Drone-based Internet of Things for Smart Agriculture: A Review

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Abstract-- *Agriculture is vital for human survival. In the modern world, there is an ever-increasing need for food with the increasing population. Hence, farmers are determined to have successful harvests in order to meet the market demand and make high profits as well. But this is difficult to achieve with traditional farming methods such as spreading seeds by hand and checking each and every plant for their health. Not only is it hard to do but it takes up a lot of time. Internet of Things is in high demand nowadays. By utilizing technology in agricultural practices, we can get more work done in lesser time. Even though most farmers around the world use some type of machinery like tractors and sprinkler systems, drone technology is still new to the field. This paper reviews several types of drone technologies available for efficient and productive agriculture by using drones for tasks such as soil quality evaluation, spreading of seeds, monitoring crops, identifying pests and even for evaluating the ripeness of fruits. Through this review, it has been demonstrated that drone technology is a suitable solution in order to overcome several obstacles in the farming industry that manual labor and traditional machinery, like tractors, cannot do.*

Keywords: Agricultural Drone, Monitoring, spraying pesticides

I. INTRODUCTION

Humans have been growing their own food ever since settling down in one place, after breaking away from their nomadic, hunting lifestyle. Therefore, agriculture has been ingrained in the society for millions of years. Through agriculture, people were able to feed themselves well enough. However, the times have changed and not everyone is able to grow their own food. Most of the city people get their fresh produce, grains, flours and other basic food staples from the villages, where agriculture is often the only source of income for villagers. Nowadays, farmers are being challenged to produce high yields due to the growing demand of crop harvest from the cities. The world depends on the farmers for survival. Therefore farmers need to be able to provide the commercial need and make profits as well. Traditional cultivation methods don't provide much of commercial benefit and the farmers too face many difficulties in doing this method. Crops are vulnerable under improper pest and plant disease control, labor expenses and time consumption. Inevitably, farmers may need to consider to incorporate modern technologies in order to increase the productivity of crops.

The advancement of information technology in recent years, brought light into the area of robotics with the development of Unmanned Ariel Vehicles (UAV). These have become very popular today with the use of drones. Drones started out with military purposes but now it has expanded to being popular in commercial, agricultural and research areas as well. We can improve the efficiency of agriculture by making use of the drone due to its advantages. Hard labor can be reduced, remote crop monitoring, crop spraying, sensing weather parameters and etc. This paper aims to provide an intensive review about the uses of drones in agriculture and how they aid farmers in their work through the comparison of various prevailing systems' modules, technologies and features.

The rest of the paper is organized as follows. Section II of the paper has a brief discussion about the methodology of this paper. Section III contains a comprehensive review on existing applications and proposals that utilize drone technology in various agricultural activities. Section IV contains an analysis about the systems described in the previous part and finally, section V concludes the review, followed by a list of references used for this paper.

II. METHODOLOGY

The purpose of this research is to review several types of drones used for various agricultural activities such as watering, pesticide spraying, growth/ temperature and humidity monitoring. A systematic strategy was followed in this research in order to find drone based IoT in the agriculture sector.

The selected applications found through the research, are implemented with different technologies and consist of different features according to its purposes and where it is used. These various types of agricultural drones are critically reviewed based on the above criterias. And finally the

There are three basic types of drones in which the reviewed agricultural drones fall under. These are explained in the subsection A through C.

A. Rotary Drones

A rotary drone consists of one or more rotors (propellors). As an example: An octocopter has eight propellors. These types of drones are a good option as a scouting tool for crop operations. They can take off and land vertically therefore any small bare area which is enough to accommodate the total area of the drone is enough. This eliminates the need to have special launching areas.

Single rotor drones have more endurance when compared to multi rotor drones. This makes them have more advantage in the fields.

However, multi rotor drones have more efficient maneuvering in the positions. But due to powering multiple rotors, these drones drain power much faster, thereby reducing the flight time. Therefore these are best used in small fields.

B. Fixed Wing Drones

This type has wings similar to an airplane and most of them have one propellor. Due to this they have more battery life and can stay up for more than 20 minutes. It also has higher speed than rotary drones and therefore, combined with the longer flight time, they can cover more area over the field.

Fixed wing drones requires space to lift off and land, similar to airplanes. Hence, they need an open path like a field path. This type cannot hover in the air in one place.

C. Fixed Wing Hybrid Drone

These combine the features of rotary and fixed wing and have several advantages. They are able to lift off and land vertically, thereby saving launching space and they fly like a fixed wing, hence with better speed. Due to these hybrid features, they are also able to hover in air over one spot. Table 1 shows the above types of drones.

Table 1: Types of drones used in the methodology.

Drone Type	Advantages	Disadvantages
Multi-rotor	Low endurance, VTOL, Efficient maneuvering.	High energy consumption, Low weight drones might be blown off-course by wind.
Unmanned helicopter	VTOL, More endurance than multi-rotor.	Less efficient maneuvering.
Fixed Wing	Higher endurance, Higher speeds.	Requires runway, Cannot hover.
Hybrid	Can hover, No runway needed.	Expensive.

Source: Author

III. LITERATURE REVIEW

The selected drone systems in this research consist of several types which cater to various purposes in the agriculture field. Since most of them are well suited for paddy cultivation, those systems can be implemented in Sri Lanka in order to aid farmers to have a better farming experience. Several Asian countries like India, Myanmar and Thailand have developed drones in order to increase the efficiency of rice cultivation. While some of the systems are developed exclusively for paddy crops, there are drones which can be used for other types of cultivation as well.

With the improvement of the software and hardware components in drones, the drone performance has also been greatly improved. This has created applications of the drone in various activities of the agricultural field. Several of best applications of drones in agriculture are discussed in below subsections A through E.

A. Evaluating Soil Quality

The condition of the soil is vital for healthy crop growth. Hence the soil quality needs to be constantly monitored. Soil quality is usually done manually by using various test kits or by sending samples of the soil to a lab for evaluation. Agricultural drones eliminate this hassle by being equipped with various sensors to examine the soil from above and being able to give accurate reports on the soil health such as the water and nitrogen quantity in the soil.

B. Seed Planting

Agricultural drones consisting of a seeding device, provide many advantages to the farmer. This method of seeding is extremely convenient in crops such as paddy where the ground is muddy and inconvenient to walk around throwing seeds. The resulting footprints are also not favorable to the farmer. Seed dispersion by using drones increase efficiency by even dispersal and it is done much faster than manual seed sowing.

C. Crop Monitoring

In agriculture, constant monitoring of the crop health is necessary starting from the land preparation until the harvesting. Traditionally, the farmer will visit his crops frequently to check up on them however this is hard when the lands are huge. In such cases, it is more beneficial to use agricultural drones and their cameras to keep tabs on the health of the crop fields.

D. Identifying Pests and Diseases

The number of agricultural drones that are intelligent in identifying pests and taking the necessary actions for it (i.e.: spraying pesticides) is generally low but they have been steadily increasing. Usually, these types of drones use image processing sensors in order to visualize the individual leaves and parts of the crop which have been infected. Another way is to use thermal or heat sensing cameras to monitor the heat properties of the crop and to detect any harmful organism or wildlife in the field. This is also very useful in identifying plant diseases as well.

E. Spraying

Since most farmers in developing countries do almost everything manually, spraying pesticides is also done by hand. However, it is risky when applying pesticides manually as there is the possibility of accidently applying more than the prescribed dosage. This could result in health hazards to both the farmer and the crop. Excessive pesticides can kill the beneficial organisms along with the pests. Also, the direct and regular exposure of human skin to the pesticide can even cause cancers. It also wastes the amount of pesticides which is a disadvantage to the farmers of developing countries who have to bare the costly losses.

The agricultural drone is a suitable solution for this problem. The automatic pesticide spraying technology implemented into drones can spray evenly over the crops and some smart drones have the ability to detect areas in the fields which need an extra dosage of pesticide. The farmer can remotely control the spray rate and the coverage area from a safe distance without exposing himself/herself to chemicals. In most spraying drones, the nozzle radius, angular velocity of the spray motor can be controlled as well as the speed and altitude of the drone.

The high speed of the drone is also advantageous in covering more area in lesser time than if done manually. This high speed spraying can also make it possible to spray the crop multiple times. The use of a spraying drone decreases soil compaction and plant damage. Soil compaction happens through the frequent use of heavy agricultural machinery such as tractors. The young plants and new shoots in the edges of the crop may be damaged by trampling. Agricultural drones have no contact with crops while spraying. Spraying drones are able to work even at night due to intelligent mapping and autonomous flight. This is operated using GPS. This is extremely useful for farmers since they can carry on their work even after sundown. However, the weight of the spray liquid and tank makes the drone consume a lot of energy for flight. Higher weight means shorter flights. Most spraying drones in the market have only between 5 and 10 liter volume tanks and this may require refilling after each flight. Spraying drones are also much more costly than traditional spraying tools.

The selected drones for this review include different types of agriculture based drones which consist of one or more of the above mentioned features. This focuses on their implemented technologies as well.

A. AgrOne

The proposed design is an autonomous quadcopter. This is a Do-It-Yourself (DIY) approach where you can use available technology to build your own drone and On-Ground sensors for agricultural purposes. This quadcopter is able to fly autonomously and capture images of the field, using the onboard camera, which are then processed to evaluate the conditions of the crops. Raspberry Pi was used to perform basic image processing. They have used the green component in the image as the indicator for crop health. It uses external Telemetry Support in order to use precise GPS coordinates for navigation and also to vary the acceleration, pitch, yaw and altitude. The authors have implemented a battery powered wireless Sensor Node which consists of a humidity sensor, temperature sensor, light intensity sensor and soil moisture sensor. Several of such sensor nodes were placed in the field to monitor and control different areas in the farm. Cloud services were used for storage, data analytics, data visualization and logging.

B. AI/AR Enabled Drone

Timely identification of plant diseases is extremely important for farmers in order to prevent extra costs for saving the crop before the infection gets out of control. It becomes very difficult to scour each and every plant to check for their health especially if the fields are very large and it is expensive to get the consultation of an agricultural specialist every time. The authors have proposed the use of Artificial Intelligence and Machine Learning techniques to identify pests and diseases at the earliest stage possible. They have also trained a ML model to predict the suitable crop for the available environmental conditions. This is very beneficial to the land as well as the farmer since most farmers tend to just grow anything that'll bring profits without selecting the appropriate crop based on the local climate and requirements of the land which could reduce the soil fertility. This agriculture drone comes with a border surveillance system. It uses a Convolution Neural Network-based human identification to recognize people and weapons and is able to alert the surveillance team if detected. Augmented Reality is a new technology that is being tested in various areas. This technology was used here to visualize the future developments without using 3D models.

C. Drone for Mapping and Monitoring Corn Fields.

The aim of this research was to propose a system that'll be able to assist corn farmers in mapping and monitoring their fields and also to evaluate the level of maturity of the crop using drone imagery technology. Once an image is captured by the drone, it is processed and the result will be one of the three: ready to be harvested, not ready to be harvested and not yet planted.

D. Autonomous Drone for Smart Monitoring

This paper proposes a drone system with swarm communication. The swarm communication is to divide the agricultural field into parts for several drones to monitor separately and to avoid collision between drones. This drone is designed to ease the burden of farmers having to make regular visits to the field for inspections. By this proposed method, farmers can control the drone and oversee the fields from anywhere by using the application installed on their smart devices. Affordability is increased by using recycled plastic waste for the drone body. The location of the drone can be traced at any time using the integrated GPS module and the drones can be configured to follow a pre-defined path over the field. The specialty in this drone is that the GPS module is integrated along with the battery. This powers up the GPS as soon as the drone is turned on. Usually other GPS drones take between 15-20 minutes to activate the GPS module so this is a huge advantage.

The ultrasonic level sensor in the drone can measure and monitor the water level in the field and can also keep pests away. An optical crop sensor is used to track the condition of the crop. An SD card is used to store all the data collected.

E. Autonomous Pesticide Spraying Agricultural Drone

The proposed model is of an aircraft type (fixed wing) UAV with the purpose of spraying pesticides over crops. This reduces the number of manpower needed and manual spraying time but it also reduces the health consequences of farmers being exposed to chemicals. The drone can carry 2 liters of pesticide as payload and it can fly for approximately 20 minutes without battery replacement. It consists of a "Return Home" feature which prompts the drone to return to the Ground Control if the battery level is down at a pre defined level, the communication connection between the drone and ground control is broken or if the pesticide in the tank is finished.

F. Precision Agriculture based UAV for Pest Control

This is a semi-autonomous quadcopter. It adopts precision agriculture by using a pesticide spraying system. The total flight time was calculated to be 5.26 minutes and it carries a payload of 100g. however, it can carry an extra payload of 500g to 1kg.

G. Aircraft Type Portable Autonomous Agricultural Drone

Most aircraft type drones require a long runway for liftoff and landing. The specialty in this aircraft type drone is that it doesn't require runway space due to its hand launching feature. The bird shaped drone aids in scaring away birds. It also includes a loud speaker which can be used to broadcast messages to anyone in the field. It can also be used to scare away other wildlife types as well. The drone can carry a payload of lightweight goods such as seeds, as delivery to farmers in the field, of approximately 1.4kg. the HD camera can capture and transmit real time video footage of the crop to the ground control station. This drone too has a "Return Home" feature in case of low battery or connection failure. It has a maximum endurance time of approximately 30 minutes. Another great achievement is that the drone consists of 6 separate parts which fit inside a portable box and the pats are easy to put together. This proposal has potential for commercial use as its price was kept within $800.

H. IoT Based Drone for Crop Quality Improvement

A problem that farmers face is that fruits don't ripen all at the same time. This untimely ripening of fruits may cause losses to the farmer if he doesn't check his crops frequently, which is not an easy task to do everyday especially if the crop land is very large. The proposed system uses Taguchi sensors which are used to sense specific gases. It can sense ethylene, propane and methane. This sensor alerts the farmer of the area where fruits need to be plucked.

I. Smart Agricultural Seed Spreading Drone

This drone was developed in Sri Lanka for sowing seeds in soft soil paddy fields. The flight path can be in either auto (pre-defined flight path) or manually controlled using a long range remote controller. It can carry 2kg of seeds and the seed dispersal amount through the nozzle can be controlled. This also consists of a "Return Home" feature. In order to keep the costs low, they have designed the system so the farmer can fix a 1.5l mega water bottle as the seed holder instead of a customized container.

Table 2: Comparison of features of the drone systems
Source: Author

Features / **Past Inventions**	Rotor/ Fixed wing/ Hybrid	Evaluate soil quality	Seed spreading	Crop monitoring	Identify pests and diseases	Pesticide spraying	Return home
(Suhas *et al.*, 2018)	R	√	x	√	x	x	-
(Rao *et al.*, 2022)	R	√	x	√	√	√	-
(Rachmawati *et al.*, 2021)	R	x	x	√	x	x	-
(Raj *et al.*, 2021)	-	√	x	√	√	x	-
(Hasan *et al.*, 2020a)	F	x	x	√	x	√	√
(Rominiyi *et al.*, 2023)	R	x	x	x	x	√	-
(Hasan *et al.*, 2020b)	F	x	x	√	x	x	√
(Saha *et al.*, 2018)	-	x	x	√	√	x	-
(Dampage *et al.*, 2020)	-	x	√	x	x	x	√

IV. DISCUSSION

The result of reviewing agricultural drones shows that there are different types of systems that have been implemented in various parts of the world for various agricultural activities. In general, most of them can be used in any crop , however there are distinct features in the drones that need to be taken in to account to find the best suitable drone for the farmer's specific need. According to the summarized version in Table 2, we found several features that are common in most of the reviewed systems while some systems had unique features. All of these features address an easier and more efficient way of conducting agricultural practices, by integrating technology into the fields. This doesn't in any way, pose a hindrance to the traditional manual faming methods that most farmers in remote areas engage in. Rather, this drone technology alleviates the speed and quality of the process and eases the

Table 3: Analysis of IoT-based drones for agricultural activities.

System Name	Reference	Advantages	Limitations
AgrOne	(Suhas *et al.*, 2018)	DIY approach, precise, GPS Coordinates, low cost.	Predefining time to capture images work only when flight controller and Raspberry are both started simultaneously.
AI/AR Enabled Drone	(Rao *et al.*, 2022)	Timely identification of plant diseases.	-
Drone for Mapping and Monitoring Corn Fields	(Rachmawati *et al.*, 2021)	Ability to evaluate crop maturity.	-
Autonomous Drone for Smart Monitoring	(Raj *et al.*, 2021)	Multiple drones with same control system working simultaneously, GPS powers up with the drone.	-
Autonomous Pesticide Spraying Agricultural Drone	(Hasan *et al.*, 2020a)	20 minutes endurance.	-
Precision Agriculture based UAV for Pest Control	(Rominiyi *et al.*, 2023)	Ability to carry extra payload.	Low endurance.
Aircraft Type Portable Autonomous Agricultural Drone	(Hasan *et al.*, 2020b)	No runway space needed, Low cost, Portable.	-
IoT Based Drone For Crop Quality Improvement	(Saha *et al.*, 2018)	Systematic Monitoring.	-
Smart Agricultural Seed Spreading Drone	(Dampage et al., 2020)	Payload of 2kg.	-

Source: Author

burden off the farmer in a number of ways. Features like night spraying is actually useful and safe compared to walking between crops at night to spray with the risk of wildlife. However, the cost of the drone, the lack of knowledge in using technology and the indecisiveness of wanting to adopt technology into their field activities is what keeps farmers away from these innovations. The below Table 3 is an analysis of the agricultural drones discussed above in the literature review.

From the above comparisons, it can be seen that some agri-drones have the potential to be used in the farming practices of Sri Lanka. The Smart Agricultural Seed Spreading Drone can be said to be a highly benefitting piece of technology for Sri Lankan paddy farmers as rice is the staple food of the locals. For crop monitoring, the Aircraft Type Portable Autonomous Agricultural Drone seems to be solution due to its multiple functions and economic price.

V. CONCLUSION

This review paper aims to provide insights into the currently existing agricultural drone systems and proposals which are used in precision agriculture in order to provide farmers with

a more efficient crop management. To meet the demands of the increasing population and food production, drone technology is a suitable solution to overcome several obstacles and hardships that manual labor and traditional machinery cannot do. With IoT and the ease of use in drones, once knowing its basic operations, farmers can remotely monitor their crops and make it perform agricultural activities. With the upcoming technologies in the near future, we can expect more farmers, both worldwide and Sri Lankan, adopting the use of agricultural drones which cost less and consume lower energy. Thus, drones have been demonstrated to possess high potential in their ability to provide systematic farming, increase the yield and to improve the profitability.

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