



Pivotal Role of Drones in Agriculture – a Review

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Indian agriculture is currently undergoing a drastic drift towards mechanization and usage of modern-day Information and Communication Technology (ICT) tools as a subsidiary to the mighty work carried over by the farmers in their respective fields to serve millions of people with food. Owing to the various efforts taken by agricultural scientists and scholars, the scope of Artificial Intelligence has also influenced agriculture and is finding solutions to the modern-day problems in agriculture such as labour scarcity, less productivity and other such consequences. One important component using Unmanned Aerial Vehicles (UAVs), popularly called Drones and their applications in agriculture. Even the union as well as the state governments of India are focussing on providing drones to the farmers as a part of fostering the concept of Sustainable Agriculture. This article reviews the various spheres where drones can be utilized and the statistics as well as the benefits of using drones in agriculture.

Keywords: Unmanned aerial vehicles; agriculture; benefits; regulations; policies.

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1. INTRODUCTION

The sector of agriculture, although it contributes to 20.2 per cent of the Gross Domestic Product (GDP) of India (Press Information Bureau, 2021), it gambles with various constraints such as abnormal monsoons, production-related issues, low productivity, labour shortage, price fluctuations, etc. Agriculture is the prime work source for a man of the rural households. The FAO report on India at a Glance, 2022 has insisted that 70 per cent of rural households still depend on agriculture and about 82 per cent of the farm households are small and marginal. It is a dire need for all the stakeholders involved in agriculture to look into this situation seriously and find out path breaking ways to achieve sustainability for our younger generation. Automation in agriculture is an emerging subject across the world. In the current trend, the concept of Artificial Intelligence has found many applications in building solutions for agriculture-related problems, which not only empower the farmers to continue farming amidst eradicating natural resources and also would improve the quality and ensure quick market penetration of various crops. Of all these, the technology of Unmanned Aerial Vehicles (UAVs), commonly referred to as Drones for agricultural purposes, play a pivotal role. Although it is in the latent stage and as a much longer road ahead, its presence can be felt in many patches of our country.

2. WHAT IS A DRONE?

Drones, which are technically referred to as 'Unmanned Aerial Vehicles (UAVs)' are useful for carrying out tasks that are sometimes considered impossible for humans to do. These were originally developed for military purposes when the first types of drones were used in First World War. But now it has found its way into the mainstream because of the enhanced levels of safety and efficiency they bring. These vehicles do not need a pilot on board and they can either be controlled manually or by relying on a system of sensors (like LIDAR detectors) [1]. Drones in general refer to multirotors. A multirotor is fixed with three or more propellers which are used for hovering or flying in any direction. However, the most commonly used type of drone is the quadcopter having four propellers [2].

"In the recent trend, drones have become essential for various tasks in different

organizations and have also helped a lending hand in uplifting industries that were about to perish. From delivery services of food orders to scanning an unreachable military base, drones are very smart enough than humans to act in a more effective and efficient way. Moving the work-related graph upwards, decrease in work pressure and production costs, excellent accuracy, refining service and customer relations and solving security issues on a large scale are some of the areas where drones find a place. In addition to it, the acceptance of drone technology is gradually rising up owing to its potential being understood by businesses" [3]. It is in this aspect that an outlook on the various literature pertaining to drone technology and the change it has created in recent times, is been carried out in this research article.

3. HISTORY OF DRONES

"Although there is not a clear reveal on when were drones first used in agriculture, a seed was sown in such a huge step during the year 1906 when John Chaytor, a New Zealand farmer, spread grass seed in a wet valley on the family farm Marshlands in Wairau, Marlborough, using a hot air balloon controlled by ropes from the ground" [4]. The founder of this novel technology is considered to be Abe Kareem for building the first fully functional drone for Israel in the year 1974, but unfortunately not meant for agricultural purposes. "One evidence shows that the drone for agriculture was first used by Thurling in 1985 by fixing a camera on the drone for taking vertical images of weeds in an oilseed crop" (Christopher Leonard, 2022). From then onwards, its spread has been phenomenal all over the developed countries. It is unknown about the fact of when drones were used first in agriculture, but the Union Ministry of Civil Aviation only in the year 2021 spelt regulations pertaining to the usage of drones in the form of policy formulations and using this, the Union Ministry of Agriculture and Farmers' Welfare came up with Standard Operating Protocols (SOPs) for drone operations in agricultural lands [5].

4. DRONES AND THEIR PARTS

Even though drones find a place in every business, many people do not know the proper name of a particular part of a drone. Hence it would be appropriate to introduce the different parts of a quadcopter and their function in the below Table 1.

Table 1. Parts of a drone and its use

S. No	Name of the Part	Use
1.	Quadcopter Frame	It acts as a skeleton for placing different components to have a uniformity of the centre of gravity of the drone.
2.	Motors	Useful for propelling the drone
3.	Electronic Speed Controller	Helps the operating pilot to adjust the height of the running drone.
4.	Flight Control / Board	Makes a log of the take-off place if any emergency situation occurs and there is no guidance from the pilot.
5.	Propellers	Used to fly the drone. During motion, they cut the air by creating a difference in pressure between the top and bottom of the rotors.
6.	Radio Transmitter	A channelled transmitter and a communicator for the drone.
7.	Battery, Electronics and Power Distribution Cables	Lithium batteries are used. These act as the power source for the drone. Other components are used only when needed.
8.	Camera	For shooting, storing and sending videos and maps to the receiver's end for data purposes.
9.	Landing gear	There are two types of landing gear – fixed and retractable landing gears. Landing gears are meant for the safe landing of the drones after flying.
10.	First Person Video	It gives the user a 3D view experience of the normal control device interface i.e., the transmitter

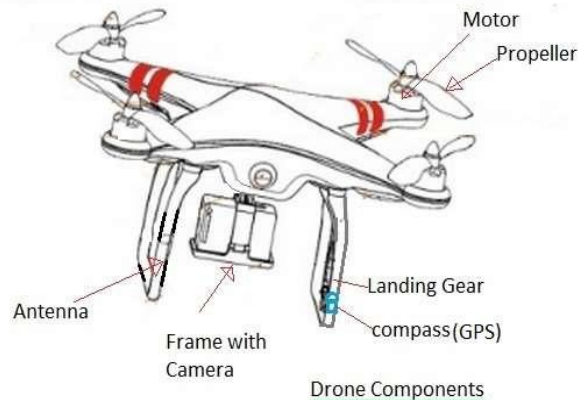


Fig. 1. Drones and their components

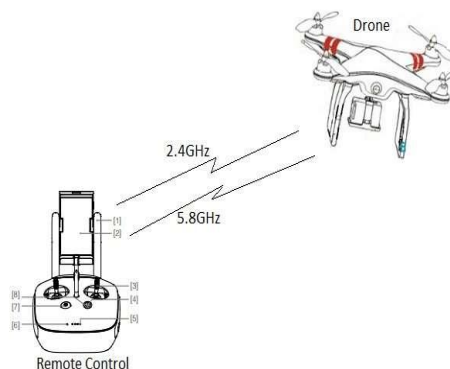


Fig. 2. Frequency to and fro from the remote control to the drones

The images pertaining to various components of drones and their remote control aspect is illustrated in Figs. 1 and 2 respectively.

5. DRONES IN INDIA

Drones are unmanned aerial vehicles that can be manoeuvred remotely by a pilot. The Indian drone industry is currently in its nascent stages. According to a Forbes report from June 2020, there are “200,000 recreational and commercial drones in the country, each costing anywhere from Rs 200,000 (\$2,600) to Rs 20 million (\$26,000) depending on size and functionality”.

Sources in the government told The Print that there are over 30 registered firms in India that are involved in making or assembling different types of drones. Based on their weight, drones can be divided into five categories — nano (weighing up to 250 g), micro (250 g to 2 kg), small (2-25 kg), medium (25-150 kg), and large (over 150 kg). All drones except nano require a licensed pilot and permit from the Director General of Civil Aviation (DGCA). Altitude and speed restrictions also vary depending on the category of the drone.

The Unmanned Aircraft System Rules, 2021, set certain conditions for operating drones. For one, it prohibits the flying of drones in Delhi’s Vijay Chowk, areas surrounding strategic locations notified by the Ministry of Home Affairs, central secretariats in state capitals, and eco-sensitive zones. Operating drones is also barred within 5 km of international airports at Mumbai, Delhi, Chennai, Kolkata, Bengaluru and Hyderabad, and at a distance of 3 km from the perimeter of any civil, private or defence airport. Drones cannot be flown within a distance of 25 km from international borders, which includes the Line of Control, and in the vicinity of military installations or areas where military activities take place (unless clearance is obtained from the local military facility). Under the rules, individuals and companies are required to obtain the DGCA’s approval to import, manufacture, trade, own or operate drones. Further, any individual importing, manufacturing, trading, owning or operating drones must be a citizen of India and above 18 years of age. Violations can mean a fine ranging between Rs 25,000 and Rs 50,000.

Nano drones can be easily purchased online, including those by Chinese giant DJI. In 2018, the brand reportedly took exception to policy guidelines that required every drone to fulfil

certain conditions for permission to operate in India. The top drone manufacturers in India currently include ideaForge, Asteria aerospace, Aarav Unmanned System (AUS), IOTech, and Hubbal Fly. The cost of a drone depends on its application and capabilities. For instance, a drone used in the agriculture sector to spray pesticides can cost anywhere between Rs 5 lakh and Rs 10 lakh; a survey-mapping drone can cost between Rs 8 lakh and Rs 12 lakh; defence ones can cost anywhere from Rs 5 lakh to Rs 1 crore, depending on specifications and endurance.

According to a 2020 report by the Drone Federation of India (DFI), urban planning, monitoring wildlife and preventing illegal activities in forests, capturing and analysing data for Indian Railways, National Highways Authority of India and state governments for transportation plans, mining, disaster management, agricultural assessments and security and surveillance are some of the ways in which drones are being used in India.

6. DRONES IN THE WORLD

Drones around the world are being used for varied purposes which has given by Francis Ronald (2016) is explained below.

6.1 Amazon Prime Air

In the works for already a few years, Amazon Prime Air service plans to use drones to deliver customer orders, such as a pair of sneakers, in 30 minutes or less. These drones are equipped with sensors that allow them to avoid obstacles along the way, land the package safely next to a customer’s home or other location, and return back to base. They are intended for non-urban areas. Several different types of drones will be used, depending on delivery variables. One of the designs is about the size of 20 DJI Phantoms and looks like a plane, but goes airborne vertically like a quadcopter. The latest progress made with the service has been in the UK, where, in July of 2016, Amazon announced that it will begin testing delivery in the near future.

6.2 Agriculture—Better Wines with Drones

Drones have been used in the agriculture industry in Japan for about 30 years, spraying pesticides and performing other tasks, with the result that about one third of all rice consumed in

Japanese homes today has been worked on by drones. About 10 days of traditional work is done in about two days, thanks to these drones.

The first such drone used in Japan was developed by motorcycle maker Yamaha Motors, but the idea has spread all over the world and adapted to many aspects of agriculture. One such endeavour is by the California-based company Vine Rangers, which is trying to use drones with infrared cameras to see what the eye cannot in the wine-making process. Using a combination of drones and software, they test for diseases and analyse stress, yield, quality, leaf respiration, and more, to improve grapes and wine.

6.3 Aerial Construction Drones

There are those who believe that, in the near future, drones will be working side-by-side with humans in laying building foundations and performing other similar tasks. And there are those who are already experimenting with such tasks. For example, the Swiss Federal Institute of Technology is engaged in a collaboration called The Aerial Construction Project, the objective of which is to investigate and develop methods and techniques for robotic aerial construction. The team has already built a 24-foot rope bridge between two structures using common-size quadcopters (which were tuned for the job). This bridge successfully withstood the weight of an adult person walking across the center rope from one structure to the other. A previous collaboration involving the same university resulted in a live exhibition of four quadcopters building a 20-foot tall tower out of 1,500 foam bricks.

As for something already in place, US company Kespry has armies of drones equipped with advanced software that are capable of helping construction companies track progress, conduct surveys, generate maps, generate 3D models with millions of data points, calculate volume, get precise elevation data and contour lines, plan road projects, and much more, and all mostly via autonomous flights.

6.4 Ambulance Drone

Made at the Delft University of Technology in the Netherlands, the Ambulance Drone aims to solve a problem that has been the cause of death in many sudden medical emergencies, such as cardiac arrest. It aims to get to the scene in those

first few minutes that often are the most important, until the real ambulance arrives. Designed with video and two-way audio communication ability, and compartments with advanced first-aid kits, the Ambulance Drone is meant to reach the victim and instruct someone nearby what to do with the first-aid equipment. The plan for the Ambulance Drone is to integrate into existing ambulance response networks. The project currently lacks commercial backing and faces many other obstacles, as do most drone ventures.

6.5 Elios, the Industrial Inspection Drone

Created by Flyability, and winner of the first-ever UAE Drones for Good award, Elios is a collision-tolerant drone capable of accessing cluttered spaces, such as where complex piping is laid inside building walls, to gather hard-to-reach data. Elios features sub-millimeter resolution, on-board LEDs for visibility in darkness, and other advanced technologies, but what makes it capable of doing its job is a flexible outer cage that enables it to bounce off of obstacles like a beach ball, and thereby not collide and break down. But at its core, Elios is simply a flying drone. Already more than five years in development, Elios aims to increase worker safety, reduce inspection costs, and lower downtime. When the final touches are placed, Elios will successfully inspect boilers, recovery steam generators, above-ground tanks, pressure vessels, ship holds, tunnels, furnaces, and much more.

6.6 Window-cleaning Drones

Also a contestant in the UAE Drones for Good competition, having reached the semi-finals in 2015, German company Window Cleaning Drones hopes to automate the washing of glass facades and roofs using drones, even at high altitudes. But they aren't the only ones. There are several such enterprises, such as The Sullivan 5000, in the U.K.

6.7 Internet Access Drones

On a more expensive note, Google and Facebook have, for couple of years now, been invested in separate drone technologies with the intention of spreading Internet access to pretty much the entire world. Technically, Google isn't invested in a drone technology but, rather, a balloon technology called Project Loon; but Facebook has money is in actual drones, solar

powered and meant to fly more than 10 miles above ground to provide Internet access to areas below it.

6.8 Wildlife Conservation Drones

In an interesting case of drone meets bold creativity, conservationists have recently found a way to lure the California condor back to its natural habitat. For some time now, this endangered species has been moving in the opposite direction of its habitat, in following a trail of dead cows to feed on. In response, forward-thinking conservationists have placed a trail of dead cows in the proper direction as bait for the condor to return. But these cows are spaced miles apart, and the only way to alert the condor of their presence is to entice nearby birds to circle the air above the carrion. Here's where the drone comes in. These conservationists set some drones airborne in a circular motion, attracting the nearby birds. Once the birds arrive in large-enough numbers, the condor takes notice and heads toward them. And this goes on at every checkpoint.

6.9 Drones for Real Estate

The National Association of Realtors has released a statement claiming that as of August 29th of 2016, real estate professionals in the US will be able to use drones for aerial photography of properties. There have already been instances of drones used for this purpose in the US, and they're actively being used in some other countries, such as Australia. But the NAR statement comes with an FAQ list detailing the rules and regulations. Aerial photography can greatly benefit real estate marketing of large mansions and surrounding areas. In fact, real estate agents will likely be investing thousands of

dollars into professional video production of drone-captured videos.

6.10 Walt Disney Light Show Drones

Perhaps more so than anywhere else, Disney theme park light shows are considered something close to out of this world. With the intent of improving these shows even more, in February of 2016, Disney filed a patent (not its first) for a drone-powered projection technology. In short, the drones would beam down imagery onto a projection assembly (which may include a wide-angle reflector). Imagine a larger-than-life Mickey Mouse projected in front of you from a drone.

7. USES OF DRONES IN AGRICULTURE

"The applications of drones have influenced even the field of agriculture since it has got wide opportunities in the recently identified technology namely Precision agriculture. They have a wide range of uses starting from soil and crop field analysis to planting and spraying pesticides. Drones can also be used with various imaging technologies such as hyper-spectral, multispectral, thermal, etc. which can provide the farming community with time and area-specific information pertaining to crop health, fungal infections, growth bottlenecks, etc. Drones are also helpful in identifying drier regions of a field and measures that can be taken for irrigating those regions. Such concrete information when provided to farmers would help them make decisions regarding resource allocation and utilization in an efficient manner" [6]. The various uses of drones in agriculture and their working and related benefits in agriculture is illustrated in Figs. 3 and 4 respectively below.



Mapping



Livestock monitoring

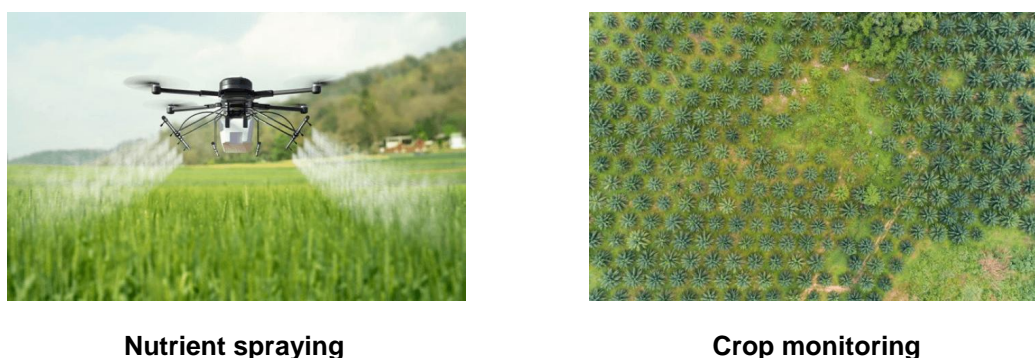


Fig. 3. Various uses of drones in agriculture

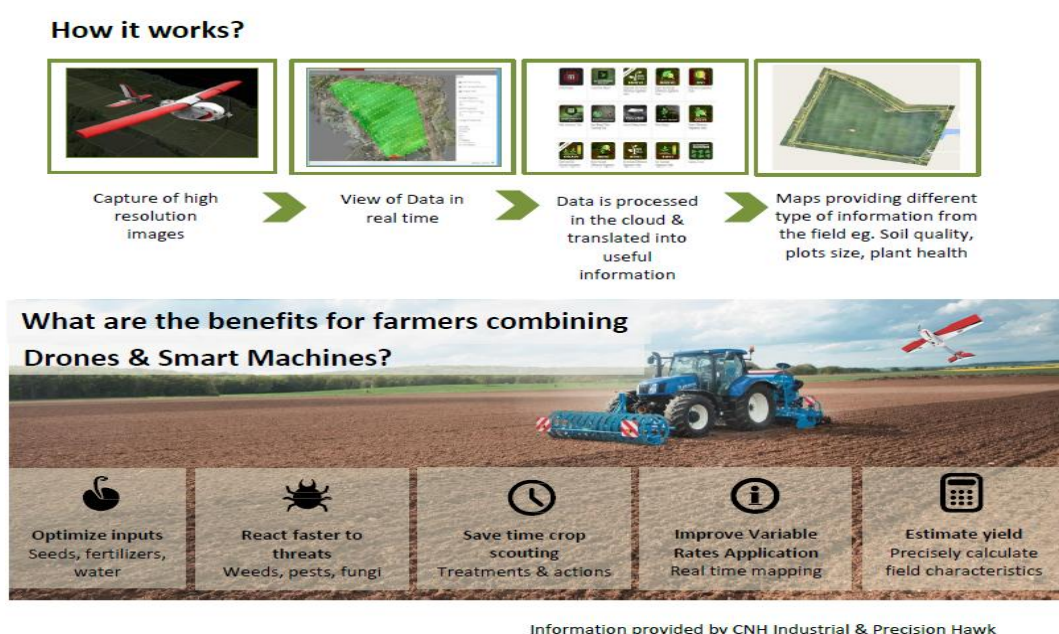


Fig. 4. Working of drones and their benefits

8. IDEAL CONDITIONS REQUIRED FOR FLYING A DRONE

Even though the drones can be flown at any time of day, many prefer to fly them at a time when there is a clear sky and the photography captures precisely the field conditions. Most of the time, the drones are used in the 'Golden Hour' viz., the hour before sunset or just after sunrise. At these times, the sun gives off brilliant colours, softer shadows and great photos. Some drone pilots prefer the 'Blue Hour' which is the hour right after sunset or before sunrise since the stream of sunlight that appears in the sky gives stunning effects on the photography. Coming to weather conditions, the optimal conditions are without much wind in the atmosphere and with moderate temperatures. One should stay away from operating drones when there are extreme

conditions such as rain, strong winds and too hot or too cold weather conditions. Also it is recommended by various experts that it is avoidable to fly a drone during winter conditions since it may slow up the battery and many times the batteries would be non – functional [7]. Hence it is essential to have an eye on the weather state before employing drones for agricultural purposes.

9. BENEFITS OF USING DRONES IN AGRICULTURE

Drones can act as a viable alternative for tackling various challenges prevailing in agriculture. They can be used for targeted input application, timely diagnosis of nutrient deficiency which can be used to provide nutrients in the right amount, crop health monitoring, rapid assessment of crop

yield and crop losses. These can be used to cover large land areas which are difficult even for the farmers to perform various agricultural activities. Drones have the capacity to operate at low heights (1.0 to 3.0 m) over the crop canopy making them suitable for spraying nutrients and adaptable to different crops. Spraying of crop and soil nutrients using drones helps farmers in saving cost, resources and time. Drones are even useful for various geographical areas such as tough terrain and hilly areas which are inaccessible [8].

10. RULES AND REGULATIONS FOR USING DRONES

In India, the Directorate General of Civil Aviation acts as the nodal agency in framing rules and regulations for the usage of drones. The drones need to be registered on the Digital Sky Platform. Drones are available in different designs and payloads with some of the drones having payloads ranging from 1 kg to 25 kg. For agriculture, drones with a payload capacity of 10 kg are being used having major advantages such as low cost and volume, low operating cost, easy for transportation purposes and has low chance of instability and accidents. In addition to this, drones of this payload capacity do not require Air Traffic Control (ATC) clearance before flying. Although there are many protocols for drone spraying, the Recommended Dose of Fertilizer (RDF) based nutrient application protocol is widely used for both granular and liquid nutrients. In India, currently, drones are being used mostly for spraying nutrients, especially for foliar spray. Hence the adjustment of various nozzles (centrifugal, electrostatic, atomizer, etc.) can be done without any difficulty.

Drones having a payload capacity of 10 kg can cover 30 acres per day which are equivalent to 6 hours per day having the stock of five batteries. The cost of operating the drone varies for different agro-climatic conditions ranging from Rs 350 to Rs. 450 per acre per operation for the time of 6 – 10 minute flight. Proper usage guidelines must be ensured when operating the drone like maintaining a distance of 1.0 m – 3.0 m from the crop canopy, flying the drone at the speed between 3.0 – 6.0 m/s and the payload of the drone should not exceed more than 10 litres per flight. The rotational speed of the disc of the drones should be in the range of 800 to 1000 rpm and it may vary according to the manufacturer. Appropriate pressure of 100 -

150µm must be maintained for an optimized droplet spectrum. One who is operating the drone should wear PPE (Personal Protection Equipment) kit. For proper maintenance of drones, the owner of the drones should follow the recommendations made by Dr. Alagusundaram committee formed for enhancing the adoption of 'Krishi' drones [8].

11. POLICY FRAMEWORK FOR DRONES IN INDIA

The agricultural drone market is expected to grow from USD 1.2 billion by 2019 to USD 4.8 billion by 2024. Some of the key factors that influence the increasing need for drones in agriculture include pressure on increased food production due to the growing population and an increase in venture funding for drones [9]. In India, any drone operator other than a foreign operator is allowed to fly a drone and as a compulsory measure must register in the Digital Sky platform by filling out Form D-2 with the specified fee under Rule 46. The provisions of the Motor Vehicles Act, 1988 (59 of 1988) shall apply for any damage caused by unmanned aerial vehicles. The drones used should be No Permission – No Take-off (NPNT) compliant and a Unique Identification Number (UIN) is obtained from the DGCA and the number is affixed on the drones [10]. In the recently announced Union Budget of 2022 – 23, the union government has indicated that the Sub-Mission on Agricultural Mechanization (SMAM) has been amended to grant up to 100% of the cost of agricultural drones or Rs. 10 lakhs, whichever is less, by the Union Government of India. The FPOs (Farmer Producer Organizations) are eligible to receive up to 75.00 per-cent grants for promoting drones among the farmers through demonstrations. A contingency expenditure of Rs.6000 per hectare would be provided to agencies that hire drones from owing agencies such as Custom Hiring Centres and those who purchase drones for demonstrations would receive a contingency of Rs. 3000 per hectare. These are available until March 2023. To promote entrepreneurship among agriculture graduates, financial support up to 50% of the basic cost of drones or Rs. 5 lakhs whichever is less is provided to them [11]. In order to promote drones through start-ups and skilling at Industrial Training Institutes (ITIs), the government has insisted on promoting 'Drone Shakti' through varied applications and for Drone – as – a – Service (DrAAS) [12]. Also, the government will also promote 'Kisan drones' for farmers to help them assess crops, digitise land

records and as well as to modernize spraying nutrients to the crops [13-21].

In order to boost the efforts of the union government in promoting Digital Agriculture, the Tamil Nadu government has decided to procure 60 drones under the SMAM scheme for conducting demonstrations on spraying fertilizers on 14,400 hectares of land, which will be implemented by Tamil Nadu Agricultural University. TNAU has been carrying out research in promoting drones in agriculture owing to the labour shortage problems being faced in agriculture. It gained great success during the evaluation of the aftermath effects of Gaja cyclone-affected districts which cost Rs.650 per care in the place of Rs. 1200 per acre when done manually (The New Indian Express, 2022).

12. CONCLUSION

Drone technology is definitely a game changer in the field of agriculture. Many Indian start-ups are investing more in low-cost drones that can help farmers and create simultaneously employment opportunities for the rural youth and enhance the knowledge of farmers too. However, the drone industry needs more path-breaking reforms by taking into account the rapid increase in population, dire needs of the farmers, operational policies and shrinking farm fields which is a matter to be worried about.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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