drones can precisely target affected areas, minimizing the dispersion of chemicals.
- Drones can provide accurate field mapping including elevation information that allow growers to find any irregularities in the field.
- Monitor nitrogen levels, Some agricultural drone retailers and service providers also offer nitrogen level monitoring in soil using enhanced sensors.

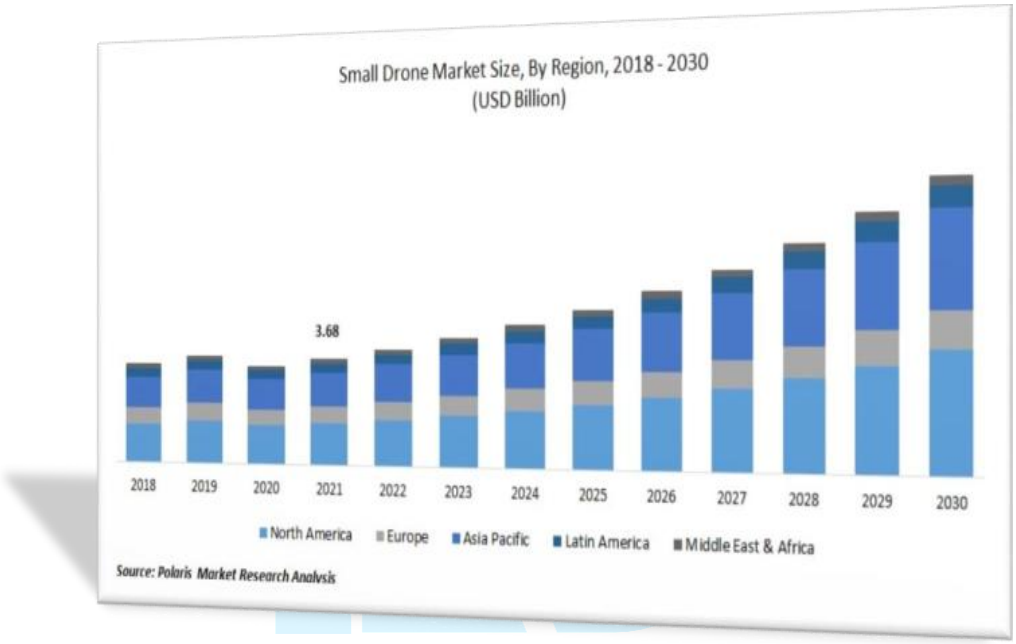


Table : Drones market in the world.

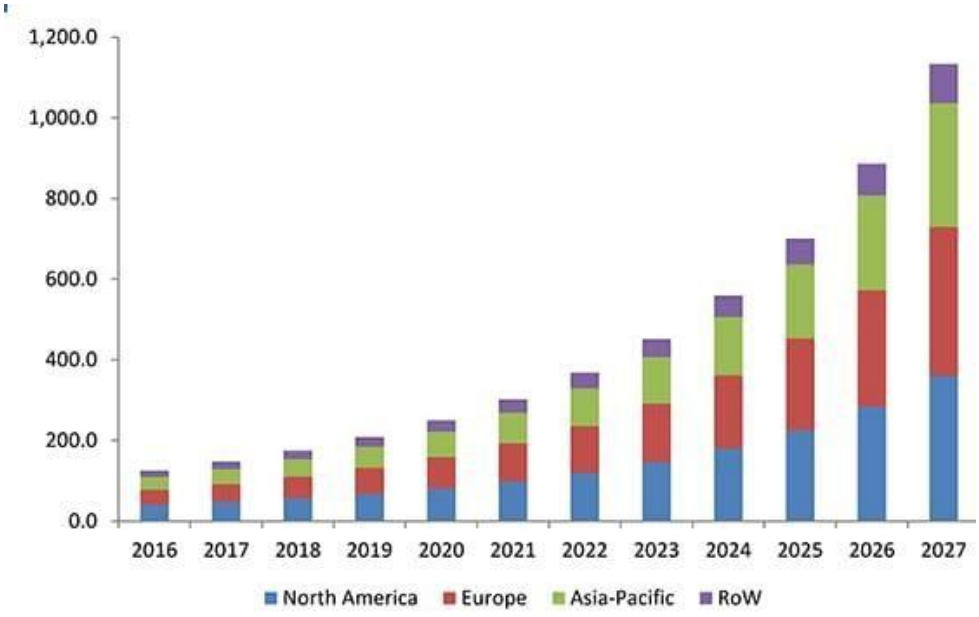
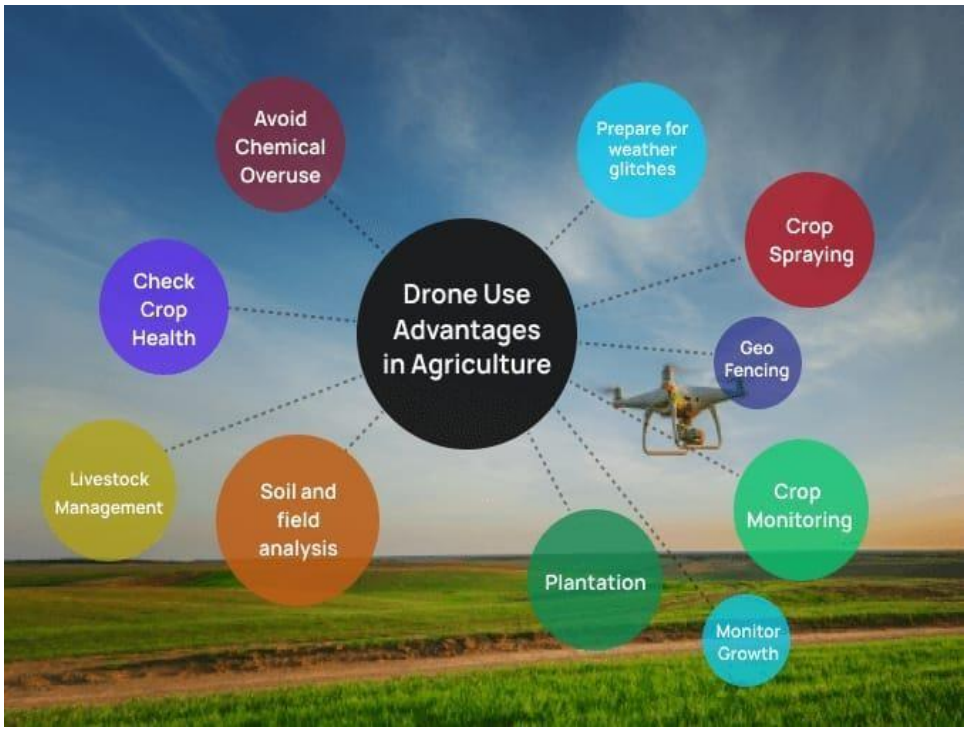


***Table*:** Usage of drone in agriculture.

Characteristics	Type of Sensor							
	Lidar	Radar	Ultrasonic	Monocular Camera	Stereo Camera	Omni-directional Camera	Infrared Camera	Event Camera
Illumination	-	-	-	Yes	Yes	Yes	No	Yes
Weather	Yes	No	-	Yes	Yes	Yes	Yes	Yes
Color and texture	No	No	No	Yes	Yes	Yes	No	No
Depth Information	Yes	Yes	Yes	No	Yes	No	No	No
Area of coverage (m)	<200 m	<200 m	<5 m	Range operational environment dependent	<100 m	Range operational environment dependent	Range operational environment dependent	Range operational environment dependent
Level of accuracy	High	Medium	Low	High	High	High	Low	Low
Size	Large	Small	Small	Small	Medium	Small	Small	Small
Affordability	Low	Medium	High	High	High	High	High	High

Table : Typpes of sensor use in drones



6. Observation

India is rapidly adopting modern technologies to revolutionize its agriculture sector. Drones, equipped with sensors and cameras, are being used for crop monitoring, spraying pesticides and fertilizers efficiently, and creating detailed land maps. IoT devices are transforming farming by providing real-time data on soil moisture, temperature, and crop health. This precision agriculture approach optimizes resource utilization, increases yields, and reduces environmental impact. Farmers can make informed decisions, detect problems early, and improve overall farm management through these advanced tools.

7. Conclusion

Drones and IoT are poised to revolutionize Indian agriculture. By promoting efficiency, precision, and sustainability, these technologies offer a path towards a brighter future for farmers and the nation as a whole. By addressing the existing challenges and fostering a collaborative approach, India can leverage these innovations to ensure food security, empower farmers, and cultivate a more sustainable agriculture.

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