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Role of Drones in Modern Agricultural Applications

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Authors' contributions

This work was carried out in collaboration among all authors. Author AD designed the study and wrote the first draft of the manuscript. Author SK analyses of the study and managed the literature searches. Author VR analyses of the study and managed the literature searches. All the authors read and approved the final manuscript.

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ABSTRACT

Unmanned aerial vehicles (UAVs) represent the technological advance used for precision farming. It provides high-resolution crop images and precise indices are implemented, valuable outputs are generated for farm management decision-making. The current paper review and addresses the different applications of UAVs in agricultural field. This paper provides the brief overview of the current drone technologies for agricultural applications, including crop health monitoring and farm operations. The new regulatory system is also deliberated, and its implications for use in agricultural. Also outlined the potential future directions for technology in agriculture and several instances are provided which are made possible through the use of UAVs in agriculture.

Keywords: Unmanned aerial vehicles; normalized differential vegetation index; automation; GPS modules and precision agriculture.

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1. INTRODUCTION

Agriculture is the core of the Indian economy and it contributes around 17.32 per cent to India's GDP during 2016-17 (Indian economy in the FY 2016-17). Agriculture is the most promising fields in which drones give the potential to solve many significant challenges of delivering high quality, accessible, healthy and nutritious food for growing population. Traditional farming has many drawbacks *viz.,* wastage of inputs resources, and improper application of plant protection chemicals to crops, due to which the soil gets degraded and food becomes toxic. In the recent past in agriculture, the automation and robotics program is introduced in order to prevail over the flaws of conventional methods. All such technologies had more reliably and precisely taken over operations such as pesticide spraying, water supply, seed sowing, and fertilizer application.

To improve the production of food grain, adoption of automated systems and mechanized options in agriculture is most necessary [1]. Automation has replaced most of the manual intervention in various farming operations and helps to increase farm land efficiency and productivity, but its concept is yet to leave its foot prints in agriculture. As per a recent survey by Price water house Coopers [PwC], the overall addressable value of drone-powered solutions is more than $127 billion in all relevant industries [2].

Early days drones are used for capturing farmland aerial photography which added tremendous value. The plan was to make farmers could fly over their fields as much as they needed to identify issues such as variance in the leaf color, irrigation leaks, or pests such as nematodes. This knowledge, however, wasn't enough for farmers and they got very less value from the photos. Although the images could help them plan their days better by emphasizing the occurrence of issues but it has become deceptive that by the time the imagery informed them about certain issues; sometimes, it was too late to remedy the situation [3].

Apart from capturing aerial imagery, drones would also be used for sprinkling water and pesticides on the crops as per requirement. This is highly efficient method as currently herbicides are sprayed over the entire length and breadth of the plant, mean time it also sprays herbicides on the unwanted weeds in the farm so that weeds are also removes. This will not only save time and fertilizers, but also preserve ecological equilibrium because less ozone-depleting gasses will be released with increased fertilizer usage. Using sensors, crop nitrogen deficiencies can be calculated in real time and crop yield potential predicted using the agronomic vegetative index, too [4]. Drones can support farmers in various ways, and everyone interested in the agricultural field. Farmers will be able to save time, resources and increase their knowledge of the various crop growth patterns. Concurrently, greater efficiency and security of the ecosystem will be in tandem.

1.1 Steps Required for Improving Agriculture Production

1. Optimize the utilization of the fertilizers i.e., where and when it is necessary, due to this fertilizers cut down to 20–40%.
2. Reduction and prevention of waste.
3. Reduction of labour and material costs
4. Reduction of pollution
5. Reduction of the risks
6. Automatic and continuous analysis of processes and field status.

1.2 Where can Drones Help

Some farmers are unwilling to utilize drones for crop management due to its initial cost. But when the cost for a visual walking analysis or an aerial survey is considered, the cost is more for an acre, but the return on the asset of a drone purchase can be reached instantly within one rising season, or even less.

There are different actions that farmer usually do with the assistance of drones to maintain crop health, pests, disease and weeds. These things essential to be recognised in order to develop a plan to address these problems and mainly soil erosion is always a concern, so erosion channel width and depth needs to be measured. Finally crop yields and population for resource management need to be estimated accurately. There are some points that are important to farmers:

a) Confirmation: Frequently checking that plants are growing at the rate expected
b) Early detection: It is essential to mitigating plant health issues with a view to minimizing impacts and having time to introduce a solution
c) Fertilizer planning: Crops never grow consistently, and fertilizer mistrust based

on plant safety, rather than simply spreading and reducing costs.

Drones are often used to apply pesticides and nutrients to plants, rather than using labour or tractors on foot. Compared to the traditional methods, such as tractors, aerial spraying is faster and cost effective.

1.3 Regulations

Sensor-equipped drones will assist a farmer in navigating a field position, monitoring it, and producing statistics on crop health and status, but only on a small scale. Under the existing rules of the Federal Aviation Administration (FAA), all measurements and observations must be carried out using a drone beyond the drone operator's visual line of sight (VLOS).

The drones are categorized into five groups according to the Civil Aviation Directorate-General:

- i) Nano: Less then or equivalent to 250 grams.
- ii) Micro: 250-2 kg
- iii) Small: 2 kg-25 kg.
- iv) Medium: 25 kg-150 kg.
- v) Large: Exceeding 150 kg.

Drones, rather than the nano category, apply to DGCA on the criteria of the Directorate-General for Foreign Trade for clearance and issue licences. Exceptions for:

- i) Nano RPA working in unregulated airspace / covered premise below 50 feet (15 m)
- ii) Micro RPA working below 200 feet (60 m) in unregulated airspace / closed property, but the local police would need to be notified 24 hours before.
- iii) RPA owned and run by NTRO, ARC and Central Intelligence Agencies but despite harassment by local police forces.

1.4 Pros and Cons of the Policy

While the new drone policy provides complex framework of application and approval procedures, there is a lack of comprehensive drone monitoring. Many of the regulatory policies for smaller drone movements are missing. Exceptions to require requirements for drones of a limited size are likely to trigger an increasingly growing number of drone operators. In that scenario, how can government track all drones that travel below 15 meters.

2. CONSTRUCTION FUTURE OF THE UNMANNED AERIAL SYSTEM

Unmanned Aerial Systems (UAS) are aerial vehicles with large ranges, shapes and sizes that can be operated remotely or fly autonomously by software-driven embedded systems based on GPS and built with different navigation systems or recording devices, such as RGB cameras, infrared cameras, etc. [5]. In order to reduce the weight, fly at a very high altitude and increase the position changing capability drones are made of up light composite materials.

Micro electro-mechanical systems, smaller GPS units, more powerful computer processors, and highly advanced digital radios can be introduced with the accessibility of inexpensive, but advanced automation technology. The innovation and accessibility of these components is due primarily to the smart phones and the economy of the parts generated by production. Autopilot software can predetermine the flight path to optimize crop field coverage; imaging software can stitch aerial imagery together into a mosaic map. The map created is the key to improving crop performance and cutting cost. Exactly, it demonstrates which crop areas require more attention. Farmers will take more time to handle their plants, and less time scouting.

2.1 Basic Components Required for Drones

- i) UAS – Fixed-Wing
- ii) GPS/Autopilot
- iii) Camera
- iv) Laptop, tablet
- v) Internet access

On-board components of drone consist of: Processor, Battery, Various Sensors, Wireless radios, and Propellers.

2.2 Brushless Motors

The modern type drone motors are planned for more efficient and consistent operation. The efficiency of motors is the most important consideration in designing a motor because it will positively or negatively affects the consumption of energy in the system.

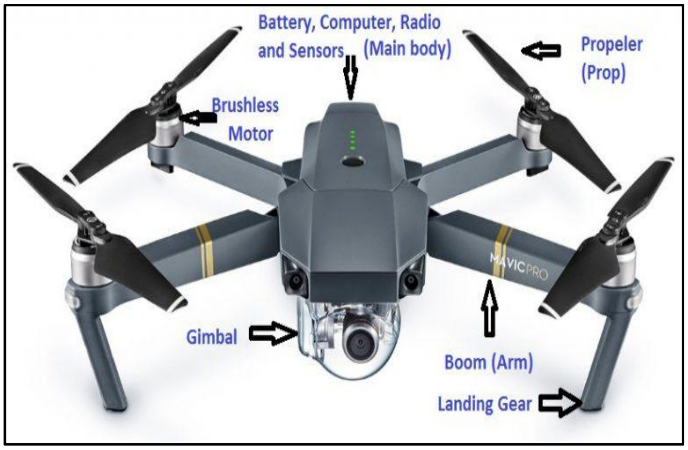

Fig. 1. On-board components of drone

2.3 Boom (Arm)

While designing a drone body, the length of the arm is need to considered and optimized. Since the arms are shorter, they are more proficient in mobility while it expands the security of the general body of the drone. It should be tough enough to withstand any harsh situations during flying and should not be too heavy at the same time.

2.4 Landing Gears (Feet)

Some drones need flat type, embedded with the main body and others may need any landing gear. The necessity generally depends on their need in higher ground clearance to adopt land gears. The necessity depends up on the drone type.

2.5 Controllers

Another important aspect of the drone is the controllers. These are gamepad like devices or sometimes smart-phones/tablets (by adopting an array of on-board technology) to enable them to do the process. Radio waves are used to stream these controlling codes from the controller to the vehicle's sensors or vice versa.

2.6 Drone Imaging Sensors

The information that can be gathered within the visual range of humans pales to what imaging sensors can do. The availability of multiple camera sensors allows drones to provide more detail than can be seen by the human eye and more information is collected from the images.

There are different types of sensors are available according to the application in agricultural field some of them are discussed below:

1. RGB (Red, Green Blue) : used for counting the plant, elevation modelling, and visual inspection
2. NIR (Near infra-red) : used for water management, analysis of erosion, plant counting, analysis the soil moisture and monitoring the crop health
3. RE (red edge): used for water management, plant count, crop nutrition
4. Thermal infrared : scheduling the irrigation, plant functioning, and forecasting of the yield

The normalized Differential Vegetation Index (NDVI) indicates the difference between the red light and the near-infrared light expressed in the plant.

Healthy performing leaves consume red light with a successful photosynthesis process and clearly reflect infrared light and dead or deficient leaves reflect both wavelengths of light. This property can be used to calculate crop quality. Obtaining the data does not require specialized sensors. A standard, modified camera can be turned into a near infrared camera with a simple filter.

2.7 Types of Drones

2.7.1 Rotary wing

- Easier to pilot, agile manoeuvring
- Vertical take-off and landing
- Flight time: 30 minutes
- Area/flite: 160 acres

2.7.2 Fixed wing

- More efficient aerodynamics
- Longer flights, higher speed
- Large space for take-off and landing
- 30 to 90 minutes
- Area/flight: 300 to 9600 acres

Fig. 2. Rotary wing drones [6]

Fig. 3. Rotary wing drones [7]

3. APPLICATION OF DRONE IN AGRICULTURE

Agriculture should not be left out of the technological advancement taking place globally in any scientific field. Additionally, the need to secure food and water supplies for a fast growing population is a challenge to be addressed using information technology. For precision agriculture UAVs represents the technological advancement [8]. Initially it is used for chemical spraying despite the fact that they were the solution to visibility problems due to cloudy weather or inaccessibility to a field of tall crops, like maize [9]. Drones have more advantages compared to satellite high resolution images and airborne sensors such as improved performance, improved efficiency, improvement in the productivity, reduction of environmental impacts and the availability of computable data from large farms [10]. However, UAVs' inability to fly in diverse weather conditions, such as rain, affects image quality or high wind, or finally increases the price of data elaboration. In 2005, the cost of drone was as higher as a 120kW tractor [10]. However, the purchase price is less as compared with the cost of image processing software to produce maps. As the cost of UAVs decreases, competition in the agricultural sector is increasing rapidly.

Fig. 4. Application of unmanned aerial systems

1. Agricultural Monitoring (Crops and Animals)
2. Weather monitoring
3. Soil/Vegetation Moisture Monitoring
4. Environmental Monitoring anfd Research
5. Aerial Imaging/Mapping (Real Estate)
6. Agritourism
7. Improve Variable Rates Application
8. Estimate Yield
9. Optimize Inputs
    - Seeds, fertilizers, water
10. React Faster to Threats
    - Weeds, pests, fungi
11. Save Time Crop Scouting
    - Treatments and actions
12. Disaster assessment and management (tornadoes, floods, wildfires, earthquakes)
    - Tower, bridge, rail and power line surveys
    - Hazardous site evaluation (chemical, nuclear, etc.)
    - Law enforcement (locate threats, document site for evidence)

3.1 Crop Monitoring

A drone (multispectral eBee SQ), provides a holistic view of a crop's growth, enabling professionals to fast and precisely identify the issues and target their field scouting. The data gathered from the drones are helpful for facilitates the better planning and monitoring improvements like ditches and fertiliser applications. Precision farming integrates sensor data and imagery with real-time data processing to increase farm efficiency by measuring field spatial variability. Data collected through drone are providing the much-needed raw data to enable agricultural analytical models. Drones can monitor soil and crop health in support of precision farming, assist in planning irrigation schedules, efficient fertilizer utilization, estimate yield data, and provide valuable weather analytical data. Vast fields and lower crop control quality together pretence the biggest challenge to agriculture. Monitoring during unpredictable weather conditions is very difficult, which make risk and field maintenance costs get increases. Earlier satellite pictures are used for monitoring but they have several drawbacks. Images quality is poor for understanding the crop and soil health and could be taken only once a day. Further, extremely high service cost and the image quality typically suffered on certain days. Today, with time series animations, it can recognize the precise development of a crop and reveal inefficiencies in growth, thus enabling better management of crops. A specific algorithm converts the collected raw data by drones to give farmers useful and comprehensible information. Some of the information's provided by these images are:

- **Plant counting:** Size of the plant, plot statistics, stands number, compromised plots, planter skips
- **Height of the plant:** Height and density of the crop
- **Vegetation indices:** Leaf area, anomaly detection, treatment efficacy, infestations, phonology
- **Water needs:** Damage/drown out irrigation, property, moisture, erosion

3.2 Soil Assessment (Soil and Field Analysis)

- Temperature and moisture
- Water issues and irrigation systems
- Ground erosion and modifications, topography
- Collecting of data for insurance claims (e.g. after storms)

Drone data can also be used to collect soil characteristics such as temperature, humidity, slope, elevation and more, allowing for more precise soil sampling and more effective seeding prescriptions.

3.3 Plant Emergence and Population

Professionals like agronomists are increasingly using data from drones in order to better understand which plants are emerging from their population and spacing metrics. Such knowledge can then guide decision replanting, thinning and pruning operations, and improves crop models.

3.4 Fertility

High-resolution images captured from the drone enable the farmers to assess crop health at different growth stages and allowing them to apply the right fertilizer at right rates at right time, reduce waste, and optimize crop health and production.

3.5 Crop Protection

The results of drone stress assessment and crop growth direct the proper and efficiently optimized implementation of crop protection products that meet each acre's exact needs.

3.6 Insurance

On-demand, high-resolution drone data is ideal for recording and reliably documenting incidents that lead to economic loss, such as crop damage, degradation and reduced safety, offering a comprehensive digital record that can support a more effective change process. Throughout the agricultural insurance and appraisal market, drones are widely used, including forensics throughout insurance claims. Drone imagery is very advantageous to provide a precise estimate of the loss. Crops are screened using both visible and near-infrared light, and the tool can detect various pathogens, reflect different amounts of green light and NIR light, and generate multi-spectral images that track plant changes and identify their health [11].

3.7 Irrigation and Drainage

In addition to crop-specific operations, drones are equipped with RGB and thermal infrared cameras that match irrigation systems planning and troubleshooting, Drones with hyper-spectral, multi spectral, or thermal sensors can either recognize dry areas of a field, or suggest improvements if appropriate. Additionally, once the crop is grown, the drones allow calculating the plant index, which determines the relative density and health of the crop, showing the heat signature, the amount of energy or the heat emitted by the crop.

3.8 Harvest Planning

Data are collected at different growing stages of plant helpful to the agronomists and agricultural engineers to improve their models, predictions and planning, resulting in better anticipation of both harvest quality and yield.

3.9 Planting

Now a day's start-up companies are developed a drone planting systems which reduces the 75% uptake rate and planting costs down 85%. These systems shoot seed pods and plant nutrients within the soil, thus providing the plant with all the minerals needed to sustain life by spraying the crops.

3.10 Variable Rate Application

Drones are designed for precise application of liquid pesticides, fertilizers and herbicides. Multispectral and hyper-spectral aerial and satellite images helps in creating Normalized Difference Vegetation Index (NDVI) maps, Distinguishing soil from grass or trees, detecting stressed plants and distinguishing crops from crop phases. Tracking crop growth at key points would also help to provide an accurate crop yield estimate and address these problems early on.

3.11 Disaster Risk Reduction

The Food and Agriculture Organization (FAO) has collaborated to develop systems for using data collection drones to assist in disaster risk reduction (DRR) efforts with the national counterparts. Such useful data are then fed into modelling systems that provide valuable information with analytical capabilities. This information can provide high-quality credible guidance to rural areas, and can help better prepare disaster relief and response services for the government.

3.12 Forestry

Open Forests uses drone-based mapping of forests and landscapes to provide a new perspective for assessment, surveillance and analysis. Hundreds of images taken by drones are stitched together to fine and high resolution orthomaps. It helps to collect various forest metrics such as carbon sequestration, tree canopy analysis, conservation features, native species tracking, biodiversity monitoring and ecological landscape features. The practical advantages of UAS are to assist the forest inventories about adaptive planning, high project customization, and rapid implementation during challenging weather conditions.

3.13 Wildlife Conservation

Drones equipped with thermal high definition cameras are also used for remote monitoring, inspection and monitoring of livestock. Assam Government and Tata Consulting Services (TCS) are partners in monitoring, identifying unauthorized settlements and deterring poachers using drone technology in Kaziranga National Park [12].

4. CONTEXT AND CHALLENGES OF DRONE IN AGRICULTURE

India is an agricultural multi-product nation with very diverse topography, climate, and soil. Micro, family farms in the country conduct a special kind of mixed agri-horti-livestock farming, which is an ideal cost-effective model for other developing countries with small farms. Multitask Indian farmers, and switch from farming to animal husbandry with ease, while remaining engaged throughout the year. This versatility has transformed the Indian agricultural sector in 2016-2017 and it contributed about 17.32 percent to the country's Gross Value (Statistics Times, 2017). Despite the transformation, Indian agriculture is still constrained by a number of factors including the unpredictable weather, scattered and small landholdings, and non-scientific way of farming, poor technological adoption. It points to a dire need for technological intervention in the system. It has to be more reliant on real time information thus enabling the farmers to make more informed decisions [13-14].

4.1 There are Several Challenges Pertaining to the Implementation of UAVs in the Agricultural Sector

- One of the key challenges related to data management is the fact that along with accuracy and precision of information, the

size of datasets grows accordingly generating up to 140 GB of data for a single square kilometre with ground sampling distance (GSD) of 1 centimetre. To address this challenge, data strategy tailored to specific requirements is necessary.
- Another key challenge is incorporating drone-borne imaging and advanced image data processing and analysing the existing agricultural processes to ensure that the agriculture sector can fully control new information [15].

4.1.1 Some of the other challenges are

- **Quality software:** Right from planning the flight path till processing the final image, software plays a crucial role in the applicability of this technology.
- **Legal aspects:** Various countries have their own regulatory to use the UAVs in agriculture.
- **Acceptability on the farmer front:** Technological unawareness may be an obstacle to its penetration.
- **Initial cost of purchase:** Drones are quite expensive with features suitable for use in agriculture.
- **Interference with the airspace:** Drones manually share the same airspace as aircraft.
- **Connectivity:** Mostly farmlands may not have sufficient connectivity, so either the farmer needs to invest in connectivity or purchase a drone capable of collecting data locally for later processing.
- **Weather dependency:** Drones operations are heavily dependent on climatic conditions, thus limiting their usage.

4.2 The Future of Drones in Agriculture

Looking into the future, drones should handle both agricultural surveillance tasks and as well as hybrid aerial-ground drone actors that could collect data and perform a range of other tasks. There are further issues that are needed to be addressed. Still some developments are going on to generate calibrated images which provide the added value of monitoring crops over time. Variability of images is also influenced by various sun angles, and cloud cover effect. The progress of drone image calibration will soon solve these technical issues, and provide practical measurements of crop efficiency [16].

4.2.1 Soil and field analysis

After getting precise 3D maps for soil, planting can be planned and nutrient status can be analysed for further operations.

4.2.2 Planting

UAS shoot seeds with nutrients in the soil with an average uptake of 75 percent, thus bringing down costs for planting.

4.2.3 Crop spraying

Drones are useful for spraying the chemical into plants according to crop requirements without wasting the chemicals and cover it equally.

4.2.4 Crop monitoring

Animations in the time series will display the precise crop development and identify inefficiencies in growth, thereby allowing for better management of the crop.

4.2.5 Irrigation

Using hyper-spectral, multi-spectral and thermal sensors to assess which areas of the field are dry or need to be modified.

5. CONCLUSION

Unmanned Aerial Vehicles is a key technology for farmers to minimize costs and improve productivity by reducing the usage of fertilizers, insecticides, fungicides and other pesticides, thus increasing overall crop safety and yield. The major advantages of drones will make UAV's widespread in the agricultural community in the next few years. The rapidly evolving technology must work in the years ahead to improve the efficacy and ease of use for drones. Moreover, major undertaking must remain the phase of flight planning, imaging, post-processing and drone maintenance. Drone Imaging seeks strategic partners to collect images of crops at all stages of growth, with a variety of pathogens at different levels of vigour. It should be able to produce high precision data to improve farming in practice if UAVs are to become a core component of the agriculture industry. The future of precision farming is very exciting, safe and valuable tools that will increase profitability for future crop production. However, precision farming is about further progress, and UAVs are expected to play a crucial role in water savings (20%-90%), chemical treatments, and labour.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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