



(A No. 162) Use of Drones and Remote Sensing in Precision Extension

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ABSTRACT

Agricultural extension services are vital for improving farm productivity, sustainability and farmer livelihoods by facilitating the transfer of knowledge and technologies. However, conventional extension approaches often face limitations related to outreach, timeliness, cost and location-specific advisory delivery. The digital transformation of agriculture, particularly the integration of drones and remote sensing technologies, offers new opportunities to strengthen precision extension. These tools enable rapid, high-resolution collection of data on crop health, soil variability, water stress, pest incidence and climatic conditions, supporting timely, data-driven decision-making and efficient resource use. Although drone-based systems can be fragmented and task-specific, their integration with artificial intelligence, big data analytics, the Internet of Things and other digital technologies is advancing smart agriculture solutions. Within this framework, drones and remote sensing enhance real-time monitoring, targeted interventions and effective communication between extension agents and farmers. This article examines the applications, benefits, challenges and future potential of drones and remote sensing in promoting sustainable and resilient precision extension systems.

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DIFFERENT TYPES OF AGRICULTURE DRONES

- **Fixed-Wing UAV:** Operates like an airplane and is suitable for covering large agricultural areas. It offers long flight duration and is mainly used for crop mapping and large-scale surveys.
- **Helicopter UAV:** Uses a single main rotor and provides good stability with higher payload capacity. It is suitable for precision spraying and operations requiring longer hovering time.
- **Multi-copter UAV:** Equipped with multiple rotors, allowing vertical take-off and landing with high maneuverability. It is widely used for crop monitoring, imaging and spot spraying.
- **AI-Integrated UAV:** Embedded with artificial intelligence algorithms for real-time data processing and decision-making. It enables automatic detection of crop stress, pests and diseases.
- **GPS-Based Autonomous Drone:** Uses GPS navigation to fly along pre-programmed routes with minimal human intervention. It ensures accurate field coverage and repeatable operations for mapping and spraying.



DRONES'S ROLE IN AGRICULTURAL EXTENSION

- **Crop Health and Monitoring Assessment:** Drone-mounted multispectral, hyperspectral, and thermal sensors enable early detection of crop stress, diseases and nutrient deficiencies using vegetation indices such as NDVI.
- **Precision Agriculture:** UAVs enable site-specific application of inputs based on real-time field data, improving resource efficiency, reducing costs and environmental impact and enhancing crop yield.
- **Soil and Field Analysis:** Drones equipped with LiDAR, multispectral, and thermal sensors generate high-resolution soil and field data for accurate mapping, fertility assessment and moisture analysis, supporting site-specific land and nutrient management.
- **Disaster Management:** Drones provide rapid assessment of crop damage during floods, droughts, pest outbreaks and other disasters, enabling timely intervention, efficient resource allocation and improved recovery planning.
- **Extension Service Delivery:** Drones enhance extension services through visual demonstrations, real-time monitoring, and virtual farm visits, improving farmer understanding, participatory learning and technology adoption.

REMOTE SENSING IN AGRICULTURAL EXTENSION

- **Large-Scale Crop Monitoring:** Satellite-based multispectral and hyperspectral imagery enables large-area assessment of crop health, biomass, and stress conditions, supporting early detection of nutrient deficiencies, water stress and pest incidence, as well as yield forecasting and long-term productivity analysis.
- **Drought and Water Management:** Satellite remote sensing supports monitoring of soil moisture, rainfall,

evapotranspiration, and surface water availability, enabling early drought warning, improved irrigation scheduling and effective water conservation planning.

- **Climate and Weather Forecasting:** Satellite observations provide short- and long-term weather forecasts and early warnings of extreme events, assisting farmers in timely decisions related to sowing, irrigation, harvesting and climate risk management.
- **Land Use and Soil Mapping:** Satellite imagery supports soil classification, land suitability assessment, erosion monitoring and land-use change detection, aiding sustainable land management and long-term agricultural planning.
- **Pest and Disease Surveillance:** Remote sensing enables early identification of pest and disease outbreaks through detection of crop stress patterns, allowing timely interventions, reduced crop losses and improved effectiveness of pest management strategies.

BENEFITS OF APPLYING DRONES AND REMOTE SENSING

- **Better Decision-Making:** Real-time, high-resolution data supports informed decisions on crop health, irrigation, pest control and input management.
- **Cost and Time Savings:** Reduced dependence on frequent field visits lowers labor costs and improves monitoring efficiency.
- **Improved Precision Farming:** Site-specific application of inputs minimizes wastage, reduces environmental impact and increases crop productivity.
- **Sustainability:** Optimized resource use and reduced chemical application promote soil conservation and environmentally sustainable farming.
- **Early Pest and Disease Detection:** Multispectral and hyperspectral imagery enables early identification of crop stress and infestations for timely intervention.



- **Scalability and Affordability:** Satellite imagery supports large-scale monitoring, while drones provide detailed field-level insights suitable for all farm sizes.
- **Climate and Disaster Resilience:** Continuous monitoring of weather extremes and natural hazards enhances preparedness and climate-resilient farming.
- **Enhancement of Extension Services:** Digital tools enable virtual training, real-time advisories and improved outreach to farmers.

CHALLENGES AND LIMITATIONS

- **High Initial Cost:** High costs of drones, sensors, software and satellite data limit adoption, especially among smallholders and extension agencies.
- **Technical Competence:** Effective use requires specialized skills in drone operation, data analysis and digital literacy.
- **Regulatory Constraints:** Strict airspace regulations and lengthy approval processes restrict operational flexibility.
- **Data Processing and Interpretation:** Large data volumes demand advanced analytical tools and skilled personnel for meaningful decision-making.
- **Connectivity and Infrastructure:** Limited internet access and weak digital infrastructure in rural areas hinder timely data use and advisory delivery.

FUTURE PROSPECTS AND RECOMMENDATIONS

- **Policy Support:** Supportive policies and financial incentives are essential to promote large-scale adoption of drone and satellite technologies.
- **Capacity Building:** Targeted training programs are required to develop technical skills among extension agents and farmers.
- **Public-Private Partnerships:** Collaboration between government, research institutions, and private firms

can accelerate innovation and technology dissemination.

- **Integration with AI and IoT:** Combining drone and satellite data with AI and IoT enhances predictive analytics and precision-based farm management.

CONCLUSION

Drone and satellite imagery are transforming agricultural extension by providing accurate, timely and large-scale information on crop and field conditions. Despite existing challenges related to cost, technical capacity, and infrastructure, continued technological advancements and supportive policy frameworks can facilitate their wider adoption. The effective integration of these technologies into extension systems has the potential to enhance agricultural productivity, promote sustainable resource management and strengthen climate resilience in farming systems.

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