Chapter

Digital Inclusion of the Farming Sector Using Drone Technology

Suman Dutta, Ajit Kumar Singh, Bhabani Prasad Mondal, Debashis Paul and Kiranmoy Patra

Abstract

Agriculture continues to be the primary source of income for most rural people in the developing economy. The world's economy is also strongly reliant on agricultural products, which accounts for a large number of its exports. Despite its growing importance, agriculture is still lagging behind to meet the demands due to crop failure caused by bad weather conditions and unmanaged insect problems. As a result, the quality and quantity of agricultural products are occasionally affected to reduce the farm income. Crop failure could be predicted ahead of time and preventative measures could be taken through a combination of conventional farming practices with contemporary technologies such as agri-drones to address the difficulties plaguing the agricultural sectors. Drones are actually unmanned aerial vehicles that are used for imaging, soil and crop surveillance, and a variety of other purposes in agricultural sectors. Drone technology is now becoming an emerging technology for large-scale applications in agriculture. Although the technology is still in its infancy in developing nations, numerous research and businesses are working to make it easily accessible to the farming community to boost the agricultural productivity.

Keywords: agriculture, crop productivity, drone technology, unmanned aerial vehicles, farm income

1. Introduction

Intensive agriculture has a number of detrimental environmental consequences. It contributes significant amounts of nitrogen and phosphorus to terrestrial ecosystems [1]. Agricultural chemicals pouring into adjacent water are also contributing to increased contamination of water bodies, as well as damage to water-related ecosystems [2]. Excessive fertilizer application can pollute the environment, but insufficient fertilizer application to replenish nitrogen and phosphorus lost via intense cropping can cause deterioration of soil fertility [3]. Furthermore, substantial soil deterioration is posing the ecosystem to reduce the productivity of many soils [4]. In addition to the environmental effect, the health risks associated with chemical usage in agriculture must be taken into account. Agricultural workers, their families, the residents of the areas surrounding crops, and farming sites may be at risk from toxins [5]. Furthermore, pesticides are absorbed by crops and natural resources posing

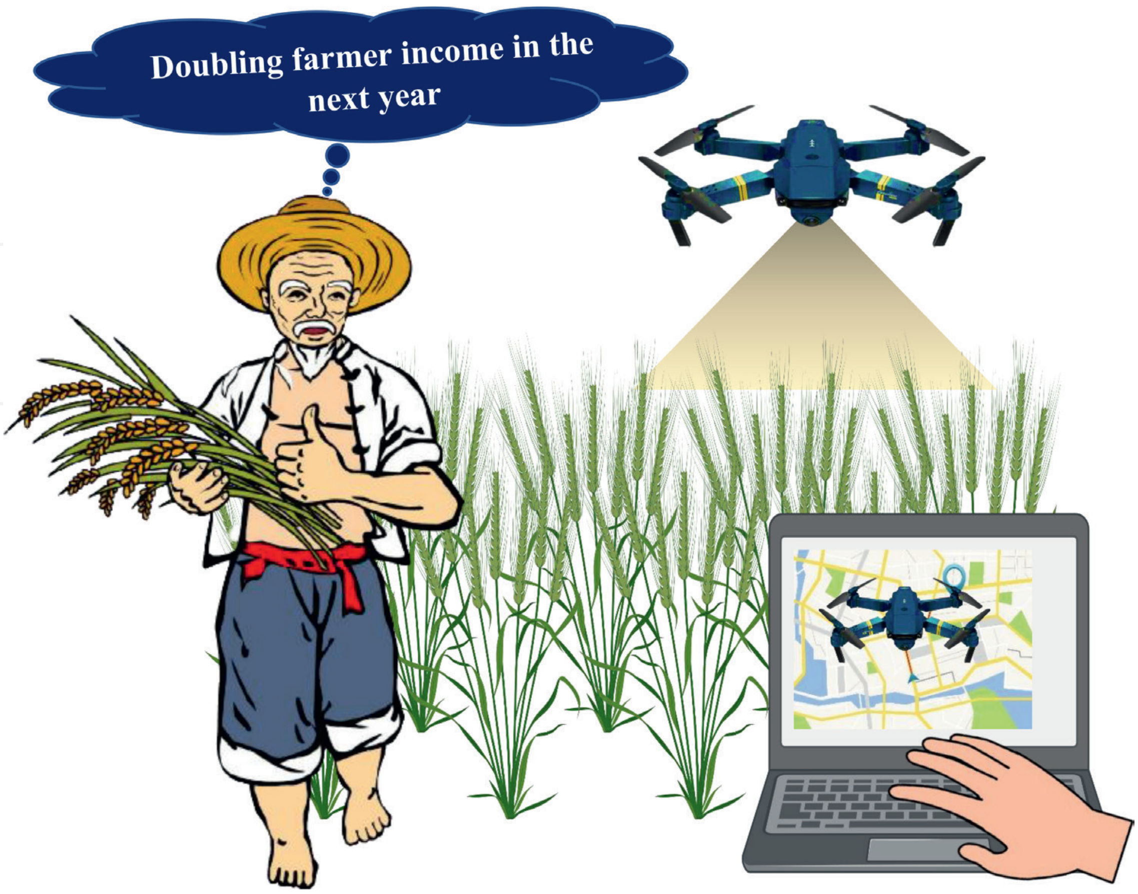

Figure 1.
Interaction between drones and farmers to double farming income.

a growing risk to animals and people, as well as having significant negative public health consequences [6]. These fatal consequences can be reduced by autonomous precision agriculture where chemicals like fertilizers and insecticides are only applied in the places of need rather than blanket application. Water deficiency, nutritional stress, and disease may be localized to assess, and a choice can be taken to solve the problem. In this regard, drones have been used in agriculture for large-area inspection, smart targeted irrigation, and fertilization [7, 8]. Some of the current uses of agriculture drones are monitoring of crop biomass, crop growth, food quality monitoring, and application in precision farming, such as determining the density of weed populations for site-specific herbicide treatments and logistic optimization of resources [9]. A few technical instances of drone application in precision farming are crop monitoring [10], pesticide application [11], soil and field analysis [12], and crop height estimations [13]. Special camera systems may gather excellent information from an unseen section of the electromagnetic spectrum termed Near-Infrared (NIR) to confirm the presence of algae in rivers or oil spills near coastlines [14]. All of these applications need the processing of pictures captured by a drone-mounted camera. The ability to detect regions where heavy irrigation is required or where a foliar disease is growing using a drone-mounted infrared camera can assist agronomists to save time, water, and agrochemicals. Simultaneously, better agricultural practices may result in higher crop output and productivity to enhance farm income. Recent years have seen a surge in interest in Human-Robot Interaction (HRI) from the academic community, government laboratories, IT companies, and the media [13]. Due to this interest, it would be beneficial to provide a general overview of HRI to act as a primer for individuals outside the field and to promote discussion on a common understanding of HRI inside the field. The body of literature is rapidly expanding with a focus on the technical disciplines of mechanical and electrical engineering, computer and control science, and artificial intelligence. The goals of drone usage are to provide a cogent overview of HRI-related concerns for emphasizing key themes on difficult topics that will probably have an immediate influence on the farming profession. The emphasis is on putting in place a multifaceted strategy to boost farmers' income by increasing productivity through the creation of resources (**Figure 1**).

2. Unmanned aerial vehicle

An unmanned aerial vehicle (UAV) can fly without a human pilot and is controlled by radio [15]. UAVs fill the void left by human mistakes and inefficiency in traditional farming practices. The goal of implementing drone technology is to eliminate any uncertainty or guessing and instead focus on accurate and dependable data [9]. Weather, soil conditions, and temperature are all important aspects of agriculture. Agriculture drones enable farmers to adapt unique circumstances and make thoughtful decisions. Multi rotors are a type of UAV that may be further defined by the number of rotors in its platform [5]. In the previous two decades, several types of UAV models such as Quad copter [16–18], Hexa copter [12, 13, 19], Octo copter [10, 20, 21], Fixed Wing [22–24], and Single Rotor Helicopter [11, 25–32] have been deployed. Fixed wing UAVs have a completely different design from multirotor. A single-rotor helicopter features only one large rotor on top and one little rotor on the UAV's tail. Quad copters, Hexa copters, and Octo copters are multi-rotors with four, six, or eight rotors, respectively that lift and propel them. A quad copter is a type of UAV with four rotors. These rotors are responsible for the quad copter's lift. The two opposing rotors rotate in a clockwise direction, while the other two rotate in a counter-clockwise direction. Pitch (backward and forward), roll (left and right), and yaw (clockwise and counter-clockwise) are the three modes of quad copter movement around the axis [5].

3. The architecture of a drone for precision agriculture

Drones are semi-autonomous in precision agriculture, as well as in disaster assistance, construction inspection, and traffic monitoring [9]. In that instance, the drone must follow the definition of a straight path in terms of waypoints and height. As a result, the drone must have a positioning measurement system such as the Global Navigation Satellite System (GNSS) on the board in order to determine its location in relation to the route points. It also has an altimeter such as barometer, laser altimeter, or ultrasonic sensor for flighting at consistent heights. The APM Planner is an example of software for determining the mission trajectory. According to Brzozowski et al. [33], the fundamental design of a drone comprises the following components: (a) frame, (b) brushless motors, (c) Electronic Speed Control (ESC) modules, (d) control board, (e) Inertial Navigation System (INS), and (f) transmitter and receiver modules. Multispectral, infrared, RGB (Red-Green-Blue), and Light Detection and Ranging (LiDAR) systems are among the sensors integrated into drones in precision agriculture [9]. The status of the observed vegetation is quantified using multispectral cameras in terms of chlorophyll content, leaf water content, Leaf Area Index

(LAI), ground cover, and the Normalized Difference Vegetation Index (NDVI) [2]. Due to the elevated temperature of stressed plants, thermal cameras have shown a significant potential for detecting water stress in crops. A drone that uses thermal and multispectral sensors has the potential to monitor vegetation in a very less period of time [34]. To digitize the terrain surface and produce the Digital Terrain Model (DTM) or Digital Surface Model (DSM) of the monitored region, RGB cameras, and LiDAR systems are commonly used [35]. The DTM depicts the soil's ground level without taking into account plant height. The DSM, on the other hand, depicts the earth's surface and all of its inhabitants. The DSM and DTM are extrapolated using the commercial program Pix4Dmapper [35]. By subtracting the DTM from the DSM, the differential model of the vine rows is produced. The UAV is equipped with a number of components that allow it to regulate its mobility in response to the perceived surroundings (**Table 1**). A drone that may be used for precision agriculture must meet the required capabilities namely (a) the drone must fly according to the waypoints,

Component	Function
Accelerometer	For quantity the acceleration the UAV
Air Pressure Sensor	Gases or liquids measurement
Altimeter	Elevation measurement
Anemometer	Wind Speed measurement
Barometer	To measure the atmospheric pressures
BLDC	To motion control
Camera (RGB)	To capture visual images
Digital Temperature	Temperature measurement
ESC	Regulation of the speed of BLDC
Filter papers	Fine substances separation
GPS	Offers geo location of an entity
Gyro	For rotational motion
Humidity indicator	To quantify the moisture in air
Hyper spectral camera	Images at narrow spectral bands
IMU	Angular rate and forces measurement
Laser scanner 2D	To captures shape of the entity
Magnetometer	Magnetic field measurement
Microsoft Kinect	For motion sensing
Multispectral Camera	Images at specific frequencies
PWM controller	For pulsing signal
Telemetry	To obtain live data from UAV
Thermal Camera	For recording low light imaginary
Video Camera	To capture electronic motion of the objects
Water sensitive paper	For spray coverage assessment
WSN	Sensing the environmental conditions

Table 1.
Hardware components of the drone.

(b) the drone must control its height of flying, (c) avoidance of obstacles during the flight, (d) the drone must automatically land based on the state of the battery, and (e) the acquired images must be stabilized [9]. Their hardware implementations are entirely dependent on important factors such as weight, range of flight, payload, configuration, and prices [5]. Hardware component assembly, software system integration, aerodynamic modeling, autonomous flight control, and implementations in the farming sectors are among the important ingredients required in developing a miniature autonomous unmanned rotorcraft aircraft [28].

4. Precision agriculture with the use of drones

Drones are UAVs that are utilized in a variety of businesses for monitoring [36]. Until now, they were largely employed by enterprises in the mining and construction industries, the army, and hobbyists. However, drone technology is now becoming more widely available for application in agriculture (**Figure 2**) [37]. For instance, Yamaha RMAX is a petrol-powered unmanned aerial vehicle created for pesticide spraying in Asian rice fields [26]. Despite the fact that the technology is still in its infancy in agriculture, numerous businesses are working to make it readily available to farmers to boost agricultural productivity. Agricultural drones can be used for soil and field studies to help in field planning. They can be used to mount sensors that measure soil moisture content, topographical conditions, soil conditions, soil erosion, soil nutrients, and soil fertility. For drones to successfully integrate into human environments, they must be dependable and secure. When utilized to aid humans physically, drones should reduce human stress and tiredness, boost human force, speed, and precision, and overall enhance the quality of farming life. Humans, on the other hand, may provide expertise and comprehension to make sure that tasks are completed appropriately.

4.1 Application of drones using multispectral and thermal cameras

It is possible to estimate chlorophyll absorption, water deficiency, pesticide absorption, diseases, and nutritional stress in precision agriculture using reflectance measurements [9]. Each pixel in the generated image has a sampled spectral measurement of the reflectance, which may be read to identify the substance present in the scene after post-processing [37]. A crop monitoring system for pesticide spraying with UAV comprises of an automated drone and a sprinkling system with a multispectral camera [5]. The sprinkling system is linked to the UAV's lower section, with a nozzle beneath the pesticide tank that sprays the pesticide downstream. The multi spectral camera scans the whole crop field and provides a spatial map as the first method of monitoring. This map shows the status of the crop using NDVI, and the farmer then decides which herbicides and fertilizers are required to use on the crop. The acquisition of spectral image data involves four resampling operations or calibrations namely spatial, spectral, radiometric, and temporal [9]. The Ground Sample Distance (GSD) refers to the spatial sampling in which the distance in meters is measured on the ground between two successive pixel centers. It is determined by the sensor aperture and the height of the flight. In contrast, in spectral sampling, decomposing the radiance obtained in each spatial pixel into a finite number of wavebands is carried out. In radiometric sampling, the resolution of the Analog to Digital Converter (ADC) used to sample the radiance obtained in each spectral channel

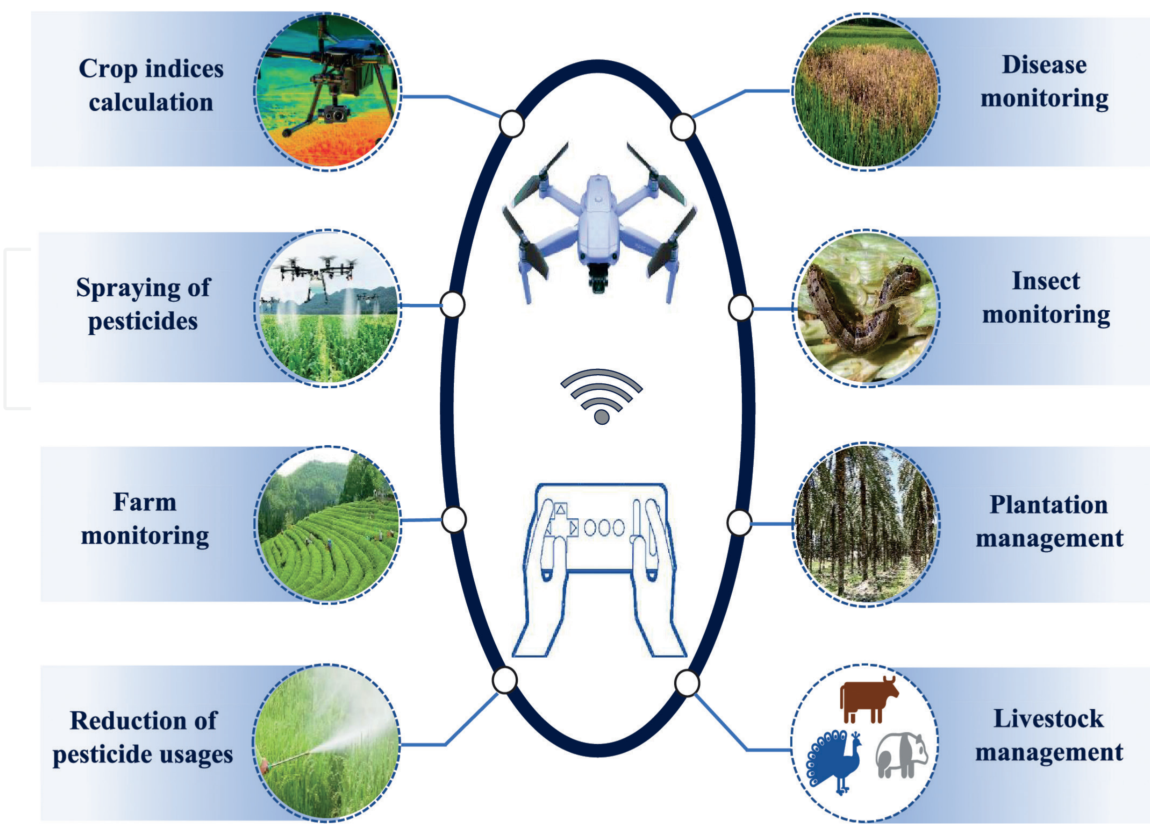

Figure 2.
Applications of the drone technology in agriculture.

correlates to the radiometric resolution. Temporal sampling, on the other hand, refers to the collection of several spectral photographs of the same scene at various times. These four sample processes must be considered while designing a flight operation using a multispectral camera and drone platform. The photos were taken by the drone offer data related to the radiance in each pixel. Image processing algorithms are used while measuring reflectance to adjust for effects owing to atmospheric absorption and the spectrum of solar light. Drones are a better platform for precision agricultural scanning than satellites because of the high spatial resolution [37]. Satellites equipped with multispectral and thermal cameras survey the large area for agriculture. Drones provide far more flexibility than satellites. In a ground-based setting, the drone multispectral and thermal sensors sample spectral wavebands concurrently across a vast region [36].

4.2 Application of drones using RGB cameras

The pictures captured by drones equipped with RGB cameras are utilized in precision agriculture to extrapolate DTM and DSM for the examined region. The right mission parameters must be determined to achieve the goal based on the spatial resolution and measurement accuracy of the rebuilt DTM and DSM [9]. The spatial resolution of multispectral and thermal cameras is defined in terms of GSD. The camera resolution and the flight height are determined based on the GSD. By capturing two successive photographs from the camera at two different waypoints, the height measurements of the landscape and the objects in the scene could be determined [38]. In most cases, a 70 percent overlapping factor between the two photos is used. The precision of a 3D reconstruction is mostly determined by the quality of the drone position measuring system. Several techniques for localizing the drone during the flight can be used: (a) differential GPS systems with a position accuracy in the order of 1 m, (b) real-time kinematic (RTK) GPS with an accuracy in the order of 2 cm, and (c) simultaneous localization and mapping (SLAM) based techniques with a position accuracy in the order of 10 cm [9].

4.3 Monitoring of the crop plants

Farmers deal with a variety of issues, such as the high cost of labor, health issues caused by contact with chemicals (fertilizers and insecticides) when using them in the field, bug or animal bites, etc. In this situation, drones can aid farmers by assisting them in avoiding these issues in addition to the advantages of being a green technology. In a single trip, the UAVs may cover hundreds of hectares of land to monitor the crop status using a variety of sensors [39]. Thermal and multi-spectral cameras were used to capture the reflectance of the plant canopy, which is placed on the quad copter's backside [10, 37]. The camera takes one image per second, saves it in memory, and transmits it to the ground station via telemetry using wireless Mavlink protocol. Blue (440–510 nm), green (520–590 nm), red (630–685 nm), red-edge (690–730 nm), and near-infrared (760–850 nm) wavelength were used to take the photos [5]. The Geographic indicator NDVI was used to examine data from the multispectral camera through telemetry [40, 41]. The embedded GPS module saves the GPS coordinates of every captured photo. The GPS coordinates are then kept in the UAV, allowing pesticides to be sprayed automatically without human intervention.

4.4 Drone to provide sprinkling system

The sprinkling system is usually linked to the bottom portion of the UAV, with a nozzle beneath the pesticide tank to spray the pesticide downstream [5]. The sprinkler system is made up of two modules namely the sprinkler system itself and the controller. Spraying substances such as pesticides or fertilizers and a spraying nozzle are included in the sprinkling system, whereas, a controller is used to turn on the nozzle for spraying. Different spraying rates and nozzles used in UAVs for spraying have been analyzed. Different Nozzle Type includes Flat fan [19], Micron air-A+ [29], Micron air ULV-A+ (ultra-low volume) [11], Universal [42], Centrifugal [27], Fan-shaped (electrostatic) [43], Electric centrifugal [31], Rotary atomizer [32] and conical [21]. A pressure pump in the sprinkler system exerts pressure to flow out the insecticide through the nozzle. It is necessary to have a motor driver integrated circuit to adjust the pressure of the pump as per requirement.

4.5 Miscellaneous application of the drone

Pollination has also been accomplished utilizing wind energy provided by UAVs. Jiyu et al. [44] investigated how the dispersal of rice pollen was affected by helicopter-type UAV wind power. They discovered that the UAV-created wind field had an uneven effect on pollen dispersal. As the insect infestation spreads fast, early detection is critical to avoid huge economic losses. A combination of high-resolution RGB cameras and multi-spectrum sensors can be placed on UAVs to evaluate the infestation intensity in potato fields [45]. Using high-quality spectral data, they demonstrated accurate and rapid pathogen detection. UAVs outfitted with multispectral cameras and thermal sensors may also identify locations where water is scarce [46]. Baluja et al. [47] conducted research to collect data for water management and irrigation control utilizing thermal and multispectral imagery. To optimize irrigation benefits, the scientists experimented with numerous UAVs. Irrigation automation will be deployed efficiently via a collaborative system combining UAVs in future smart farming. It is not a matter of surprise that UAVs can make planting more efficient [48]. When planting seeds and nutrients, a method must employ them to disperse evenly to offer ideal circumstances for plant growth and development. Although the use of UAVs for planting is still in its early stages, it is believed that this approach would yield efficient results if the UAV is equipped with image recognition technology and planting tasks [2]. UAVs are typically outfitted with cameras and sensors for crop monitoring for spraying pesticides. Yamaha RMAX, an unmanned helicopter, was launched for pest control and crop monitoring applications in agriculture [26]. Various UAV types have already been used for military and civilian purposes [5]. Using laser power beaming technology, UAVs can be used to extend the flying duration [49]. The proportional integral derivative (PID) controlling method is used to regulate the aerodynamic domain, tuning, and trimming phases of the UAV [50–52]. The images were then processed and analyzed using the NDVI method. Sensors and vision systems can also help UAVs to reach their full potential [53]. Another technique was implemented on the ground, in which a sprayer system was put on a UAV to spray pesticides [36]. The combination of UAVs with a sprayer system has the potential to provide a platform for pest management and vector control. Heavy lift UAVs are necessary for large-area spraying for this purpose [20]. In pesticide applications, the PWM (pulse width modulation) controller improves the effectiveness of the spraying system placed on the UAV [11, 29]. Pesticide deposition from the developed UAV is virtually identical to that of ground-based sprayers. The RMAX is a crop sprayer designed for high-value crops [5]. Because of their speed and precision, UAVs are increasingly being used in spraying operations. However, several variables affect the spraying operation in the field such as some sections in the crop field not being fully covered during spraying, overlapping spraying in the crop areas, and the spraying process extending beyond the outer margins of the crop field [5]. To overcome these obstacles, a swarm of UAVs was utilized in a control loop of an algorithm for efficient spraying operations [54]. In a lower altitude context, a blimp integrated quad copter aerial automated pesticide sprayer (AAPS) was designed for pesticide spraying based on GPS coordinates [18]. A low-cost, user-friendly pesticide spraying drone operated by an Android app called 'Freyr' was developed [55]. Using a double pulsed laser, a particle image velocimetry approach was employed to quantify the downwash flow field droplet mobility and deposition over the crop at various spinning speeds of the rotors of an octa copter [21]. Furthermore, filter papers and water-sensitive papers are employed to investigate spraying deposition and droplet coverage over many spraying swaths [30, 56]. However, numerous issues need to be resolved in order to have dependable and safe physical human-drone contact. In the near future, it will be important to successfully integrate drones into everyday situations; as a result, dependability and safety standards must be established. Although there are undoubtedly additional cognitive challenges involved due to how humans perceive drones (and vice versa), as well as other objective measures linked to defect detection and isolation. Safety and reliability in particular serve as the primary evaluation criteria for the mechanical design of control systems. Focus is placed on dependability with special attention paid to sensors, control architectures, failure management, and fault tolerance.

5. Drones as vehicles to increase farmer income: a perspective from Indian initiatives

The Union Ministry of Agriculture and Farmers Welfare has published rules in the year 2021 to make drone technology accessible to stakeholders to provide a significant boost to the promotion of precision farming in India [57]. The "Sub-Mission on Agricultural Mechanization" (SMAM) guidelines have been updated, and now allow for grants of up to 100% of the cost of an agricultural drone in order to purchase drones for use in large-scale field tests. Farmers can make decisions to increase crop yield since they have access to timely information and advice through the internet and telecom mediums like the Kisan Call Center and Kisan Suvidha Application. Crop health is closely monitored in real-time using drones and artificial intelligence. The drone uses include mapping water spread areas, water sampling, mapping macrophyte infestation, and aquaculture management techniques [57]. Variable rate technology is also employed for pesticide and liquid fertilizer applications. Precision livestock farming also makes use of artificial intelligence and drone technologies, notably for monitoring the health of cattle. The focus is on implementing a multi-faceted approach to increase farmers' income by raising production through the development of resources for better irrigation, using nutrient inputs effectively, lowering post-harvest losses, adding value, reforming agriculture marketing, reducing risk, and offering security and assistance [57].

6. Limitation of drone technology

Agriculture with intelligent practices may be used anywhere around the globe. In developing and under-developing nations, smart agriculture using UAVs has begun to increase the farm output in agriculturally important crops. Furthermore, it allows farmers to produce more from their smaller holdings [58, 59]. However, there are considerable limitations and issues in their application at this early level of research and development. Self-life of battery and flight time restrictions are the big issues for the potential application of UAVs [2]. Research on increasing the power of drone batteries is still going on to find a good solution. Lithium-ion batteries are now in use as they provide a bigger capacity and longer flying time than traditional batteries. Despite the fact that battery management necessitates regular maintenance, the majority of UAV operators result in higher expenditures as the UAV necessitates a more frequent replacement of the batteries. As a result, researchers are creating optimal hybrid battery solutions [60, 61]. Swarm-control approaches, which employ numerous UAVs to efficiently accomplish a variety of tasks, are also being investigated by researchers [2]. Swarms provide realistic methods for reducing battery costs and operating more efficiently with shorter flight hours. Multimodal input, such as visual, tactile, and aural feedback, is also needed to improve the user interface [2]. UAVs are often difficult to operate by ordinary people in agriculture and therefore, are typically used by specialists to do agricultural operations. Improving the user interface can make it easier for people who are unfamiliar with drones to control them. Human-centered user interface and feedback are very effective when dealing with multi-UAV systems [62]. To use drone technology, farms need to get approval from the government authorities and eventually restrict its use. Even though agricultural UAVs have enormous promise in agriculture, at these early stages of study and development, there are significant restrictions and problems to use them. HRI with automation has received great attention from various communities to date, particularly in the farming sector. This is in line with the fact that HRI in aircraft piloting has long been a topic of active study in the field of human intelligence [63]. In any case, research into many facets of human interaction as well as participation in the creation of drones is very important. While those in the human factors field can undoubtedly benefit from a deeper comprehension of dynamic control of computer science guided by artificial intelligence [64]. Therefore, there should be a very close look for opportunities to collaborate on research, conceptual design, and evaluation with engineers in these fields.

7. Conclusion

Intensive agriculture has a lot of negative effects on the environment. It supplies large quantities of nitrogen and phosphorus to terrestrial ecosystems leading to growing pollution of water courses and bodies of water, as well as ecological harm. Furthermore, significant soil degradation is reducing the productivity of many soils, putting the ecosystem at risk. Aside from the environmental impact, the health hazards linked with agricultural chemical use must be considered. Pesticides are also absorbed by crops and natural resources, creating a rising threat to public health. Chemicals like fertilizer and pesticides are only sprayed where they are needed rather than being distributed across a large region. Therefore, the implications of autonomous precision farming using a drone minimizes such negative impacts. UAVs are already being used in precision agriculture and remote sensing in developed nations. It is extremely quick, and it has the potential to minimize a farmer's workload. However, precision agriculture with UAVs is still in its early stages, with room for advancement in both technology and agriculture applications. A large number of experimental investigations using UAV-based remote sensing for agricultural applications have been conducted. Drones have been employed in agriculture for large-area surveillance and smart targeted irrigation and fertilization. Using a drone with an infrared camera to detect areas where high irrigation is necessary or where a foliar disease is spreading can help agronomists save time, water, and usage of agrochemical inputs. Better agricultural operations using advanced technology like drones may result in improvement in crop yield and productivity.

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Conflict of interest

The authors declare no conflict of interest.

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