

AUTONOMOUS AERIAL SPRAY SYSTEM FOR SUSTAINABLE AGRICULTURE: A REVIEW

ABSTRACT:

Drones are nowadays emerging as a component of precision agriculture along with contributing to sustainable agriculture. The use of advanced technologies such as drones in agriculture offers the potential for facing several major or minor challenges. The major applications of drones in agriculture are spraying, irrigation, crop monitoring, soil, and field analysis, and bird control. This review analysis considers the latest trends and applications of leading technologies related to agricultural UAV equipment and sensors development. And also, the use of UAVs in real agricultural environments. Furthermore, the future development of agricultural UAVs and their challenges are considered. There is a problem with workflow for the use of UAVs in such applications, as it is a relatively new area. In this paper, we review the available agricultural drones and the most recent applications of UAVs for Precision Agriculture using sensors on it for agriculture data, and current trends and future challenges are suggested.

Keywords: Agricultural applications, Components, Sensors, Smart Agriculture, Unmanned Aerial Vehicles UAVs)

1. Introduction:

“The adoption of modern technologies in agriculture, such as the use of Unmanned Aerial Vehicles (UAVs) or drones (Dynamic Remotely Operated Navigation Equipment), can significantly enhance risk and damage assessments” [1]. “UAVs are one type of aircraft that can fly autonomously in the air without the involvement of a pilot on board, and the aircraft’s motion is controlled remotely by an operator. An operator controls the UAV’s movement from a distance. UAVs have been widely employed in agriculture due to the quick development of smart agricultural technology, assisting farmers with tasks like crop monitoring, crop spraying, weed, disease diagnosis, etc. The use of drones in agriculture has been introduced for big areas inspection and smart targeted irrigation and fertilization” [2, 3]. “UAVs are now a better choice for farmers in the agricultural industry thanks to some of the sophisticated characteristics, including cheap maintenance costs, quick setup, low acquisition costs, and live data collecting” [4].

It is impossible to overstate how useful drones will be in achieving sustainable agriculture in the near future as a component of green

technologies. Farmers currently deal with a variety of issues, such as the lack of or high cost of labour, health issues caused by contact with chemicals (such as fertilisers, insecticides, etc.) while using them in the field, bites from insects or other animals, etc. Drones are now becoming a part of precision agriculture and helping to promote sustainable farming. The market for agricultural UAVs is growing rapidly [5], and several venture companies have emerged. “According to market research by Price-Waterhouse-Coopers, the market size of agricultural UAVs is forecasted to grow to about \$32.4 billion by 2050, accounting for about 25% of the global UAV market” [6]. Major UAV companies include DJI, Parrot, PrecisionHawk, AGEagle, and Trimble Navigation. Although various UAVs have been developed and commercialized, some challenges remain to be addressed for advanced agricultural solutions. Leading technologies include precision positioning, navigation, controls, imaging, communications, sensors, materials, batteries, circuits, and motors. Depending on the use of the UAV and the characteristics of the farming sector various technologies (e.g., equipment development, nozzle controls, and big data) are required. It is challenging to provide information

about all UAV technologies. Therefore, in this paper, we focus on the components of drone systems, sensors, and platform types, which are mainly examined in terms of research and development.

2. Drone components:

The complete drone system is a combination of different components as shown in fig. 1.

Frame: - It is important to consider the weight of the frame because if the weight is high then there can be difficulties in the lifting of the drone. The design of the frame is a trade-off between strength and additional weight, which will require longer propellers and stronger motors.

Propeller: -“It is made up of carbon fiber which possesses high strength. Longer propellers can achieve greater lift at a lower rpm but take longer to speed up/slow down. Shorter propellers can change speed quicker and thus are more maneuverable; however, they require a higher rotational speed to achieve the same power as longer blades. This causes excess motor strain and thus reduces motor life span” [7].

Electronic speed controller (ESC): -It is used to vary the Revolution Per Minute (RPM) of the motor.

Flight controller: -Maneuvering operations and also it provides Auto level function. The accelerometer and gyroscope sensors in the Flight controller process the signals from the receiver and gives the output to the ESC to control the UAV.

Power distribution board: -A board that allows transferring the power from the battery to ESCs / Motors and generates a power supply for the flight controller and other peripherals with different voltage levels.

Brushless direct motor: -1 per propeller, its movements can be controlled via an electronic controller and speed feedback mechanism.

These motors are energy-saving as compared to the brushed dc motors.

Radio transmitter and receiver: -Firstly, the transmitter should be calibrated with the flight controller using the receiver. After the calibration, the transmitter is linked with the drone, and as per the command of the transmitter, the drone will work [8].

Battery: -Generally, the battery used is a Li-Po battery due to its high power density and ability[9].

Fig. 1 Components of UAVs

3. Types of Unmanned Aerial Vehicles based on wings and Rotors:

“The number of rotors corresponds to differences in payload and UAV size as shown in fig. 2. Octocopters, helicopter types, and fixed-wing types have the largest payload capacities (9.5 kg) and are mainly used for spraying” [10]. “Quadcopters and hexacopter are relatively small and carry a smaller payload (1.25–2.6 kg). They are used for reconnaissance and mapping” [11], [12]. Fixed and rotary-wing UAVs have the largest payload (23 kg), followed by helicopter-type (22 kg). Currently, fixed- and rotary-wing UAVs are increasingly being used for precision agriculture. Multi-rotor UAVs are used for extremely precise tasks.

Fig. 2 UAV based on wings and

1] **Multi Rotor UAVs:** “These UAVs are mostly used for applications like aerial surveillance, photography, etc. These are easy to manufacture and are the cheapest of all kinds of UAVs. Different categories of Multi Rotor UAVs are Tricopters which have 3 rotors, Quadcopter which has 4 rotors, hexacopter which have 6

copters and octocopter with 8 rotors”[13]. They are unsuitable for projects like long-distance surveillance and aerial mapping due to their restrictions, which include a flying time limit of 30 minutes and limited speed. **2] Fixed-wing UAVs:**“These UAVs are controlled autonomously without a human pilot on board. They have an average flying time of 2 hours and some of the recent FixedWing UAVs can fly up to 16 hours. They are ideal for long-distance operations. Some of the limitations are high costs and highly skilled training to operate. They need a runway for launching” [14].

3] Single Rotor UAVs: These categories of UAVs look very similar to helicopters. These UAVs have only one huge rotor and a smaller one near the tail of the UAV. They can fly a higher number of times compared to multi-rotor UAVs. Some of the limitations are more complex and prone to operational risks, and higher costs.

4] Hybrid Vertical Take-off and Landing (VTOL):“These UAVs are a hybrid of fixed-wing UAVs and rotor-based models. These UAVs are equipped with sensors and can be controlled remotely” [15].

Some sensors are mounted on the drone for mapping, surveying, and detection of crops related to diseases for easy identification, different types of agricultural sensors are available and described as below:

4. Types of Agricultural Sensors

1) Location-based Sensors:“Location sensors are used for locating different areas and spots in the agriculture fields” [17], [18]. The farmers utilize various location sensors that help them during the different stages of the life cycle of crops. Normally, GPS receivers are used for finding the longitude and latitude of a particular point on the earth's surface with the help of a GPS satellite network. These smart location sensors play an important role in precision agriculture by pointing out the location in fields

of monitoring growing crops for watering, fertilization, and treatment of weeds.

2) Electrochemical Sensors:“These sensors are used to extract a composition from a particular biological sample such as plants, soil, etc”. [19]. These sensors are typically used in smart agriculture to measure pH levels and soil nutrient levels where sensor electrodes pick up particular ions in the soil. **3) Temperature and Humidity Sensors:**“Temperature and humidity are among the most important weather factors which directly affect the health and growth of all types of crops. Correct measurement of these environmental factors is helping the farmer adjust the quantity of fertilizer and water” [19]. There are many different kinds of temperature and humidity sensors that may be used by farmers to measure and keep an eye on the temperatures and humidity levels in their fields and greenhouses. These sensors run on batteries and include wireless functionality.

4) Optical Sensors:“These sensors work on the principle of converting light rays into an electrical signal” [21]. “There are several optical sensors (such as RGB camera, converted near-infrared camera, six-band multispectral camera, high spectral resolution spectrometer, etc.) that have been used in UAVs for precision agriculture related applications” [22]. A brief description of a few sensors working on this principle as described as the following.

(a) Visible Light Sensors (RGB):“Visible Light Sensors (RGB) are most popularly used by UAVs in precision agriculture and related smart agro applications. It is a recognized fact that the human eye is sensitive to red, green, and blue bands of light. The RGB sensor in the UAV camera captures the image such that they reproduce the same effect as seen with a human eye. Also, the costs of the RGB sensor-based cameras are relatively affordable, lightweight and extremely good at creating orthomosaic maps that capture images and aerial videos of the entire field at a single instance as shown in fig. 3. This enables to take quicker observations

and after entering the geographical data into the
GPS, one can immediately get into the root of
the problem

Table 1: Review of used smart agriculture UAVs with applications

Sr. No.	Agriculture UAVs	UAV Type	Potential Application
1	eBee SQ	Fixed wing	RGB imagery, spanning vast areas of every flight, Soil Temperature
2	Senterra PHX	Fixed wing	Weed management, pest management, crop health monitoring
3	Lancaster 5	Fixed wing	Plants counting and number, assessing plant quality, creating prescription maps
4	Honeycomb	Fixed wing	Navigating, surveillance, Soil H2O levels, air pressure
5	AgEagle RX-60	Fixed wing	Aerial Imaging, crop health monitoring, maps prescription
6	Dji matrice 600 Pro	Multi rotor	Plants counting, Navigating, aerial photography
7	Dji matrice 210	Multi rotor	Fire-fighting, pipeline inspection
8	AgBot	Multi rotor	Plant height, assessing plant quality

[16]

without affecting the entire field” [23]. The RGB cameras thus help in the detailed inspection of agricultural assets efficiently and effectively in varying weather conditions. The associated challenges of this sensor include its inadequacy to analyze the large number of agro parameters requiring spectral information existing in a non-visible spectrum.

Fig. 3 Image by Visible Light Sensor

(b) Multi-spectral Sensors:“Multi-spectral sensors are extremely appropriate for UAV-based agricultural analytics. These sensors capture images with exceptional spatial resolution and also possess the capability to determine reflectance in near-infrared” [23] as shown in fig. 4. As a result, these sensors are highly useful and crucial for farmers, scientists, and agronomists. In order to conduct a crop health analysis, multi-spectral data gathering is a must. Researchers can perform precise analytics and generate information on plant vigour, canopy cover, leaf, and several other plant sections due to the multiple bands of light. Early diagnosis of plant diseases, weeds, pests, and the computation of vegetative biomass would be next to impossible in the absence of such multi-

spectral data.**Fig. 4 Image by Multi-spectral Sensor**

(c) Hyper-spectral Sensors:“Hyper-spectral sensors are extremely capable of capturing detailed images in the spectral and spatial range. These sensors are equipped with area detectors that quantify the captured light resulting from the conversion of incident photons into electrons as shown in fig. 5. The successful use of hyper-spectral sensors in UAV is possible through the availability of pre-built systems constituting of the sensor manufacturer, the UAV manufacturer and the party responsible for system integration at the pre and post flight level” [25]. The combination of all these three aspects ensures the commercial success of the hyper-spectral sensors in measuring a hundred bands, performing data processing, and achieving decision-making in agriculture and forestry.

Fig. 5 Image by Hyper-spectral Sensor

4) Thermal infrared sensors:“Thermal sensors are widely used for many agricultural-related applications such as monitoring of various conditions of crops and soil. The thermal cameras detect the radiations relevant to their wavelengths and convert it to a grayscale image

generating heat in this process” [26]. “The applications of these thermal sensors mounted on UAVs are irrigation management/scheduling by calculating the soil

conditions, and the ability to capture high-resolution pictures from different ranges (average range 50 to 100 meters). It is also, possible to

and crop water stress,

Table 2: Smart agriculture UAV’S with specifications

Operation	UAV type	Indices	Sensors		References
			Type	Model	
Irrigation	Fixed-wing UAV	Crop water stress index transformed Chlorophyll absorption in reflectance	Multispectral camera	Canon IXUS 125 HS	29
		Near Infrared domain (NIR), NDVI	Digital camera	Tetracam MCA-6	30
	Quadcopter	Difference Vegetation Index (DVI), NDVI	Multispectral camera	Parrot SEQUOIA	31
Crop monitoring	Octocopter	NDVI, soil adjustment vegetation index	RGB sensor	Panasonic Lumix GX1	32
	Quadcopter	Green-red ratio index, visible-band difference vegetation index	Digital camera	Sony ILCE-6000	33
Spraying	Helicopter	Route precision	Image transmitter	-	34
	Quadcopter	Droplet coverage rate, density, droplet size	Digital plant canopy imager	Camas CI-110	35
		Observed deposition rate, fieldwork rate	Multi-spectral camera, Hyper-spectral camera, Near-infrared	-	36

detection/prediction of

various crops disease” [27], [28] (e.g., pathogen), mapping soil texture, and crop maturity monitoring as shown in table 2.

5. Applications of drones in agriculture

There are various applications of drones in agriculture: -

The main advantages of using UAVs for smart agricultural applications as shown in fig. 3 include mobility of UAVs in variable weather

use UAVs for determining and monitoring the quality of crops, and monitoring attacks attempted by pests/weeds/animals. The farmers and other stakeholders can access the data gathered through UAVs from cloud-based platforms remotely through apps from their smartdevices which can help in predicting the yield of the crop, requirements like pesticides, fertilizers, seed sowing, etc.

[37]

1) Crop spraying: -Drones can be used to spray chemicals like fertilizers, pesticides, etc. as shown in fig. 7 based on the spatial variability of the crops and fields. The number of chemicals to be sprayed can be adjusted depending on the crop conditions, or the degree of severity of the insect-pest attack. In this way, drones pave the pathway to precision agriculture.

Fig. 7 Crop spraying

2) Crop monitoring: - “Drones can be used for monitoring the conditions of crops throughout the crop season as shown in fig. 8 so that need-based and timely action can be taken. Quick and appropriate action can prevent yield loss. This technology will eliminate the need to visually inspect the crops by the farmers” [37].

Fig. 8 Crop monitoring

3) Crop irrigation: - Drones loaded with thermal, multispectral, or hyper-spectral sensors can identify the parts of the field with moisture deficits using multispectral indices. This helps in planning timely irrigation to the identified areas with precision as shown in fig. 9.

Fig.9 Crop irrigation

4) Aerial mapping: -By using different kinds of sensors pertaining to visible, NIR, and thermal infrared rays, different multispectral indices can be computed based on the reflection pattern at different wavelengths image of aerial mapping is shown in fig. 10. These indices can be used to assess the conditions of crops like water stress, insect-pest attack, diseases, etc. The sensors mounted on the drones can detect the prevalence of diseases or deficits even before outward symptoms manifest. They are therefore a tool for identifying infections before they become serious. Drones can function as an early warning system in this way, allowing timely remedial action to be done based on the severity of the stress.**Fig. 10 Aerial mapping**

5) Livestock management: -“Drones can be used to manage the large herd of livestock as shown in fig 11. The sensors having high-resolution infrared cameras present over the drone can detect the diseased animal swiftly by their heat signatures. The detected diseased animal can then be separated from their fellow animals, and early treatment can be provided. So, the drone could be used for precision dairy farming”[37].

Fig. 11 Livestock management

6) Soil and field analysis: -“Drones can be used to mount sensors that are able to analyze as shown in fig. 12 the soil conditions, terrain conditions, moisture content, nutrients content, and fertility levels of the soil which can be further used for planning the pattern of sowing of different crops, irrigation scheduling as well as for managing fertilizers application considering spatial variability of the crop growth and field conditions”[37].

Fig. 12 Soil and field analysis

7) Pest control: -Apart from soil conditions, drones can also detect and inform farmers about field areas inflicted by weeds, disease, and insect pests.

8) Weed identification: -“Drones can be used to identify the weeds present in the field. These weeds could be timely rooted out from the field so that they do not compete for resources with the main crop as shown in fig. 13”,[37].

Fig. 13 Weed identification

9) Land surveying: -It is nearly impossible to estimate the overall state of crops in large fields. Drones-based agriculture mapping can help farmers remain area-wise updated on the plant's status and point out which field areas require attention as shown in fig. 14.

Fig. 14 Land Surveying

6. Current trends and future challenges: -

“Currently, simultaneous localization and mapping (SLAM) technology, which leverages autonomous driving, is being used with UAVs. SLAM technology maps in real-time using a camera and/or LiDAR. It recognizes its own position and identifies obstacles, autonomously traveling or performing tasks. The technology does not require the use of existing controllers, and it is efficient and practical because it works autonomously. With these developments, we arrive closer to smart agricultural capability” [38], [39]. “Practical limitations, such as the short flight time, are also expected to be solved by the advancements in technology. These improvements will ensure that farmers can reap more from the use of UAVs for remote sensing in Precision Agriculture”[40].

7. Conclusion: -

This paper gives a systematic and comprehensive overview of the latest development in UAVs and sensors. It is apparent that the agriculture industry is undergoing an important turning point during the last few years. The traditional practices in agriculture are transforming into a new "intelligent" perspective in the process of cultivation. Agricultural UAVs shows unlimited potential in agriculture. We review the platform's control, applications of agricultural UAVs, and different sensors that have been developed or understudied. Besides, various limitations, available applications, and the latest trends in agricultural UAVs are introduced to describe the direction of future research. This review paper is regarded as an eye-opener for Industry and Agriculture for the development and integration of more drones for making Agriculture tasks better and in turn, yielding the best crop quality in near future.

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