



Techniques, Answers, and Real-World UAV Implementations for Precision Farming

Ashish Srivastava^{1,2} · Jay Prakash²

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Abstract

In adopting state-of-the-art technologies, a domain known in time is Agriculture for fertility optimization, expense saving, assistance, and environmental safeguard. In this aspect, deploying UAVs remains a modern example in the Agriculture sector, encompassing various possibilities at ease. Concerning innovations, UAV (drone) invention remains the standard talked-about technology. UAV's broader view includes drone ranges like micro, mini, small, and medium aerial vehicles. Initially developed applications for the military now have used assistance like firefighting, courier services, mob surveillance, facial recognition, and many more. Within the paper, UAV applications in agriculture are of primary interest, with a notable centre of attention being crop farming. This paper presents a comprehensive survey on UAV types, crop health, agricultural sensors, remote sensing with UAVs, animal marking, pesticide sprinkling, other possible agricultural use, and Precision Agriculture. We explore the approach utilized for each UAV type application and the UAV technical characteristics and payload. Beyond uses, UAV's services and implied advantages within agriculture are further exhibited beside talks on business correlated hurdles and additional apparent difficulties limiting the broad adoption of UAVs into agriculture. The belief of the work done in the paper will prove worthwhile to Researchers working on an amalgamation of UAVs in PA. With our work, they can make a necessary spontaneous understanding of the agricultural aspect and how it should work. Those farmers attempting modernized agricultural method optimization approaches on various levels by this work benefit from new ways of using UAVs within their farming. UAV businesses exploring innovative UAV use capacities can examine the future concerning the UAV run in agriculture furthermore strengthen their endeavours within the trend.

Keywords Unmanned aerial vehicle (UAV) · Precision agriculture (PA) · Remote sensing (RS)

✉ Ashish Srivastava
ashish.srvstava88@gmail.com

Jay Prakash
jpr_1998@yahoo.co.in

¹ Computer Engineering and Applications, GLA University, Mathura, U.P. 281406, India

² Department of ITCA, Madan Mohan Malaviya University of Technology, Gorakhpur, U.P. 273010, India

1 Introduction

The adverse effect of climate change did introduce significant challenges affecting multiple sectors directly or indirectly; one such sector is agriculture. Agriculture is a vital area; therefore, it cannot be just let go. For an increment in food production by 70% by the year 2050, the global population has to discover innovative (new) solutions; this concern did raise by FAO of the UN and the ITU. Such a severe concern and reaction to this significant challenge demands adopting new technology (ICT) in the agricultural sector to a good effect, minimizing wastage and monitoring crops in real-time, suggesting abilities for increment in the agrochemical products' productivity as pesticides and fertilizers. On a counter note, with minimal operational cost. The speedy progression of the UAVs record of last decades and their imagination with enormous latent has evolved, and split-shift researchers applicability in different use. WSNs and IoT will be worthwhile simultaneously with economic PA applications, an aerial form of crop monitoring with innovative spraying tasks.

Dependency on farmers' traditional knowledge of Farming in developing countries is heavily supported by inconclusive agricultural methods generally performed, driving to lowering fertility and degeneracy of resources. Further, automation alliance with agriculture is not thoroughly done compared to countries like the USA, Japan, and others. Therefore maintaining a farm stands a time-spending with the exhaustive operation process. Consequently, PA allows noted possibilities for development. Frequently, farmers face issues like unexpected atmosphere shifts and sudden parasites attack that can seriously influence the health of agricultural products. The WHO manually assessed one million cases of adversely affected pesticides within the crop area. For the plan above, innovative technologies like drones or AI drones outfitted with precise sensors, cameras, and fertilizers will encourage producers to handle the threats and stop parasites in the cultivated field [1] that can damage plants or crops. A certain number of plants in a cultivated area with some plants or seeds are distributed. There are chances that some parasite attack will result from the nature of the plant or seed within the land, and such an attack will severely damage the farmer. To react to such an attack in a time frame effectively by counterstep where the exact position of parasites ahead is unknown as they can be distributed in any part of the considered area spawn and migrate in a scattered behaviour. In these cases, a UAV (drone) group, FANET, can be instrumental in managing the by and large field to surround the struck plants or notice parasitoids in motion.

Although scientific progressions toward biofertilizers over chemical fertilizers, genetics, and chemistry evolution have added remarkably to agricultural technology, agricultural product production, keeping in mind the accelerated progress of the global population, has to increase primarily. At the same time, it tackles severe challenges like climate change in the agricultural sector and the restricted accessibility of productive/fertile lands with accelerating stress for freshwater. The ICT services will be a workable solution for these crucial hurdles. More concretely, the accelerated expansion of the UAV and IoT technology coupled with image and vision data calculation will encourage PA solutions to handle the challenges above.

PA uses significant data references combined with farmers' environmental and crop high-level scientific mechanisms. Helping to make better-informed arrangements also carefully maintain their territories, intending to accomplish economic and environmental targets both [2, 3]. Growing interest has been seen recently in PA all over as an encouraging move towards adhering to an unparalleled desire for producing added food, including the higher qualities energy of more sustainability with optimizing externalities [4]. Over recent

years PA practices have evolved significantly with the estimation of the global market to reach \$43.4 billion by 2025 [5]. RS exists as the method of acquiring data concerning a target, an area, or an appearance by analyzing images obtained through a machine that avoids direct corporal connection with them [6]. RS examinations are principally built on developing a deterministic correlation among the volume of returned emitted or backscattered electromagnetic energy in particular bands or frequencies, moreover, the studied phenomena' chemical, biological, and physical characteristics. Generally, RS is related to satellites, including crewed aircraft outfitted with various sensors [7, 8]. In current times, noteworthy technological advancement, including UAV platforms, has been registered [9]. UAVs have become a standard tool for data acquisition with first use in military applications. Admittedly, UAVs' low-altitude nature of RS remains the most potent tool in PA.

Using RS technology, the PA of any interested variables can be performed based on a previous map. RS empowers producers to gather, imagine, and assess crops, including soil fitness situations, at multiple production steps conveniently and cost-effectively [10]. It can assist in early indicators to recognize possible difficulties and render chances to approach specific problems swiftly. In RS, the platform class shows properties like range with deployment time, an object distance from sensors, image acquiring time, and position. UAV capacities extend the potential to change common RS platforms for monitoring crops in real-time, pot discovery, classification of trees, water pressure or force estimation, disease disclosure, yield estimates, several pests, and nutrient supervision policies. UAVs have not yet made it entirely into the mainstream of PA practices. However, they perform a more significant role in precision cultivation, supporting agriculture specialists to lead the system with sustainable agriculture methods while preserving and growing profits [5]. UAVs render producers, farm experts, and businesses that assist the enterprise with high-quality data and images. UAVs can perform an extensive chain of agricultural works supporting PA, including clay complexion scanning, irrigation records plan, seed sowing, fertilizers use, and climate analysis. UAVs present definite benefits above other RS principles, together with:

- Fast data accumulation of clear tone, scale, and resolution.
- 3D covering height and its dimensional information.
- Ability to take multi-angular data with mounted camera and sensors.
- Commanding multiple sensors simultaneously.

Satellite images remain high-priced for a standard producer in PA, and typically, their resolution and tone remain unsatisfactory due to the climate conditions. Consequently, airborne image taken by Unmanned aircraft offers a more dependable nature to satellite images; however, the process is likewise high-priced. Contrarily to the preceding claims, small-sized UAVs, also known as drones, are significantly cost-effective and can deliver high-quality images. Those images can also bring out the vegetation indices (Table 1), enabling producers to monitor product changeability with present spring conditions uniformly. For instance, the NDVI [11–13] can contribute to solid biomass levels. NDVI values further interpretation and valuable conclusions concerning crop diseases, water stress, pest infestations, nutrient deficiencies, and other relevant crop production conditions. Agriculture implies a broad ecosystem that influences and moreover remains affected with numerous data [14]. These data are relative to quantitative environmental characteristics like climatic temperature, clay temperature, compound composition, moisture, and qualitative data with the growth itself, viz. disease appearance and plant condition. The collected data, including proper processing tools, will contribute innovative perceptions to the rural community [15].

Table 1 Various Vegetation Index with formula [25]

Vegetation index	Acronym Vegetation indices derived from multispectral	Formula
Ratio vegetation index	RVI	$\frac{NIR}{R}$
Normalized difference vegetation index	NDVI	$\frac{NIR-R}{NIR+R}$
Normalized difference red edge index	NDRE	$\frac{NIR-RE}{NIR+RE}$
Green normalized difference vegetation index	GNDVI	$\frac{NIR-G}{NIR+G}$
	RGB - based vegetation Indices	
Excess greenness index	ExG	$2 * G - R - B$
Normalized difference index	NDI	$\frac{G-R}{G+R}$

ICT progressions will expedite the drive for deeper data-centric farming [16]. IoT [17] and cloud computing [18] progressions do combine to achieve valuable data collection [19, 20] method, farsighted data interpretation [21], moreover proper data distribution to farming stakeholders [22].

In PA potential application concerning UAV stands crop spraying [23], Japan was the first country to do so. Modern UAV containers offer massive vessels whose volume might touch nearly 10 ltrs. Besides this, the flowing speed release might also get over 1ltr/min, traversing a given area. A synchronized UAV-based spraying process provides efficient and accurate use of agrochemical products, minimizing the volumes of agrochemical products and contributing to environmental protection. According to the AUVSI, 80% of UAV utilization will be for agricultural purposes very soon. In Germany, Sales of UAVs touched 400,000 units in 2017 and were expected to 1 million in 2020 [24]. A global information provider, the NPD Group, estimates UAV sales in the US multiplied in 2017 by a record increase of 117% compared to the previous year [24]. The perspective for UAVs in PA improvement is immense. Now, this agriculture drone business does predict to be meriting US\$32.4 billion. A shred of clear evidence about producers, researchers,

and manufacturing does start to notice UAV's advantages ahead of conventional techniques. Therefore now it's essential to realize the inclinations with constraints about convenient UAVs concerning diverse agricultural works.

With 80% of UAVs utilization for agricultural objectives shortly. A clear sign of how UAVs are harmonizing to execute the central role within the growth/expansion concerning the agricultural division. The principal motive to initiate this subject is the upgradation aspect, with a broad study centred on UAVs' components, features, specialities, characteristics, and importance in PA. The article can be interpreted as a preceding shrewdness into UAV choices with raisers and enthusiastic researchers concerning PA processes.

1.1 Work Motivation

A particular pattern denotes that higher than 815 million individuals remain long-term hungry; furthermore, roughly 64% do locate within Asia [24]. Results suggest that climate change is also a significant factor, but we cannot stop it; instead, be prepared by technological advancement. 64% is an issue with a serious concern if it will not be

tackled within the time the world has seen in the case of COVID-19. The whole human community will suffer again, probably more than COVID.

Accordingly, food businesses, farming associations, researchers, including scientists associated with the agriculture division must expand different means or adjust pleasantly to prevailing ones to tackle the difficulties because of environmental change. Under these circumstances, agriculture must utilize ICT-operated assistance to impact reliable, precise, and up-to-date data significantly. Further expressly, a vital progression in this area is exhibiting miniature agricultural UAVs concerning low altitudes. Notwithstanding their operative limitations, like bounded battery time, UAV's contribution to gathering estimable data about the crops and biochemical attributes helps influence relevant decisions and policies with farmers, producers, and the government.

1.2 Significant Contributions Also Paraphrased Research Flow

In this study, we present a systematic survey, which constitutes the best of our knowledge. The literature survey covers UAVs (varying altitude) with PA determinations plus demands in the agricultural sector. The preparatory work concerning our article is summarized within the subsequent cores:

1. The article's perspicacity is on how Low Altitude UAVs will be helpful for PA, providing further thoroughly systematic viewpoints concerning farmers and their viewpoint with issues.
2. UAV strength and functioning have enabled us to apply it to newer domains; we present UAV potentials and study the equivalent empowering technologies for agriculture.
3. We address critical elements concerning UAVs and their associated technologies, further handling UAVs' possibilities to deliver to growers and producers.
4. Combination of UAVs amidst the current agriculture sector to bestow a UAV infusion for better growth and knowledge to farmers and associated companies.

All acronyms practised during this research paper are discussed in Table 2. The article's perspective remains the following. Part 2 includes the Related work concerning UAV use over individual authors with their prospects. Part 3 deliberates on Aspects of PA with the principal aims of PA followed by the PA cycle. Part 4 discusses the RS idea in PA with RS systems that can be further applied in the PA system. Part 5 reveals the various Agricultural sensors through which the farmers can increase their production and tackle the need and problems of the field. Part 6 lists various UAVs with their types for use in the Agricultural domain. Part 7 outlines the Drones movement and Mobility models dedicated to the Agriculture sector for proper utilization and effective result. Part 8 explains the numerous applicability of UAVs in farming and their detailed discussion. Part 9 explains UAVs to use in livestock farming for monitoring animal health, identification, and other use. Part 10 discusses the Flying regulation use of UAVs for Agricultural tasks in different countries. Part 11 concludes the study by summing up and examining this subject from PA and farmer's positions. To help researchers focus their efforts, we provide some preliminary suggestions for future research directions in Part 12.

Table 2 List of Acronym used in paper

AI	Artificial Intelligence	LiDAR	Light Detection and Ranging
AUVSI	Association for Unmanned Vehicle Systems International	MIT	Massachusetts Institute of Technology
CAA	Civil Aviation Authority	ML	Machine Learning
CCD	Charge-coupled device	NDVI	Normalized Difference Vegetation Index
CMOS	Complementary metal-oxide- semiconductor	NPD	National Purchase Diary Panel
COVID	Coronavirus disease	OBIS	Object-Based Image Analysis
DJI	Dà-Jiāng Innovations	PA	Precision Agriculture
DSS	Decision Support System	pH	potential/power of hydrogen
EASA	European Aviation Safety Agency	RGB	Red Green Blue
EU	European Union	RFID	Radio Frequency Identification
ESSWM	Early Season Site-Specific Weed Management	RS	Remote Sensing
FAO	Food and Agriculture Organization	SIFT	Scale-invariant feature transform
FANET	Flying Adhoc Network	SOC	Soil organic carbon
GIS	Global Information System	UAV	Unmanned Aerial Vehicle
GPS	Global Positioning System	UAS	Unmanned Aerial Systems
ICT	Information and Communications Technology	UN	United Nations
IoT	Internet of Things	USA	United States of America
IR	Infrared	VTOL	Vertical Take-off and Landing
ITU	International Telecommunication Union	WHO	World Health Organization
LARS	low altitude remote sensing platform	WSN	Wireless Sensor Network

2 Related Work

The concept of UAV deployment within the agriculture field has existed before. Sugiura et al. [26] first introduced UAVs in the cultivation; their work generates crop maps using an unmanned helicopter with a 42 cm error map. Fukagawa et al. [27] presented a different innovative system by controlling UAV remotely and attaching a multispectral image sensor for crop growth. Moving with the idea of controlling UAVs remotely, Xiang and Tian [28] expanded a method that facilitated collecting multispectral images from UAVs by the beforementioned waypoints of crops. Yang [29] analyzed by distinguishing among airborne imagery, multispectral or hyperspectral to recognize root decay. They further ended that both methods remain uniformly effective.

Hung et al. [30], focused on low-cost, low-altitude UAVs, further elaborated a method for identifying and segmenting objects on trees with low altitude UAVs with a 20 cm/pixel spatial resolution. Swain et al. [31] used a radio-controlled unmanned helicopter which acquires spatial and temporal resolution images for yield estimation and calculation of cumulative biomass regarding a rice crop over 20 ms of rice plot by a LARS. For estimating NDVI values, they used LARS sensor-based images to help farmers conclude the total biomass of crops.

AldanaJague et al. [32] similarly employed a low-altitude UAV with a multispectral camera. Further, they commanded their introduced technique could monitor soil characteristics like SOC content and accuracy. Huang et al. [33] revealed the remote sensing concept

by UAV with RGB and infrared cameras. The method could differentiate the weed species in their experimental work and recognize particular plant

disorders, including conducting a crop damage assessment. Disease identification and specific pests are made with enrooted vision and ML procedures by Di Martini et al. [34]. They further used different UAVs for PA, including forest monitoring.

UAVs are outfitted by a wireless communication arrangement to interact with wireless sensors, ground control, and IoT nodes for data collection or transmit commands within the communication range. UAVs reach areas wherever direct communication is not possible. With this type, the communication range increases significantly, enhancing the data collection capacities of collection nodes. Costa et al. [35] introduced a method for deploying UAVs and WSNs in agriculture. A wireless communication system was installed for data exchange between UAV and ground nodes. After receiving feedback from ground sensors, other UAVs equipped with sprayers spritz to the crop. Data processing is done outside the field in a system developed by Arnold et al. [36]. UAV works like a mobile gateway that collects data from each sensor placed on the ground.

Many authors worked on the concept of Multi UAVs for more comprehensive knowledge in agriculture, with individual UAVs performing a single defined role. Ju and Son [37] used UAVs for RS. In four (4) separate states: Auto-Single-UAV, Auto Multi-UAV, Tele-Single-UAV, and Tele-multi-UAV. Performance in all four cases on various parameters was done, and on experimental results, the multi-UAV system's performance is better than an individual UAV.

Another work by Skobelev et al. [38] remains on using multi-UAV for PA focused toward agents. Their model connects UAVs into a swarm and proposes coordinated hovering forms and modifications when required. Both simulations and test flights did a performance evaluation.

Various authors have proposed drones or micro-drones adoption in the PA domain, mentioning that drone application in PA will give exciting results with numerous benefits to farmers. De Rango et al. [39] have introduced a bio-inspired coordination protocol concerning UAVs' command and control in agriculture. Further mentioned in PA, sycophants or unforeseen climatic shifts are critical subjects to producers for crop degradation and farming conditions. Moreover, it suggested that FANET use modern sensors and actuators for the intelligent agriculture domain.

The author entitles UAV utilization [40] to spray mixed certainty chemicals like pyrethrin, fungicides, and herbicides. Sprinkling UAVs remain fitted concerning these assignments because there is a possibility that numerous fields require ultra-low employment of a restricted quantity of pesticides per given area with particular field zones that too on a definite time. Devraj [41] suggests a web-based practice that expedites farmer's/growers in diagnosing parasitoids regarding important crops while advising proper medications. Mogli and Deepak in [42] completed a review on drones application in PA. Further, suggested UAVs used in battling against diseases in agricultural fields after an attack of parasites and insects on plants, decreasing the fertility of the crops. Using Pesticides and composts to kill them to enhance crop quality further suggested spraying using UAVs. However, if done by individuals manually, it continues to have over a million cases of harmful consequences.

Shakhatreh et al. [43] in their paper explained Civil Applications with critical Research Challenges and different use of UAVs in different research fields in continuation to the use in PA under the civilian environment. The main application included with a few mentioned here is plant virus exposure, earth surface mapping, crop development mapping, and crop yield mapping. In their survey, Yang et al. [44] performed sensing by UAV in a crop field. Instead of using traditional methods for manually sampling author focused on using UAVs,

sparing individual time and power. UAVs, outfitted by multiple sensors, stand as an ideal approach for faster phenotyping and high throughput; moreover, the advantage of flexibility with timely work.

3 Aspects of Precision Agriculture and Why?

The need to strike a balance between agricultural productivity and environmental sustainability is just one of the modern challenges that can be met by applying precision agriculture [45–47], which uses cutting-edge information and communication technologies. UAV and its networks in this situation to measure/monitor specified environmental factors and enact control decisions from data obtained.

The Agricultural practices after the Industrial Revolution have increased with extra notable power inputs by large machinery, composites/mixtures, including biofertilizers instead of chemical fertilizers. Still, these systems may direct soil depletion, soil salinization, low soil richness, and compaction of subsoils, with adverse productivity and environmental evidence [48]. PA denotes an innovative and combined agriculture strategy that empowers farmers to practice evidence-related decisions on the field level to ensure optimal resource use to minimize the environmental impact on society's adverse implications [49]. In PA, utilizing traditional knowledge with spatial information collectively improves the system's sustainability, prolific, and productivity. The frequent technologies employed in PA include GIS, GPS, RS, AI, and ML-enabled data processing concerning timely growth supervision [48].

The principal aims of PA are:

- To boost the production of the crop,
- For improvement in products quality,
- Effective utilization of agrochemical products with right time, place, and quantity,
- To preserve farmer's energy as agriculture is a time-consuming process
- Protection of the physical environment against pollution.

The PA cycle [50] (see Fig. 1) defined by following steps:

- Data gathering: Clay complexion, crop parameters, and seed sowing with regional climate situations are estimated, observed, and drafted.
- Data analysis: Data analysis by training different growth patterns or visual examination and fitting data methods are tried to recognize spatially changeable parameters.
- Application: Results obtained of processed data, farm authority, choosing the appropriate area, the right biofertilizers at the right time, and possible application for better growth and productivity.

Data gathering moreover database creation are essential parts of PA, requiring a wide adoption of sensors with deployment within the land to assure correctness and exactness of on-field judgments using a DSS, finding reports like crop's tone, completion grade, and soil properties, water level, pest control. All is possible through sensor deployment with minimal cost. Remote sensing with high-resolution satellite comparison helps study variations within both crops, including soil conditions. But, difficulties are the availability and

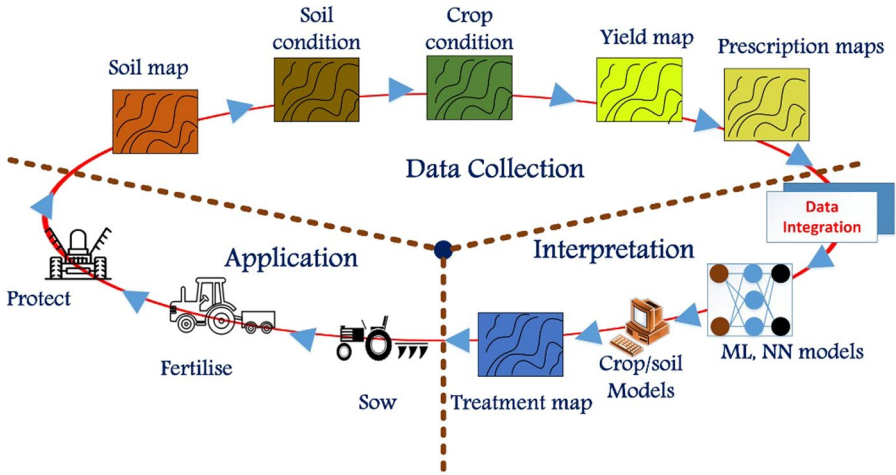


Fig. 1 PA cycle

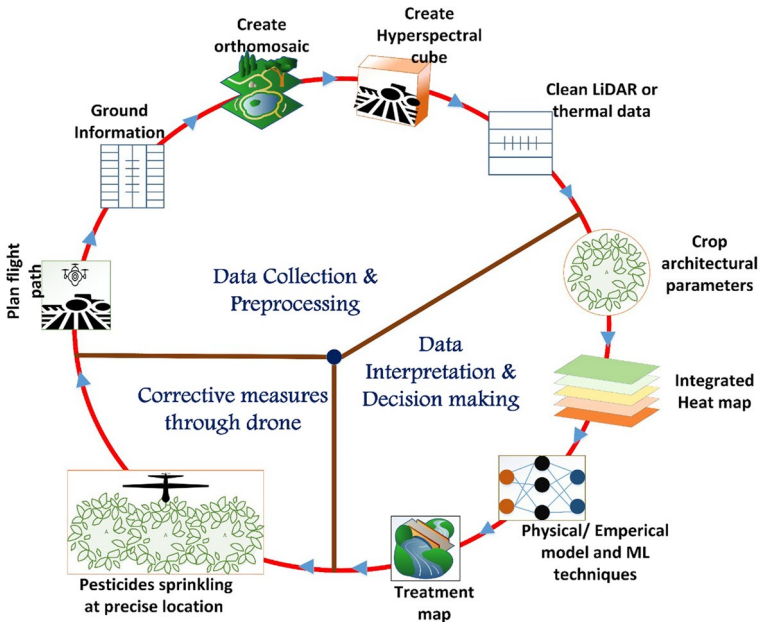


Fig. 2 UAV based PA [3]

price, the two utmost factors of non-deployment or use. An option is “small UAS,” which is needed to operate PA [1]. Figure 2 displays UAV based PA cycle.

4 Remote Sensing for Data Gathering: Why? What is it Commonly Used for?

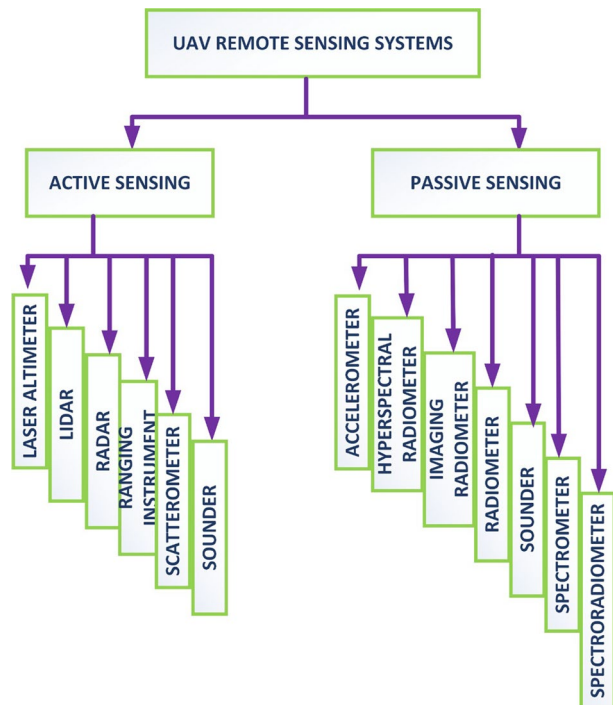
It helps you save time and money by letting you collect a lot of data without sending people to different locations, and it also gives you crucial data for keeping tabs on and predicting what will happen.

Existing UAV nature in gathering data from sensors placed on the ground and transmitting it back to the control station in real-time [51] is more effective and faster than conventional approaches. Sensors outfitted might be utilized as aerial sensor networks toward environmental monitoring and hazard control [52]-datasets originating from UAVs remote sensing used in the extended area of utilization yield estimations, drought inspection, water state, tree classes, disease discovery, and many more [53]. Within the section, we introduce UAV RS systems (see Fig. 3) and challenges by sensing with UAVs.

4.1 Remote Sensing Systems

The two primary RS systems are active, and passive [54]. In an active RS system, the sensors provide the energy source to recognize the objects. For object/target investigation, the sensor transmits radiation to it for detection [55] and measures the reflected radiation of the

Fig. 3 Classification of UAV RS system



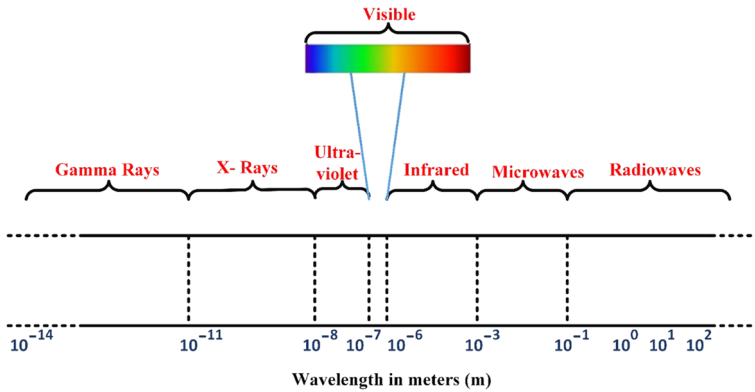


Fig. 4 Electromagnetic spectrum [56]

target. Various active remote systems applied in RS applications work in the microwave division of the electromagnetic spectrum (see Fig. 4), which helps in propagation within the atmosphere in nearly all conditions [54].

The active RS systems comprise various types shown in (Fig. 5A). Further, in a passive RS system, the naturally emitted radiation is detected by a sensor or mirrored by some object, as explained in Figure. The standard active sensors in RS remain LiDAR plus radar. The LiDAR sensor works by directing a laser beam over the earth covering and ascertaining the range of objects through time calculation within transmitted and bounce-back light pulses. On the other hand, a two-dimensional image is produced by a radar sensor of the surface marking the limit and energy's magnitude reflected on all objects.

Most passive sensors work in the electromagnetic spectrum's visible, infrared, thermal, and microwave divisions [57]. Thus, the passive RS systems comprise various types shown in (Fig. 5B). The spectrometer is the standard passive sensor in RS and is meant to detect, measure, and analyze the spectral content of incident electromagnetic radiation.

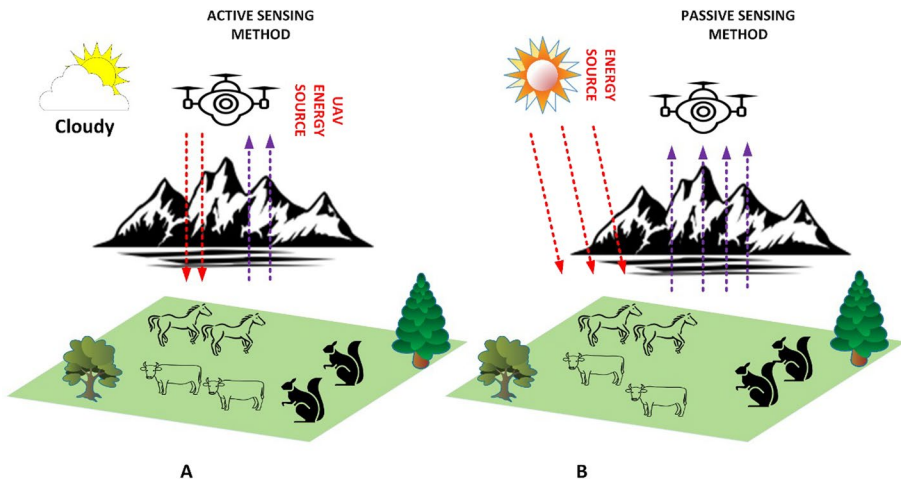


Fig. 5 Active and Passive sensing view

Fixed-wing UAVs viz. Viking aircraft [58–60], and VTOL Quadrotor viz. LIDAR [61] is appropriate in RS applications for real-time estimation, large-scale mapping, soil depletion, with numerous other activities. A contrastive study of UAV RS systems on Application, sensor, and frequency is listed in Table 3.

5 Types of Agricultural Sensors with Best Fit

By conventional farming, production increase on a large scale is impossible, keeping in mind the global population. Technological advancement and suitable sensors in UAV for smart farming are discussed and explored [62] in this segment:

5.1 Location-Based Sensors

Their use is in finding complex fields and spots within agriculture areas [63, 64]. The growers use different location sensors to identify various stages of crops' life cycle. In particular, GPS transceivers remain utilized in determining the longitude and latitude concerning some particular location at the earth's surface in conjugation with the GPS. In PA, an essential role is played by smart location sensors for pointing to those locations that require biofertilizers, treatment, watering, with other field issues.

5.2 Electrochemical Sensors

These sensors are used in the composition extraction of an appropriate biological sample like plants and soil [65]. These sensors detect different pH and soil nutrient levels where sensor electrodes recognize particular ions inside the soil.

5.3 Temperature and Humidity Sensors

The quintessential climate factors that undeviatingly hit the condition and growth of each crop are temperature and humidity. Accurate estimation of several environmental constituents helps the producer customize the volume of compost and water [66]; for such critical influencing factors, various sensors stay open for a more precise result for farmers of open land and conservatories. The working functionality of such sensors remains wireless, furnished with a battery-run.

5.4 Optical Sensors

The working principle of those sensors transforms light rays within electrical signals [67]. In UAV-based PA-related applications, [68], several optical sensors (like RGB cameras, multispectral cameras, and various others) have been used. Some of the working sensors on this principle are:

5.4.1 Visible Light Sensors (RGB)

UAVs most popularly use visible Light Sensors (RGB) in PA and are linked to innovative agro uses. For example, understanding human eye sensitivity is to RGB light bands. RGB

Table 3 Contrastive study of Active and Passive sensor [43]

Kind of RS	Operational frequency	Nature of the sensor	Purposes
Active	Microwave segment of ES	Laser altimeter	UAV's height is measured concerning the mean Earth's exterior for topography determination of the surface below it
		LiDAR	For calculating object distance by reading the time amid transmitted and back-reflected beams
		Radar	By the recorded range and returned energy magnitude of objects, a surface 2-D image is produced
		Ranging Instrument	Used in finding a range among the same microwave machines on a couple of programs
		Scatterometer	A map of surface wind speed and direction is determined by estimating back-reflected radiation within the microwave spectral range
		Sounder	Its use is in measuring heat, and moisture with the vertical distribution of precipitation
		Accelerometer	It holds two accelerometers types: the translational and angular accelerations
		Hyperspectral radiometer	It distinguishes within various marks by the spectral acknowledgement within every narrow band
		Imaging radiometer	To draw an image, provided 2-D array pixels are used
		Radiometers	They are used in measuring electromagnetic radiation intensity in the spectrum of any band
Passive	Visible, IR, TIR, and microwave segment of ES	Sounder	Its use is in measuring heat and moisture with the vertical distribution of precipitation
		Spectrometer	Intended for detecting, mapping also interpreting the spectral content of electromagnetic emission
		Spectroradiometer	For measuring radiation intensity within various wavelengths bands, furthermore remote sensing of particular geophysical parameters

sensors mounted on UAV cameras reproduce captured images of the same effect to the human eye. Thus, quicker observations of the entire field by captured images, aerial videos at a single instance, and GPS data root problem identification are possible without ruining the whole land [69].

5.4.2 Multi-spectral Sensors

For acquiring UAV-built agricultural investigation, multispectral sensors are deeply relevant with multispectral cameras (see Fig. 6). Striking spatial resolution images captured by sensors reflectance in near- infrared [70], making it appropriate for farmers, researchers, and agronomists. The multiple light bands empower the conduction of accuracy investigation and unfold acumens inside the plant-multispectral data inadequacy in plant disease detection, insect identification, and other issues are nearly tricky.

5.4.3 Hyperspectral Sensors

Detailed images in the spectral and spatial range need Hyperspectral sensors for capturing images. It is outfitted by field indicators that specify the take-over light by converting occurrence photons toward electrons. Conversion is possible with CCD and CMOS sensors. To use this sensor in decision-making within agriculture, UAVs must have pre-built systems.

5.5 Thermal Infrared Sensors

These sensors assist in showing an entity's heat, exhibit images, and illustrate the corresponding build upon the accumulated information. In capturing thermal energy, Infrared sensors, including optical lenses, remain utilized in thermal cameras. The thermal cameras recognize the radiations belonging to wavelengths by converting each to a grayscale image-producing heat respectively [71]-applications of thermal sensors in various agricultural activities is by UAV mounted sensors for crop monitoring with soil tone, water balance, pathogen, and other diseases [57, 72], plus many more. Table 4 illustrates different types of agriculture sensors.

6 Types of UAVs

A UAV signifies an onboard pilotless aircraft that doesn't urge direct individual association when flying; moreover can operate and control remotely.

6.1 Rotary-Wing UAVs

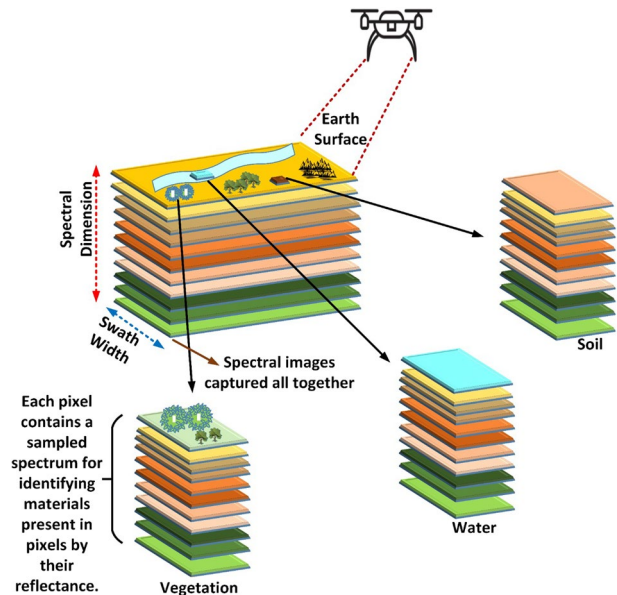
The rotor UAVs, additionally termed rotorcrafts, have the benefits of constant flying on a single point at a given amount of time while maintaining mobility properties. Such characteristics are essential for numerous distinctive natures of purposes. They lack flying at relatively high speed rather than staying for an extended period in the sky. They are usually the common, extensively accepted UAVs within every manner of purposes, particularly under PA. The extensive applicability has a view toward this: the more economical prices

Table 4 Regularly employed Sensors in UAV during agricultural works [73]

Sensor Kind	Make	Key Features
RGB	Canon Powershot SX540	20.3 MP 442 g
	Olympus PEN E-PM1	12 MP 216 g
	Sony Nex-7/ILCE	24.2 MP 416 g
	Ricoh GR3	16.9 MP 257 g
	Sony α 7r	36.4 MP 407 g
	MicaSense RedEdge	R G B Red Edge NIR 1280*960 230 g
Multi spectral	MCA camera	4, 6, 12 bands (user-selectable) 1280*1024 497 g (per camera)
		4, 6, 12 bands (user-selectable) 1280*1024 600, 700, 1300 g
	Mini MCA	4, 6, 12 bands (user-selectable) 1280*1024 497, 530, 1000 g
		R G Red Edge NIR
	Parrot Sequoia	2 MP 72 g (Includes 16 Mp RGB Camera)
	InGaAs	Infrared 640*1512 R G NIR
		Tetracam ADC lite
	Tetracam ADC micro	2048*1536 pixels 90 g range: 100 m
Velodyne VLP-16		FOV: 360 deg Horizontal \pm 15° Vert Accuracy: 3 cm 830 g
Laser	Hokuyo UTM-30LX	Range: 30 m FOV: 270 deg Angular res: 0.25 deg Accuracy: 50 mm 210 g
		Nikon Forestry Pro II Ragefinder/Hypsometerm
	DJI Zenmuse XT	Range: 7 m-1600 m FOV: 7.5 degrees 170 g 640*512
Thermal	Xenics Bobcat 640 GigE SWIR/vSWIR	7.5–13.5 μ m Weight: 270 g
		500-1700 μ m 285 g 384*288

Table 4 (continued)

Sensor Kind	Make	Key Features
	Thermoteknix MicroCAM Integrator	17 μ m 60 g
	FLIR Vue Pro R	640*512 113 g
MultiScanner	RapidSCAN CS-45	670, 730, 780 nm

Fig. 6 Bicopter UAV based crop monitoring with Multispectral camera

than the different varieties of UAVs. In extension, the nature of UAVs is fit when the crop analysis is not particularly extensive, which is usually the case. A UAV of this type may be:

6.1.1 Multi-rotor UAV

This category includes rotary-wing UAVs with various rotors, viz. bicopter, tricopter, quadcopter, hexacopter, octocopter. Each has their advantage and limitation; diverse applicability with varying use will prove worthwhile.

6.2 Fixed-Wing UAVs

Under this category, UAVs with kept wings require a runway to take off from the ground or launch position initially. This UAV class has the necessary endurance and ability to fly at fast velocities. In carrying more payloads, fixed-wing UAVs remain a better-suited option and, in each flight, can easily cover large areas. On the contrary, in comparison to other UAVs, they are also expensive. One new model regarding fixed-wing UAVs earlier not

identified and is in up growing phase with a keen interest in researchers and companies yet holds an up-and-coming technology denotes the solar-powered UAVs [74]. These UAVs have significantly prolonged flying backgrounds since they use and collect solar energy throughout the day or when available and use it as a source (fuel) to fly. For this reason, long-endurance operations will be preferred more in contrast to others.

6.3 Single-Rotor UAV

Although named Single rotors, they combine central and tail rotors like conventional helicopters. These UAVs possess one colossal rotor with a smaller one at the UAV's tail. The Colossal rotor works in lifting while the smaller one works on controlling the UAV. Fly time remains higher with other UAVs in comparison to multi-rotor. High cost, more compact, and operative risks are the limitations.

6.4 Fixed-Wing-Multi-rotor Hybrid UAVs (Hybrid VTOL)

Besides, it is also known as a fixed-wing jet or alleged as a hybrid UAV or VTOL aircraft [75]. It can operate in nearly any likely condition with an ideal multi-rotor design. The hybrid VTOL UAVs are remarkably prominent concerning the relevant flight routines that are supposed to be helpful for agricultural purposes.

7 Drone's Movements

UAV (Drone) plot is requisite for the simulation of a practical situation. More clear insights are by a drone's mobility model, which shows a drone's probable flight movement on a map. The drones' movement representation uses a 2D and 3D representation by set speed; the steady boundary turns with no collisions. Thus, a planned speed stays almost realistic in situations where the drone's movement is on the map.

Various mobility models of UAVs (FANET) are listed by Srivastava et al. [76]. Area scanning by UAV in the following defined Mobility model (see Table 5) and relevant to Agriculture mentioned below:

7.1 Path Planned Mobility Model

This model aims at unchanging pathways used via UAVs and is compelled to continue this, apparently producing a random motion where the planned route ends. UAVs may include inconstantly turnabout directions besides redoing the entire method once again.

7.1.1 Semi Random Circular Movement Mobility Model

The preceding model (Fig. 7A) empowers all nodes to form a disklike (or arch) move about a decided novel centre [77]. Doing a complete turn waits for a short term while the UAV randomly chooses a different radius. Thus, the disklike plans control overcoming crashes between UAVs.

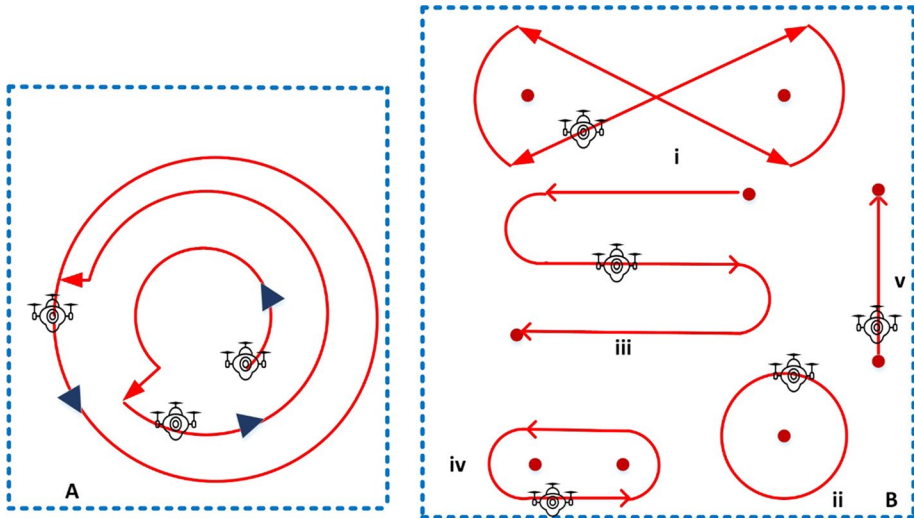


Fig. 7 Drone Movement

7.1.2 Paparazzi Mobility Model

[78]

This mobility model functions in a path-based manner, using five likely movements shown in (Fig. 7B):

- Eight: The trajectory pattern of the UAV has the 8-like design of about two set points.
- Stay-At: The trajectory pattern is utilized if the UAV has to hold the position about a subject of concern.
- Scan: This mobility pattern is chosen when we have no subject of concern, and a UAV needs to look at an entire area. The source point and the terminating bounds of an area need scanning-the area to be monitored has no information. This pattern may be commonly used.
- Oval: An area bounded by paired points needs scanning; UAVs consider this trajectory pattern. The mobility pattern UAV focuses the scan with the ellipse. For the scanning area, the position of the two focuses is moved closer at each pass-through.
- Waypoint: Under this model, UAVs follow a straight path to the destination position; every possible UAV movement represents the state machine.

Paparazzi [79] UAV action build on the state machine shown in Figure.8

8 UAVs Applicability within Farming

Following the MIT, UAV application to the Agriculture business will proffer a methodical transformation, outlining and maneuvering real-time gathered data and processing. With the rise in the global community and the aftereffect influence on agricultural expenditure,

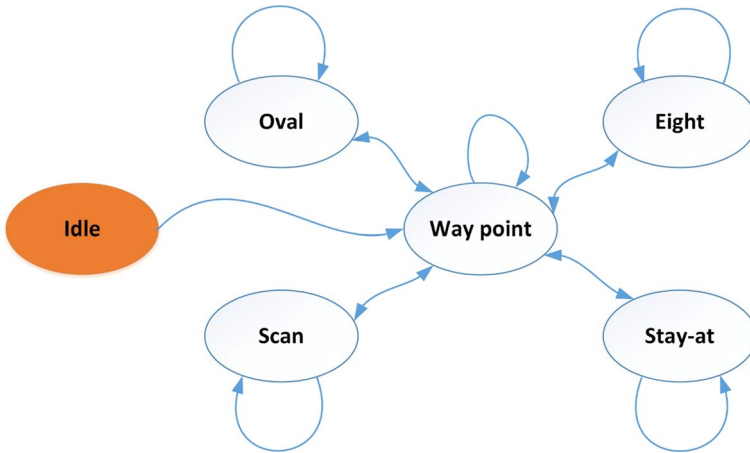


Fig. 8 Paparazzi UAV action

Table 5 Unique sequencing on MM, UAV competency with pertinence

CM	MM	UAV's nature	Pertinence
	Random Walk	RW	
PR	Random Way Point	RW	Ecological sensing/Traffic and urban Monitoring
	Random Direction	RW	
	Manhattan Grid	RW	
	Boundless simulation Area	RW	
TD	Gauss Markov	RW	Ecological sensing/Traffic and urban Monitoring
	Smooth Turn	RW/ FW	
	Semi Random Circular movement	RW	Farming supervision/Traffic and urban monitoring
PP	Manhattan Grid	RW/ FW	
	Exponential Correlated	RW	
	Particle Swam	RW/FW	
GB	Spatio Temporally Correlated group	RW	Ecological sensing/Exploration and rescue
	Column	RW	
	Nomadic Community	RW	
	Pursue	RW/FW	
	Pheromone-based	FW	
TB	Distributed pheromone repel	FW	Exploration and rescue/Monitoring
	Mission plan based	FW	
	Self-deployable point coverage	RW	

CM: Class of Mobility, PR: Pure Randomized, TD: Time-Dependent, PP: Path-Planned, GB: Group based, TB: Topology based, MM: Mobility Model, RW: Rotatory Wing, FW: Fixed Wing

Table 6 Principal aspects of UAVs adopted in agriculture [73]

Type	UAV	Payload (kg)	Endurance (min)	Dimensions (m)
Octacopter	MK Okto XL 2	4	46	0.95*0.73*0.45
	Okto-XL	2.5	25	1.045*0.45
	DJI Agras MG-1	10	–	1640*1471*482
	Spreading Wings S1000	6–11	15	1.1*1.1*0.38
	ARF-MikroKopter	2.5	28	0.73*0.73*0.36
	AT8 UAV	2	30	1.2*1.2 *0.4
Hexacopter	EM6-800	1.2	25	0.8*0.8*0.32
	Matrice 100/S1000	1	40	0.65
	DJI M600	4.5	16	1.6*1.5*0.7
	Hexacopter P-Y6/A2500_WH	3	21	1*0.45
	HEXA-PRO™ UAV	2	40	0.85
	AIR-200	3	40	2.2
Quadcopter	Parrot AR/2.0	–	12	0.52*0.51
	Parrot Anafi	–	25	224*67*65
	Phantom 2/3 Pro/4 Pro	0.3	30	0.35
	DJI Mavic Pro/inspire 1/inspire 2	0.2	21	0.29*0.28*0.11
	Jifei P20 UAV	12	20	1.8*1.8*0.47
	MD4-100/1000	1.2	45	1.03
Helicopters	3DR Iris/Solo	0.4	22	0.4*0.63*0.15
	Yamaha Fazer R	32	25	3.66 *770*1.078
	Rotomotion SR200	20	240	2.5
	SKeldar V200	40	300	4.6
	Gatewing X100	0.2	15	1*0.6*0.1
	zangão uav	1.1	60	1.95
Fixed wing	Trinity F90+	–	90	2.394
	eBee SQ/Plus	0.3	59	1.1
	M23 UAV	14.6	25	3.1*2.9*1.4
	Tuffwing Mapper	2	40	1.2*0.6*0.2
	Airborne XT	200	3900	9.9*3.6*1.9

precision-based agriculture [80–82] is the need of the hour. One such technology is UAV incorporation in PA. UAV utilization fields are bestowed in later subsections. Table 6 lists UAV characteristics to be used in Agriculture.

8.1 Soil and Field Analysis

UAV's use in gaining soil information is much more effective in the initial stage of a crop cycle. Collected data assist in the initial soil report and is beneficial in preparing seed plantation patterns. In addition, farmers making irrigation plans will get assistance from these data and further determine the volume of compost required on the soil or field following planting. With the data-driven procedure, farmers can increase the overall yielding capacity of a farming product, curtailing composts and pesticides. By UAVs, a group of those are achievable through remote analysis of images at a lower cost than satellite images. Pena

et al. [83] explained an OBIA on a range of UAV images of the Spain maize field with six-band multispectral cameras. While in [84], UAVs that capture remote image specifications and configuration are given by an author for ESSWM. For weed seedling discrimination, the evaluation of image spatial and spectral properties is necessary for UAVs outfitted with multispectral cameras—further, detecting and locating weed seedlings in a sunflower field UAV operated at different levels altitudes for generating those images. The research result helps in selecting suitable sensors for ESSWM.

8.2 Crop and Spot Spraying

Crop spraying ordinarily denotes an arduous task for producers and farming product firms. It means extensive land coverage comprehensively to assure precise crop growth. Uncomplicated crop spraying for producers is using Agricultural UAVs with coverage of widespread land within a short time. With sensors mounted onboard, UAVs readjust their altitude automatically, sprinkling over variable fields. Using UAVs has various advantages for farmers in crop spraying, like time with expense, efficient spraying till roots and soil reaches further, and farmers' protection from prolonged danger to possibly toxic compounds previously linked with hand-operated spraying. Lv et al. [85] illustrated the potentiality of evaluating droplet deposition in aerial spraying with infrared thermal imaging. First, the UAV flight speed effect was investigated on the spray droplets; moreover, a UAV test at variable flight speed was also conducted, saving approximately 90% on chemical herbicides by Spot spraying. Various work [86–88] was done in defining spot spraying effectiveness with UAVs.

Algorithm 1 Proposed UAV sprinkling Algorithm based on provided Area

```

Step1: area = length * width * height
// Area of the entire field.
Step2: length, width, height = map(int, input().split().strip())
// Length and width of the field, along with the height at which the drone is
flying, are provided as the input.
Step3: requiredFluid = area*1000
// Fluid required to cover the entire field.
Step4: fluidPresent = int(input())
// Fluid is already present in the container. Here, the initial assumption is of
100L fluid has already been present in the container.
If (fluidPresent < requiredFluid)
{fluidPresent += requiredFluid - fluidPresent}
// If the present fluid is less than the required fluid, then go back and refill
the container with the remaining fluid.
Step5: print("Sprinkling ....")
Step6: print("Covered area successfully completed!")
//When it gets sufficient fluid, sparkle over the field.

```

8.3 Crop Monitoring

Broad farm areas and low efficiency remain common farming difficulties in crop monitoring. In addition, monitoring has a direct impact on unstable weather situations. With agricultural UAVs, these challenges faced by farmers can be overcome with no risk and fewer

field maintenance expenses. Guo et al. [89] explained the event of a quantitative depiction of outcomes like stress maps of the crop from UAV and underscored the UAVs value in RS when employed within PA by single-rotor with multispectral cameras. Processing of UAV images by a framework and aligning generated mosaic images for mapping with GIS integration.

8.4 Irrigation

With thermal cameras in Agricultural UAVs, farmers will have colossal perspicacity in precise farm areas. The effectiveness of thermal cameras for farmers helps determine low soil moisture areas and dry outcrops; in the health sense, it can be easily determined. With conventional farming, this level of precise monitoring was not feasible without an agricultural domain expert who could provide satisfactory clarifications. UAV integration will help farmers proffering the ability to manipulate all by themselves. Baluja et al. [90] examined the variability of vineyard water state with thermal and multispectral imagery employing UAV. Khanal et al. [91] work focused on using thermal sensors in PA and its relevant applications. Gonzalez-Dugo et al. [92] deal with assessing the diversity of water rank in the commercial farm as a need for the precision irrigation market. Again, a high-resolution airborne thermal comparison remained used.

8.5 Health Assessment

Fungal and bacterial conditions are most common in farming and directly affect a crop's health. Therefore, the farmer's aspect needs to assess the same in farming. Manual scanning accuracy in large and dense areas might not be significant. However, UAVs examining a crop utilizing visible also near-infrared light can discover temporal and spatial reflectance changes for the exact health conditions of the complete farm, which will help overcome such diseases. Farmers on crop damage assessment process and documentation for insurance claims remain easy. Jianwei et al. [93] confirmed health assessment with UAV by outlining remote sensing benefits. They employed a superior SIFT Algorithm to match images and assortment with excellent results.

9 UAVs in Livestock Farming

Livestock farming is growing animals as food, including other utilities like medication, leather, fleece, and manure. Therefore, besides different agricultural aspects, Livestock farming continues strenuous and challenging. Individuals are, though, not quite fit for the before-mentioned tasks over an extended time. Therefore, functional relevance under this assembly is using a machine in Agriculture to do the redo jobs quicker and perhaps effectively longer than a human. UAVs accordingly have no limitations and have discovered working applicability within livestock farming. Some applications are:

9.1 Livestock Sensors

In a country like South Africa and Europe, animals are grown in considerable numbers in millions, which are monstrous figures; hence, keeping track of and regular reckoning such

vast numbers of animals is challenging, time taking, and more labour engaging. UAV's application in performing inventory headcounts concerning livestock over those extensive grazing fields [94] will decrease inaccurate counts by image recognition [95] or use of IR cameras [96]. The authors in [97] proclaimed 73% count with 78% tracking accuracy with UAVs counting and detecting the animals.

9.2 Animal Health

Ahead of summing, at the Texas A & M University, UAVs mounted with infra-red cameras are used in monitoring animal health (see Fig. 9) under new work. The concept behind this work is a premise about animals having heightened temperatures having a fever. UAVs in regular or within any pandemic can recognize, and proper vaccination can be given [98]. The same study on health monitoring is done in [99].

9.3 Monitoring & Identification

Animals tagged with RFIDs, or other sensors can be monitored easily with UAVs by individuals. The recognition is likely done by employing UAVs mounted by regular cameras, IR cameras, or RFID readers. A significant test of RFID application is RFID tags, which have a concise range, a concerning issue. A possible move might be:

- Canvas QR codes for scanning by UAV cameras to recognize them easily.

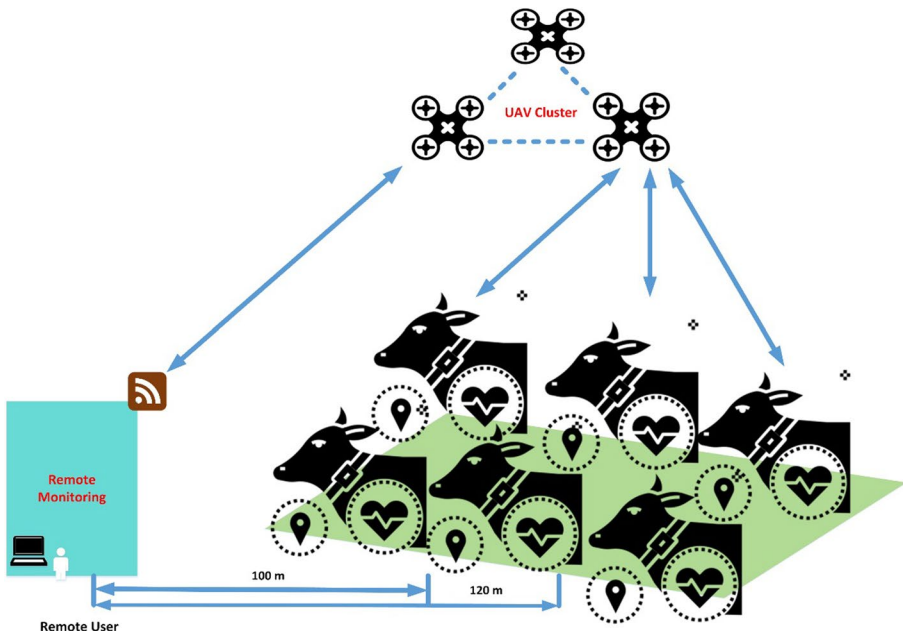


Fig. 9 Animal health monitoring with UAV

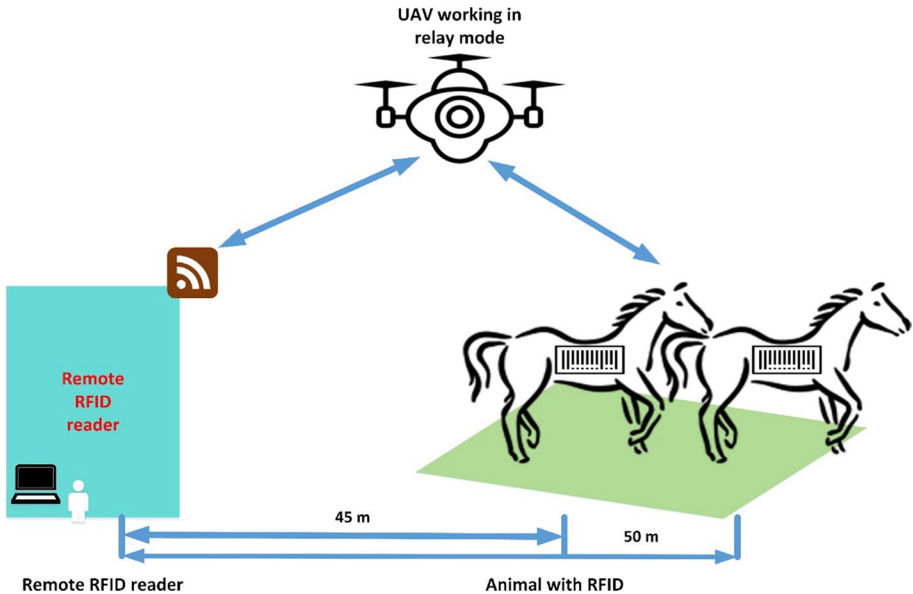


Fig. 10 Animal identification by UAV in relay mode

- UAV's usage is relaying like RFLy being examined by MIT [100]. Within RFID chips and readers, RFLy works as a relay. A 50 m span to passive RFID chips with RFLy is possible.

Monitoring of specific movements of animals with their feeding behaviour [101] is easy for farmers. UAVs have been broadly used to keep an eye on threatened animals grown in confinement and freed for free. Figure 10 shows a potential use case of UAVs and RFID tags in animal identification.

9.4 Aerial Mustering

In mustering, aircraft are used to find and group animals in a vast land area compared to traditional methods where dogs and humans on horses were used. Helicopters possess challenges like long practice, licensing charges and certifications, fuel price, apparent signs, high-risk danger, and disasters. Option to the above solution is the use of UAVs in aerial mustering is relatively unscathed, more economical to operate, and less practice time, yet capable of achieving comparable results. In countries like Australia and New Zealand, its successful utilization has been for marshalling sheep and cattle [102]. Various case studies of the applicability of DJI Phantom in Agriculture are addressed within [103], with UAVs (see Fig. 11) using sirens to drive animals.

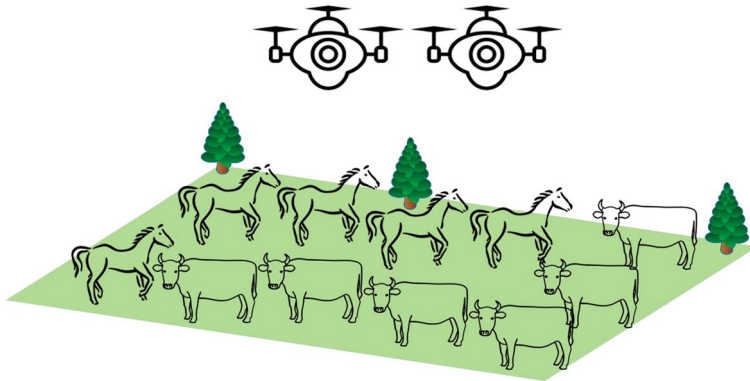


Fig. 11 Aerial mustering with UAV

10 UAV Flying Regulation for Agricultural Tasks

Laws and regulations are different specifically concerning each country, and some might be common worldwide—consequently, several countries of drone statutes specified within hobby and business activities. However, hobby flights have significantly fewer restrictions compared to business flights. Thus, the maximum standard height is 300–400 ft. or 120 m for drones—the aforementioned is a locked height to evade collisions with different aircraft. Further recommended not flying above oneself or adjacent mobs and non-enabling beyond the line of sight, particularly daylight flight. In countries specific, the Indian Government, in a deadline "public notice no. AV-22011/4/2015-DG dated 13 January 2020, issued by the Ministry of Civil Aviation, Government of India", made mandatory for registering personal drones. Talking on Europe main aspects of regulation for drones' technological and operational specifications is reducing people's risk with another aircraft seclusion, safety, and information assurance issues. With the above concerns in 2019, the "Easy Access Rules for Unmanned Aircraft Systems" was made by EASA and set three divisions concerning the UAS controls with various safety provisions:

- Any prior operational authorization for the Open category is not a subject nor any operational declaration by the UAS operator.
- The competent authority authorization is required for a specific category before the operation with the operational risk assessment report except for explicit standard scenarios wherever a statement by the operative is satisfactory. The operator contains a light UAS operator certificate.
- If the certification of UAS is required holds by an operator approved by the competent authority, it is termed Certified.

The regulatory framework for services under the 'certified' class is advancing. Agriculture operations by UAV in almost all cases could be categorized in the "open" category, with a maximum takeoff mass vehicle is less than 25 kg. Further, the maintained distance of UAS should be 120 m from the closest point of the earth's surface, except when overflying an obstacle. On 31 December 2020, the latest European drone laws came into action. Certified by EASA do not need registration. However, an operator must register with the CAA

of their EU country of residence for the unique registration number of Europe. This must be exhibited on a drone with a label and synchronized with 'Drone's remote identification system.' The national CAA determines the valid registration phase, which needs renewal when invalid. Meanwhile, drones weigh less than 250 g; operators need not register with no camera or other sensors to detect personal data-applicable regulations to most countries worldwide, a complete list mentioned in [104]. Class G airspace flights can keep the UAV within a visual line of sight. In addition, the UAV flight has to be carried out at 400 or below 400 feet in daylight with a speed limit of 100 mph.

11 Conclusion

In solving agricultural challenges, we examine various means. PA becomes essential with the limited availability of fertile lands, the accelerating necessity for fresh water, and the calamitous outcomes of environmental transition. The ICT assistance function has developed significantly and swiftly in both reaches and balances, benefiting digital technology. Enhancement in cultivation processes is by use of UAVs since they can perform the various before mentioned functions. UAV's use in PA operations with various agricultural UAV types and technical characteristics are reviewed within the research, and it renders a viewpoint for the effective use of adopting UAVs. A discussion of the extensive and important factors of practicing UAVs in PA is made available. This extensive work gives producers and enthusiastic researchers preparatory insight into deciding the relevant UAV and systems for PA operations. Numerous concerns in the work here are named in adopting UAVs in agricultural examination with a diversity of utilized methodologies. Regardless, UAVs' applicability in PA transfers agricultural benefits and shapes the UAV revolution. Future work will incorporate how to effectively use the technological advancement so that it helps out in an effective manner, and this work will give the current researchers a brief insight into agricultural UAVs and how they can play a positive role in planned farming purposes.

12 Research Directions

UAVs/Drones used in agriculture [105] are the wave of the future in countries like India, which have large agricultural economies. It has the potential to revolutionize farming in many different ways. Although this method is more challenging to learn at first, once mastered, it yields results rapidly. Farmers need to know what goes into every step of the process. Goal-setting, deploying a drone and software that operate well together, and getting used to the basics of using the technology are all challenging tasks. In order to collect reliable data, farmers will need extensive training or work with outside drone experts. Using drones in agriculture presents a number of interesting research opportunities, including:

1. Scouting crops like sugarcane, coconut, etc., where manual surveillance is very difficult;
2. Irrigation scheduling based on crop water stress detection
3. Pest control spraying on mountainous terrain, crowded fields, etc.
4. Field image collection for weed detection and control by using deep learning and vision-based systems
5. A farmland survey to rapidly assess crop damage and production loss This will help the government offer adequate compensation and insurance.

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7. Stubblefire avoidance guidance for farmers through biomass estimation
8. Mapping in-channel habitats and detecting illegal fishing to aid in the prosecution of offenders in the fisheries industry
9. The observation of diseased animals' behavior

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Declarations

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Ashish Srivastava is an Assistant Professor in the Department of Computer Engineering & Applications, GLA University, Mathura, India. He received his Ph.D. degree in Information Technology & Computer Application from Madan Mohan Malaviya University of Technology, Gorakhpur, India. He received his master's degree in Computer Science & Engineering (Computer Networks). He received his bachelor's degree in Information Technology. His research interests include MANET, FANET, Antenna Communication, UAV, UAV Video, image processing, and Routing protocols. He has published papers in International Journals, International Conferences, SCI, SCIE, ESCI and Scopus indexed Journal. He is a Review Board member, Editorial Board member in various journals with Section Editorial Board Member, and reviewer across multiple SCI, SCIE, ESCI and Scopus journals.



Jay Prakash is an Associate Professor in the Department of ITCA at the Madan Mohan Malaviya University of Technology, Gorakhpur, India, and has a total teaching experience of 20 years. He has published more than 38 papers in national and international journals (SCI, SCIE) and conferences. His core teaching and research interests are in the domains of networks, parallel and distributed computing, architecture, and video and image processing. He conducts research in the design, analysis, and various applications of networks and distributed environments and also uses techniques from machine learning and soft computing. His research focuses on noise suppression in video and images in the transform domain, various protocols of networks, antennas in communication, and gateway discovery in Adhoc networks for Internet access.