AGRICULTURAL AND BIOTECHNOLOGICAL REFLECTIONS

ADVANCING DRONE-BASED IMAGING SYSTEMS FOR REAL-TIME CROP MONITORING AND PRECISION MANAGEMENT: INNOVATIONS, APPLICATIONS, AND FUTURE DIRECTIONS IN SMART AGRICULTURE

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Abstract	Article History
Agricultural drones represent a disruptive technology that is essential in addition to the critical transition from animal to mechanical traction in agricultural practices. These devices offer unique operational capabilities which cover both target-area zonation through producer-defined requirements and rapid land area scanning at 80 hectares per hour. This technology functions at a basic level that enables all level of farmers to operate it. This article examines future prospects of the technology while considering current advancements and tools as well as describing how producers are using drones.	

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INTRODUCTION

All scientific evidence suggests that female food gatherers worldwide turned into plant tenders during the time period of 20,000 to 30,000 years ago for valuable food-producing and health-promoting plant species and fiber-producing species. The initial stage of domestication developed when women picked seeds from vegetation showing the best characteristics. During the period of 10000 to 12000 years domesticated female farmers in at least four global regions managed the cultivation of plants. The first internal combustion engine tractor was invented by John Froelich during 1892 while he managed to sell only two units. Historians agree John Froelich invented the tractor during 1892 but he managed to sell only two of his creations. Agricultural drones only entered agricultural practice during the 1980s for crop and field mapping purposes. Forecast models suggest a human population growth to 8.5 billion for 2030 then 9.7 billion for 2050 before reaching 10.4 billion by 2100. Future generations will face food production challenges among various other issues that stem from this situation. The world may use drone technology as a tool to reach its global food requirements during upcoming decades. To nourish nine billion people who represent 70% of the world population in 2050 farmers worldwide must increase their agricultural output by three times because natural resources continue to decrease. From 2006 levels agricultural output needs to expand by 70% as declared by the United Nations Food and Agriculture Organization (FAO). Agriculture encounters disruption as robots along with automated systems enter the field. The agricultural benefits from automation become clear as customers pay fewer prices for food while environmental impact declines and work expenses decrease over time. Modernization of the agricultural industry has become possible through technology advances including controlled environment agriculture systems and weeding robots and autonomous tractors. The Internet of Things (IoT) and aerial photography along with smart greenhouses among other modern agriculture techniques enable successful connection and information exchange.

Classification of Agricultural Drones

The airframe of unmanned aerial vehicles (UAVs) typically contains polystyrene plastic with a radio operating at 2.4 GHz and 5.8 GHz for drone communication alongside the capacity to deliver image and video information through first-person vision systems. A receiver or remote controller (which has two to eight channels for controlling the aileron, elevator, and camera), an onboard computer (which includes GPS and an inertial measurement unit, a device that uses a combination of accelerometers and gyroscopes to measure and report data like speed, direction, and gravity), a pressure sensor, and a flight data recorder (whose software is installed on a ground control station), a battery (usually lithium polymer, or LiPo), with varying battery capacity, and cameras (which are able to detect objects in the visible to near infrared (NIR) spectrum). Drone technology offers multiple advantages since it provides easy operation and allows flexible observation of distant areas for forest fire detection and extensive agricultural monitoring across large territories. Drones exist in two basic aircraft varieties which include rotary-wing helicopter designs as well as fixed-wing models. The International Civil Aviation Organization (ICAO) calls these aircraft either unmanned aircraft or unmanned aerial vehicles (UAVs) while they are often named drones. Drones work as identifiers through authentication processes and also operate without human direction. UAS represents the advanced technologies behind drone operations thus

the term specifically replaced UAV when used here. Aircraft function with sensor technology as an enabling factor. Remote sensors work as specific devices (sensors) and technological systems for recording distant information. Single-rotor drones belong to one group while another group consists of multi-rotor drones and fixed-wing drones make up the last group of agricultural drones. The following terms describe aircraft models: "Aircraft of micro or nano scale sizes are named MAVs (micro) or NAVs (nano) but these aircraft maintain VTOL (vertical take-off and landing) capability which makes runway usage optional." LASE drones operate via low-altitude short endurance flight mode hence they are called small UA systems or sUAS and function without runways to deliver easy field logistics for deployment and retrieval for easy transport. The category with small UAS requiring a runway for operation includes this type. Both LALE and "Low Altitude Long Endurance" describe this grouping.
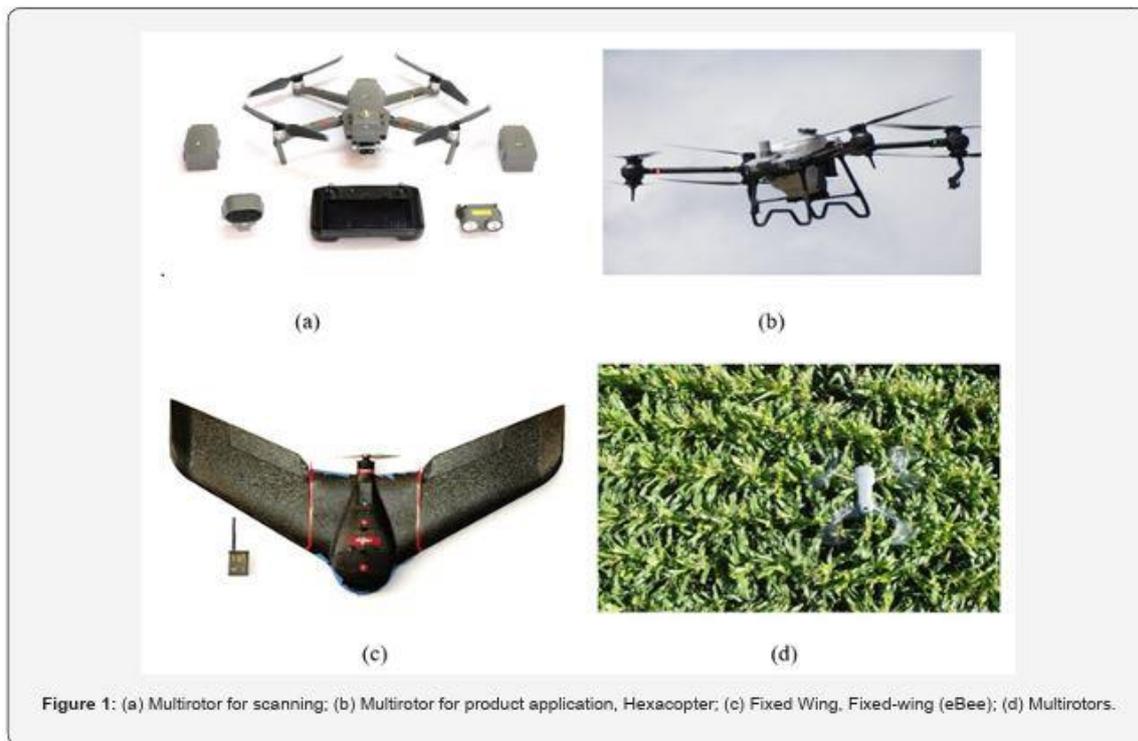

Figure 1: (a) Multirotor for scanning; (b) Multirotor for product application, Hexacopter; (c) Fixed Wing, Fixed-wing (eBee); (d) Multirotors.

There are two types of agricultural drones: to scan plantations Figure 1(a) and to apply the necessary treatment Figure 1(b). Furthermore, we can differentiate them into fixed-wing aircraft Figure 1(c), used to cover large areas, and Multirotors Figure 1(d), used when the field is smaller or more abrupt.

i. The drones are equipped with at least one of three types of sensors to carry out the different monitors, RGB, thermal and multispectral. The RGB camera [22] captures the observable radiation or spectrum, or simply light; Its wavelength is between 380 and 780 nm. The acronym RGB stands for Red, Green, and

Agricultural Drone Maneuverability

The European Commission endorses Industry 5.0 as a formal initiative and intends to start its agricultural sector application in 2021. The expansion extends to two different areas: agricultural service delivery and operation efficiency enhancements. Technology has been continuously advancing through all historical periods and leading to new applications in agricultural practices. The innovations produced effective reductions in agricultural production costs together with agricultural work hours. Humans have produced the ultimate innovation in drones. These

tools perform numerous operations effectively. The system can fill various positions within agricultural operations. Drone technology allows farmers to conduct time-efficient monitoring of farms which they previously needed to complete via land vehicles. The application of this technology led to better agricultural production results along with fewer agricultural production challenges. Utilizing any dangerous materials including pesticides or herbicides startup and operation functions of drones enable a safe remote control approach. Drones currently offer a solution for producing food requirements of future populations. The implementation of agricultural drones allows farmers to boost their ongoing farming operations. Drone technology enables farmers to view their fields using many different angles of observation. The information collection capabilities of drone systems enable communication between robotics systems together with AI machinery and data analytics structures and IoT frameworks. The installation of wireless sensors on autonomous drones makes them a highly effective data collection system that remains operational without traditional telecommunications infrastructure. Smart agriculture becomes viable through this method for locations that are distant from urban areas. Researchers and investigators must spend their efforts on precision agriculture because drone technology advancements make this field truly worthy of study. Multiple contemporary agricultural systems enable the effective implementation of information systems combined with sensors technologies and modern equipment and managerial practices.

Application of fertilizers, pesticides, and irrigation with use of drones

Yields of agricultural crops directly rely on the application of fertilizers and insecticides through chemical practices. The chemical application method becomes possible through wireless sensor data feedback. The system processes control adjustments that drone sprayers can use for sensor data analysis. Agricultural drone technology delivers various benefits to farmers including reduced operational expenses together with minimized crop growth loss, greater yield production and decreased vehicle traffic in agricultural fields. Drone technology enables effective pesticide distribution that may replace conventional methods which are dangerous as well as time-consuming especially when operating in difficult locations or challenging tasks. The combination of artificial intelligence and machine learning helps researchers evaluate drone-acquired high-resolution pictures with NDVI index technology for understanding soil conditions and both plant health and agricultural yield prediction. Drones receive several sensors and cameras which enable agricultural applications as one aspect of their many agricultural operational tools. The World Health Organization (WHO) puts the number of harmful impacts caused by hand pesticide spraying on cultivated crops at one million instances. The assessment of drone use in precise agriculture dedicates analysis to their operational value which includes growth monitoring of plants alongside growth estimation and pesticide quality assessment and soil factor determination. Drone professionals identify significant opportunities across many agricultural application areas. Such technologies deliver advantageous results for farmers who make use of them. Drone technology serves multiple applications across cattle farms together with horse stables to track animals while gathering needed data for making growth decisions and welfare decisions for the animals. The reduction in expenses for drones will become possible through these developments while package delivery services

remain unaffected. The combination of small drone technology together with advanced remote sensing systems serves as an effective detection system for identifying water shortages in pasture management.

Drones Crop Surveying and Mapping

The main function of drones is crop monitoring which international media services and agricultural specialists need on a regular basis. Since the beginning of the agricultural industry drones have become fully exploited for their adaptable and user-friendly characteristics. The answers generated by drones are rapid and valuable which improves both analytics and software applications. Among the various drone types there are specific models which prove unfit for agricultural applications. The agricultural drone market features two distinct categories which include multirotor drones and fixed-wing drones. The available hardware versions share identical carrying capability and operate in approximately the same price range while becoming accessible to the public soon. The research to preserve natural resources today demands three fundamental tools: sensors along with satellite imaging and real-time data measurement capability. Other authors illustrate the specialized applications of these devices throughout forestry areas and biodiversity preservation and precision farming and meteorological processes and emergency response. Robotics along with computer vision and mapping technology enables the development of aerial remote sensing and mapping as a new form of analysis. Data collection through this technology becomes possible through various existing devices that serve multiple operating purposes. Small UAVs are categorized into micro or small drone categories according to their dimensions along with fixed wings and multirotors permitting specialized advantages for different missions.

Machine and deep learning in the drone's precision agriculture

The Internet of Things together with other emerging technologies makes it possible to monitor environmental conditions in real-time allowing precision and smart agriculture to develop significantly. Drone technology alongside the Internet of Things has enabled devices to obtain photos at extremely sharp resolutions that many agricultural research activities now use. The fields of raw agriculture and information technology have made significant progress to merge with smart agriculture through years of development. Through digital technology applications smart agriculture has achieved its position within current digital development practices to produce information and carry out content update procedures across multiple media assets. Global economy remains heavily dependent on agriculture during this present period. Digital agriculture integrates precision agriculture with agricultural technology as its scientific discipline to enhance farming outputs while decreasing climate change impacts through big data exploitation. Agsential systems will face increased stress to support the growing population numbers. Farmers encounter multiple threats regarding their crop production along with both its quantity and quality. Improvements in technology play a crucial role for enhancing market performance while sustaining sustainability under the current intense competitive environment. Attention should be given to determining the right procedures for managing land in agriculture while addressing the increasing water issues. Machine learning operations from the Internet of Things will develop several programs to maximize agricultural output quantity and quality through comprehensive assessment of information from the increasing agricultural commodity requirements. Modern communication technology advancements have led to advancements in

agricultural operations that enable all equipment to exchange data with each other. Data collection processes and speed have improved in the innovative era through artificial intelligence developments especially deep learning techniques. The current technology used for digital agricultural land processing delivers more effective outcomes compared to traditional image processing approaches.

Future directions of drones in precision agriculture

Low-altitude remote sensing functions as an innovative agricultural development approach which precision agriculture implements within agricultural drone applications. The current context includes multiple applications for thermal remote sensing systems. The technology can detect sudden exterior temperature changes of plants to automatically recognize crop conditions at present. RS research science operates by employing tools to collect data about things in addition to crops and forests and cattle. The structural capability of the equipment allows researchers to gather data without physically touching the survey subject. Drone systems with remote sensing thermal sensors enable users to conduct yield estimation and plant classification and produce mapping systems as well as monitor crop conditions while identifying diseases and water stress in plants. The second application of drone sensors might offer an early warning system to detect crop distress and health degradation pre-damage occurs. The drone proves to be a highly beneficial instrument. Remote sensing drones benefit both rescue missions and agricultural needs and conservation efforts as well as civil society requirements. The IoT vision can greatly benefit from this data which serves as an information source for developing critical decisions. Before the development of Internet of Things technology the obtainment of real-time environmental insights was impossible yet present-day technology has made it possible and creates extensive opportunities for precise agricultural practices. Drone monitoring systems within the Internet of Things platform use cameras and sensors and GPS attachments for on-site crop analysis to achieve various benefits for agricultural monitoring. Drone data together with photos enable the combination of IoT and AI precision farming methods to enhance crop production speed and lower costs for making better decisions during the farming process. The increased costs resulting from innovative technology adoption (robots) exceed the revenue benefits that horticulture producers experience. Every element of production needs advancement in order for the horticulture industry to sustain its growth. The recent improvements in drone technology enable companies to obtain affordable thermal imager images that provide outstanding both temporal and spatial resolution thus enabling better field condition analysis and better agronomic decisions. Current knowledge enables the development and use of remote sensing techniques for evaluating environmental stressors that lower plant production as well as for non-destructive monitoring of crop growth and development. For on-site agricultural management methods, remote sensing technologies from ground, air, and space platforms may offer extensive spatial and temporal information on plant responses to the local environment. This is made possible by advancements in computer and positioning technology. Thermal imaging technology transforms things' unseen radiation patterns into visual pictures. The agricultural and food sectors can monitor and characterize goods in a range of activities thanks to our 2D temperature profiling technology.

CONCLUSION

Farmers regularly use drones as extremely versatile and strong equipment in their operations. These might possibly provide better conditions for cattle along with plants and soils. Our technology allows us to identify multiple crop indicators including health status together with insects and soil water levels and general environmental conditions at any moment. The adaptation capabilities of drones allow the installation of numerous camera systems which subsequently enables multiple software program analysis for different terrain conditions and indications. The equipment is deployed to execute moderately dangerous operations of seed planting and chemical deployment.

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