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Efficacy of Drone Technology in Agriculture: A review

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ABSTRACT

Drones are unmanned aircrafts that are sent by a pilot on the ground to perform a task with a remote control or that are automatically flown by loading a previously made flight program. The applications of drone technology in the agriculture are addressed in this paper. This technology has broad scope in various fields such as managing water in agricultural systems, water stress detection, disease and pest detection, yield/maturity estimation, weed flora detection, monitoring of workforce, maintaining the livestock and concern logistics. It saves operating time, work accuracy, input costs such as land, water, seed and agro-chemical, and workforce in agriculture.

Keywords: Drone, Unmanned aerial vehicle, Agriculture, Water management, Sensor

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INTRODUCTION

Drones are considered to be the greatest invention of mankind. It can be extensively used in many areas such as defence, industry, and agriculture. At this time, almost 85% of drone technology is largely utilized by military and rest 15% by civilians for various applications. However, with certain restrictions, drones are also prohibited in some countries like India to fly over public places and government buildings (Puri *et al.*, 2017). Association of Unmanned Aerial Systems International (2016) reported an annual growth of 85-92% every year mainly in the growing market of agriculture. According to World Health Organization (WHO) it is estimated about 3 million workforces are affected by poisoning from pesticides from which approximately 18000 die every year (Kurkute *et al.*, 2018). It can be efficiently used in agriculture for certain activities such as water management, weather phenomenon, infestation of disease & pests on crops, land fertility and many others. Recently, it has been observed drones technology can cover nearly 10 to 15 times of the area which can be covered with traditional land based techniques (Dileep *et al.*, 2020). Irrigation sector is the biggest consumer of water which is almost 80% of available water resources in India, serving around 25 to 40% water use efficiency (WUE). Therefore, it is necessary to improve WUE by achieving maximum yield. In order to improve WUE, advanced information and communication technology (ICT) is playing a vital role. ICTs have been widely used in precision farming which entail soil nutrient mapping, land levelling system, variable rate technology for seeding and fertilizer application, early warning system for pest and disease, spraying of agro-chemical and yield monitoring etc. (Bujang and Bakar, 2019).

It has been seen those advanced technologies such as drone are widely used in different agricultural applications using with different sensors (Ram Kumar *et al.*, 2018). For example, determining and monitoring the productivity of rice fields, monitoring wheat production using various fertilizers and, healthy & diseased determination of areas etc. (Kurt and Kinay, 2021). Information obtained by drones with different sensors i.e., soil moisture, electrical conductivity (EC), pH, surface temperature, weed or pest infestation and photosynthesis activity, are used for reduction of the overall cost of agricultural production, increase of production efficiency, precise crop harvest estimation and reduction & adaptation of climate change.

The drone technology is now extensively used in water management issues faced in agriculture and irrigation sector. Furthermore, various issues in agriculture management come up due to climate change are crucial and there is immediate requirement for adoption of advanced technologies such as drones, image processing etc (Dileep *et al.*, 2020). At the same time, this technology may lead to increased crop production, productivity and its quality (Daponte *et al.*, 2019;).

DRONE

DRONE (**D**ynamic **R**emotely **O**perated **N**avigation **E**quipment), also known as UAV or Remotely Piloted Aircraft (RPA), is an aircraft that can go automatically, with GPS control, without a pilot (Rani *et al.*, 2019; Varma *et al.*, 2022). Unmanned Aircraft Systems (UAS), commonly known as drones.

In other words, in recent time, drones are aircrafts that are sent by a pilot on the ground to perform a task with a remote control or that are automatically flown by loading a previously made flight program.

As per Goldman Sachs report, it had been predicted that the agriculture sector will be the second largest user of drones in the world by 2022.

Classification of drones

Drones can be categorized in two types i.e., fixed wing airplanes and rotary motor helicopters (or quad copter).

Fixed wing drone

It can fly at higher speeds ranging from 25-45 miles per hour (mph) and cover the range of 500 to 750 acres per hour depending on the battery fly time (Puri *et al.*, 2017). These are

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generally faster than rotor-based systems and larger in size, allowing for higher payloads (Filho *et al*., 2020).

Rotary motor drone

It can fly over constant speed. They experience from limited battery life and can take off and land off safely in small confined areas and are absolutely best for starters to learn drone flying. Multi-rotor and single-rotor drones do not need specific structures for take-off and landing (Filho *et al*., 2020).

There are numbers of multi-rotor drones with different numbers of rotors. These are generally three rotors (tri-copter), four rotors (quadro-copter), six rotors (hexa-copter), eight rotors (octo-copters). While, tri-copter drones have only three rotors, they have a cost advantage despite their low weight carrying capacity and mobility. Quad-copters have four rotors. Two rotors rotate clockwise while the other two rotors rotate anticlockwise. Quad-copters are the most preferred drone because of its cost and functionality. Hexa-copters have similar advantages as quad-copters, but they have the potential to carry more load and flying to higher altitudes due to their more rotors. For balanced and stable flying of hexa-copters, three out of the six rotors rotate clockwise while the other three rotors rotate anticlockwise.

Specifications of drones types

Item	Fixed wing drone	Quad-copter
Weight (kg)	2.5-6	1.5-5
Speed (m/s)	11-17	8-10
Battery type	Lithium polymer	Lithium polymer
Photo capture capacity	3 photos per second	3 photos per second
Flight altitude (m)	150	90
Flight duration (min)	90	45
Area covered in single flight (Km^2)	4-5	2-4
Type of terrain	Plain area	Hilly area

Source: Kolhe and Munde (2019**)**

Classification of drone based on all-up weight (including payload)

Drone can be classified as nano, micro, small, medium, and large drone based on the all-up weight including payload. As per the drone rules, 2021 of ministry of civil aviation, Government of India the drones are classified as follows

Table 1: Drone classification based on all-up weight

Types of drone	Weight	Remote Pilot Licence
Nano	= 250 g	Not required
Micro	More than 250 g and upto 2 kg	Not required for non-commerical and required for commercial use
Small	More than 2kg &upto 25 kg	Required
Medium	More than 25 kg upto 150 kg	Required
Large	More than 150 kg	Required

As per the guidelines of directorate general of civil aviation, Govt. of India, it is mandatory to have remote pilot license for the person who wants to operate drones of higher weight than nano drones (more than 250 g). In the case of micro drones for non-commercial use, remote pilot license is also not required. Others requires remote pilot license for the operators.

Operation coverage of drone

The 15-cm resolution of UAV cameras is over 40,000 times better than the most commonly available satellite data and even 44 times better than the best commercial satellite images (Stehr, 2015).

Cost estimation of drone

Drone technology is practically cost-effective. There cost can range from as little as approximately 80000 for a starter system and can go up to 8-16 thousand, depending on the size of the machine and any extra cameras or features added (Stehr, 2015).

Canada, Europe, Asia, and South America do not have as many regulations, so their drone use is more expansive. Japan in particular does a lot of spot applications of herbicides in rice crop and in their less accessible highland fields (Stehr, 2015).

Benefits of drone

Drone technology can really benefit for the collection of spatial data on a local and regional scale. Compared to alternative ways of collecting spatial data, using manned aircraft or satellites, drones are:

- cost-effective means of collecting high quality data with survey precision.
- not constrained by third-party relations (e.g., contracting, scheduling, purchasing, etc.) when deployed by in-house staff.
- easily deployed for quick response to emerging issues such as flood or pollution events.
- highly maneuverable for acquiring data in remotely difficult to accessible areas.
- flown at lower attitudes to avoid weather effects i.e., cloud cover etc.
- secure means of collecting data, especially when the capacity to collect and process the data can be done in-house.
- able to monitor a field every week throughout the crop growing season.

Required steps for improving agriculture production using drone

- Optimize the application of the fertilizers i.e., where and when it is necessary, this may cut down fertilizers to 20–40%.
- Optimize the utilization of the water and irrigation scheduling.
- Reduction and prevention of agricultural waste or post-harvest losses.
- Reduction of workforce and input costs.
- Reduction of the environmental risks.
- Automatic and continuous analysis of processes and field status.

Possible applications of drones in agriculture research, development and extension

Drones have the following advantages compared to satellite high resolution images and airborne sensors such as improved performance, improved efficiency, improvement in the productivity, reduction of environmental impacts and the availability of computable data from large farms. Despite the transformation, Indian agriculture is still constrained by a number of factors including unpredictable weather, scattered & small landholdings, non-scientific way of farming and poor technological adoption.

Calina *et al.* (2020) reported that drone technology can help farmers to optimize the use of inputs such as seeds, fertilizers, pesticides, water, respond more quickly to threats such as weeds, diseases and pests, and save time for on-the-spot surveillance. Celen *et al.* (2020) reported that drone technology can be used in agriculture for disease and pest detection, water stress detection, yield/maturity estimation, weed flora detection, water resources control and monitoring of workers based on remote sensing and plant monitoring techniques. Daponte *et al.* (2019) reported that at present agriculture drones can be applied for biomasses, crop growth and food quality monitoring, precision farming, and harvesting and logistic optimization.

In addition to above, drones offer the option of producing with a new perspective and approach in terms of developing agriculture, increasing efficiency, and making correct land control. Nowadays, drones are going to become an alternative of traditional pesticide sprayers used by farmers in agriculture. Its spraying rates are 40 times faster than conventional pesticide sprayers. It saves 90% water and 30-40% pesticide with smart spraying systems. Drones can spray agro-chemical as well as observe crop production and post-harvest losses. For livestock farms, it can also be used to monitor animals and collect useful information/data of animal health and population.

With growing reliance on drones, the agriculture sector has potential applications for this technology due its flexibility in point and spatial data acquisition. Wide spectrum of research and extension activities in agricultural development call for such innovative tools to save on time, human and economic resources and increase accuracy & efficiency. Although, drones have applications in all areas of research, our focus of utilizing the drones will be on precise mapping of land use land cover, acreage estimation fruit crops at regional scale, crop monitoring and crop protection.

The possible applications of drone technology are listed below:

1. **Efficient water management**: This technology helps in utilizing water economically because it uses ultra-low volume (ULV) spraying technology.
2. **Assessment of temporal land use land cover changes**: Land use land cover in the eastern plateau and hill region is rapidly changing. Drone-based remote sensing will assist in assessing the changes in land use land cover over a temporal scale.
3. **Crop monitoring and diagnosis of abiotic and biotic stresses**: This includes applying fertilizer at the appropriate time, inspecting for insects & pests, and monitoring the impact of weather conditions.
4. **Judicious and precise application of agro-chemicals**: Foliar application of nutrient, plant protection chemicals and fertilizers with precision on taller trees (litchi, mango, guava, jackfruit etc.) and field & vegetable crops. Application overuse is avoided.
5. **Crop and weed species distribution mapping**: The use of UAVs equipped with advanced cameras and sensors capable of detecting specific weeds. More precise weed management planning can improve the effectiveness of mechanical methods and/or reduce herbicide application. It can also delay the emergence of weed resistance.
6. **Monitoring of crop growth and development**: It can gather information about the health of the soil and the crop using infrared mapping, allowing for timely completion of need-based farm operations.
7. **Geo-fencing**: Thermal cameras mounted on drones can easily detect animals, birds, and humans. As a result, it can protect fields from external damage caused by animals.
8. **Livestock management**: It can be used to monitor and manage livestock because their sensors have high-resolution infrared cameras that can detect a sick animal and take appropriate action.
9. **Fisheries management**: Unmanned aircraft systems offer tremendous opportunities for fisheries managers to improve resource monitoring through real time survey data and combat illegal, unreported, and unregulated fishing.
10. **Agro-forestry management**: It can collect a variety of data points and aid in predictive planning and analysis for agricultural crop planting with trees.
11. **Horticulture and plantation crop management**: This includes applying fertilizer at the appropriate time, inspecting for insects & pests, and monitoring the impact of weather conditions. Combination of drones equipped with multi-spectral sensors and satellite based remote sensing platforms can be used to estimate area under different horticultural crops in the region.
12. **Water body and makhana surveillance:** Spread of water bodies as well as area under makhana, singhara and other water loving crops for proper planning and management. It also helps in water resource mapping at village or at watershed scale.

Case study of application of the drone in different areas

Efficient water management

A case study was conducted on the application of drone for mapping of the command area of irrigation project in Pune region of Maharashtra state of India, on about 5 lakhs ha command area. Its objective was to identify the crop-wise area and using this information for the preparation of statement of water charges. The outcome of the drone survey resulted in an accurate estimation of the area irrigated and an accurate identification of crops. This data/information helped in time saving and increased revenue of the department.

Characterizing water bodies

Erena *et al.* (2019) described new equipment (aerial, floating and underwater drones) based on open-source technology that allow for data acquisition in water reservoirs and performing bathymetric surveys. The authors tested their devices on 21 reservoirs from the Segura River Basin in South-East Spain. For each reservoir, the authors carried out two flights, acquiring aerial images that allowed them to obtain a photogrammetry survey of the reservoirs. Surface water vehicles and underwater remote-operated vehicles were used for bathymetric surveys. Moreover, underwater vehicles performed water-quality measurements. Their results showed that the annual loss rate of water storage capacity was

0.33% on average for the surveyed reservoirs. Koparan *et al.* (2018) describe a system for performing water quality measurements on site. This system consists of a custom-built hexacopter equipped with a multi-probe based on open-source electronic sensors that allow for measuring water temperature, electrical conductivity, dissolved oxygen, and pH. This device was tested on a 1.1 ha agricultural pond and the measurements proved to be reasonably accurate, allowing one to obtain maps displaying the spatial distribution over the pond of the measured parameters. Gao *et al*. (2019) explore the advantages of integrating unmanned aerial vehicle (UAV) photogrammetry and image recognition for measuring water level. The developed system captures water fluctuation using an UAV airborne camera, and the obtained imagery is processed for measuring the water level by calibrating a set of parameters.

Assessing crop water requirements

Aguilar *et al.* (2018) present an evaluation and validation of the MOD16 algorithm, based on satellite information. The evapotranspiration values obtained by this approach were compared with ground-based eddy covariance measurements in five Northwestern Mexico locations. These sites are arid or semiarid and devoted to wheat cultivation or natural vegetation (shrubs). The indicators used showed a high variability among the studied sites in the performance of MOD16, usually underestimating evapotranspiration. The authors concluded that MOD16 allows for a fair estimation of crop water needs in the studied sites; however, due to the lack of ground-based measurements, a generalized use of this satellite-based approach cannot be supported by the current data. Ramírez-Cuesta *et al*. (2019) presented a tool integrated into ArcGIS for estimating crop water needs from satellite images. The dual crop coefficient approach was combined with imagery from Landsat 7 and 8, and Sentinel 2A. This study shows a user-friendly tool that requires a low number of inputs, and describes the spatial variability of crop water demands within an entire field. The statistical indicators showed good adjustments, with root mean squared errors ranging from 0.01 to 0.02 in both lettuce and peach crops; however, certain underestimations were observed.

Characterizing crop water status

Sabzi *et al.* (2018) developed a five-step algorithm for apples grown in outdoor conditions. They tested this algorithm in an apple orchard under 16 different light intensities. The accuracy of the proposed algorithm was higher than 99%, outperforming existing methods.

Crop monitoring

Sensor equipped drones can collect spectral data and create maps showing crop health changes. Multispectral and RGB cameras equipped drones offer the advantage of imaging the near infrared portion of the electromagnetic spectrum over the crops, thus providing the crops health conditions (Daponte *et al.,* 2019). Combination of Excess Green-Red (ExGR) vegetation index and YUV color space gives the best result with accuracy greater than 95.8% (Ghazali *et al.,* 2022). This technology increases consistency and efficiency of crop management, besides reducing the cost (Press Information Bureau, 2021).

Variable rate fertility

By using drone technology, variable-rate application (VRA) maps to determine the strength of nutrient uptake within a single field, the farmer can apply 300 kg/ha of fertilizer to struggling areas, 200 kg/ha to medium quality areas, and 150 kg/ha to healthy areas, decreasing fertilizer costs and increasing yield (Veroustraete, 2015).

Cattle herd monitoring

Drones are a solid option for monitoring herds from overhead, tracking the quantity and activity level of animals on one's fields. In the Kaziranga National Park in India, drone has also become a tool for tracking human poachers.

Disease surveillance

Schmale of Virginia Tech is using drones to discover pathogens that have not landed in vacancies. He captured the air spores of Fusarium graminearum, which destroys wheat and corn and has drifted away by a few kilometers or more (Ren *et al*., 2020).

Mechanical pollinator

A New York-based startup has developed a pollen dump drone that helps pollinate fruits such as almonds, cherries and apples. They reported that its drone rate could be increased from 25% to 65% (Ren *et al.*, 2020).

Agricultural insurance investigation

The drone has the characteristics of maneuvering fast response, high-resolution image and high-precision positioning data acquisition capability, application expansion capability of various task devices, and convenient system maintenance, which can efficiently perform disaster-damaged tasks. Through aerial surveys to obtain data, post-processing and technical analysis of aerial photographs and comparison with field measurement results, insurance companies can more accurately determine the actual disaster area. Insurance companies can use drones to get a better idea on the extent of damage after a hail storm, easily determining whether a field has 70% compared with 90% loss (Stehr, 2015).

Planting

A seed dropping mechanism using drone, seeds are dispersed upon reaching the predetermined positions, with maximum capacity of 60 seeds per minute and also capable of dropping 28800 seed balls in 8 hours (Ghazali *et al*., 2022). Start-ups have developed drone planting systems that achieve an uptake rate of 75% and decrease planting costs by 85% (Ahirwar *et al.,* 2019).

Crop spraying

In fact, experts estimate that aerial spraying can be completed up to five times faster with drones than with traditional machinery (Ahirwar *et al.,* 2019). Human being charges 100/- to 200/- rupees per day for pesticides spraying, as compared to them drone takes 3 watts of power then it will charge 10/- rupees only of electricity (Kurkute *et al*., 2018). Some of the aspects that give drones a competitive edge over manned crop dusters are their relative ease of deployment, reduction in operator exposure to pesticides, and potential reduction of spray drif. Drone is capable of spraying 1.15 and 1.08 hectares per hour for groundnut and paddy crop, respectively (Ghazali *et al.,* 2022). Spraying the pesticide with drone from 3.5 m height gives higher droplets coverage rate and uniformity on wheat canopy than ground spraying (Ghazali *et al*., 2022). Use of drones to spray pesticides can save about 80% of operating time, 90% of water consumption and 50% of pesticide use (Bujang and Bakar, 2019; Varma *et al*., 2022).

Mapping and soil analysis

Compared to the terrestrial mapping i.e., theodolite, drone mapping has a lower implementation cost (RM 6000 or 1500 USD or Rs. 19909.93 cheaper), about 68 times faster, and requires lower manpower (Ghazali *et al*., 2022). It is also helpful in acquiring information such as pH level, soil type, and chemical contents in the soil. Drone in combination of orthophotos, multispectral images, and digital surface model (DSM) data produced the most accurate classification, with accuracy rate near 90%.

Laws for operation of drones in different countries

Drone operation is regulated by a designated rule in different countries. In USA, Federal Aviation Administration (FAA) notified the New Small Unmanned Aircraft (UAS) Rule (107) for commercial or work operations of drones. As per this rule drone weighing less than 0.55 lbs does not require permission for flying but drone weighing 0.55 to 55 lbs must be registered with the FAA. Drone must fly within the visual line-of-sight. In Australia, the drone rules and operations are governed by Australian Civil Aviation Authority (CASA) which was launched in 2002 and further modified in 2016. As per this drone weighing upto 25 kg does not require approval for operation on own properties. Small commercial drone operators were exempted from paying regulatory fees (US $1,400) under new policy. In Japan Ministry of Land, Infrastructure and transportation (MLIT) deals with the drone rules and regulations for operations. Here drone can't fly at dawn and dusk and must maintain a distance of 30 m of distance from the people and objects. Flying drone above 150 m airspace require MLIT approval (Pathak *et al*., 2020).

Laws for operation of drone in India

The new drone rule in India was notified on 25 August, 2021 and named as drone rules-2021. This rule will be applicable to all the UAV registered or being operated in India, to all the persons operating, owning, leasing, transferring, or maintaining a UAV in India. Operators must ensure that they follow the following drone laws when flying a drone that weighs over 250 grams in India. This rule is follows as given below:

- All the drones must bear a unique identification number and must be registered on the digital sky platform of DGCA, GoI.
- Before every flight one must check the airspace map of the digital sky of the DGCA, GoI. The drones will not fly in red and yellow zone designated by airspace map of the digital sky, which is dynamic in nature, without prior permission whereas in green zone no permission is required (Exception: if restriction applied in intended area).
- The green zone means the airspace upto a vertical distance 120 m (400 feet) above the land areas or territorial water of India, which has not been designated as yellow or red zone for UVAs operations. It is area located between a lateral distance of 8 and 12 km from the periphery of an operational airport and airspace upto a vertical distance of 60 m (200 feet) above the area.
- Yellow zones mean airspace as defined in green zones where the operations of UAVs are restricted and requires approval of air traffic control authority of the area.
- Red zones or "no drone zones" are airspace area designated by Government of India above land or territorial waters of India which requires permission from central government of India to fly a UAV.
- Do not fly your drone over densely populated areas or large crowds.
- You must fly during daylight hours and only fly in good weather conditions.
- Do not fly your drone in sensitive areas including government or military facilities.
- Uses of drones or camera drones in these areas are prohibited.
- You must be at least 18 years old and have completed a training course.
- All drones must be equipped with a license plate identifying the operator, and how to contact them.
- You must only fly your drone within visual line of sight.
- You cannot fly more than one UAV at a time.
- Do not fly your drone within 50 km of a border.
- Do not fly your drone more than 500 m into the sea, from the coastline.
- Do not fly over national parks or wildlife sanctuaries.
- All drones above the class of nano drones must have liability third party insurance.
- Owners or remote pilot must report any accident to DGCA digital sky platform within 48 hours.

Initiatives for implementation of drone in India

In March 2021, the Ministry of Civil Aviation published the Drone Rules, 2021. On 21 December, 2021, the Ministry of Agriculture and Farmers Welfare (MOA&FW) released standard operating procedures (SOP) for use of drones in pesticides application for crop protection and for spraying soil and crop nutrients. On 19 February, 2022, the Prime Minister of India flagged off 100 Kisan drones in different parts of the country for spraying pesticides and other farm inputs. On 18 April, 2022, MOA&FW has released a memorandum on listing interim approved pesticides to be used for spraying by a drone for a period of two years. On 27 May, 2022, the Prime Minister of India inaugurated "Bharat Drone Mahotsav-2022" at Pragati Maidan, New Delhi. It is a testimony for use of modern tools for increasing efficiency and precision in agriculture operations. The Indian Council of Agricultural Research (ICAR) has planned to launch a programme "Agri-Drone in ICAR" to foster agriculture research, innovations, training and demonstration in the country for multiple use of unmanned aerial vehicle (UAV), i.e. drone technology to revolutionize the Indian Agriculture and ensure country's food security.

Sil (2021) reported that West Bengal's Burnpur based the Iron & Steel Company (IISCO) has got government approval to use drones for conducting perimeter surveillance of the plant. In 2021, Tractors and Farm Equipment Limited (TAFE), Chennai has been allowed to use drones for conducting aerial spraying to assess crop health and prevent crop disease. In the same year, Mahindra & Mahindra, Mumbai has been allowed to conduct drone based agricultural trials and precision spraying on paddy and hot pepper crop in the state of Telangana and Andhra Pradesh. Bayer Crop Science, Mumbai has been allowed to use drones for conducting agricultural research activities and agricultural spraying.

State governments in Karnataka, Haryana, Punjab, Tamil Nadu, and Madhya Pradesh are collaborating with drone manufacturers, farmer producer organizations, and state agriculture universities to develop fertilizer spraying drones. The state governments are also collaborating with state universities to help farmers become acquainted with the use of drones.

A study conducted by the Blue Weave Consulting (2022), agriculture drones market in India is forecast to witness a four-fold increase by 2028. Agriculture drones are spray drone-enhanced unmanned aerial vehicles that are used to improve agricultural operations efficiency, crop yield, and crop growth monitoring.

Drone startups in India has reported that precision farming technologies have been shown to boost yields by up to 5%. Drones equipped with NDVI (Normalized Difference Vegetation Index) imaging equipment employ detailed color information to determine plant health. It has also reported that drones can plant 400,000 trees per day, and 10 drones can plant 400,000 trees each day.

The Government of India also released a certification scheme for agricultural drones on 26th January, 2022 which can now carry a payload that does not include chemicals or other liquids used in spraying drones.

On 16 November, 2020 the Indian government granted permission to the International Crops Research Institute (ICRISAT) to use drones for agricultural research.

The guidelines of "Sub-Mission on Agricultural Mechanization" (SMAM) have been amended which envisages granting upto 100% of the cost of agriculture drone or Rs. 10 lakhs, whichever is less, as grant for purchase of drones by the Farm Machinery Training & Testing Institutes, ICAR institutes, KVKs and SAUs for taking up large scale demonstrations of drone technology on the farmers' fields (Press Information Bureau, 2022).

Global agriculture drones market

The major companies in the global agriculture drones market include Pix4D (Switzerland), Agribotix (US), Sentera Inc. (US), Precision Hawk (US), Trimble Inc. (US), 3DR (US), Aero Vironment Inc. (US), Drone Deploy (US), AgEagle Aerial Systems, Inc. (US), ATMOS UAV (Netherlands), DJI (China), Delair (France), Parrot Drones (France), Nileworks Inc. (Japan), Yamaha Motor Corp. (Japan), OPTiM Corp. (Japan), senseFLY (Switzerland).

CONCLUSIONS

There is no doubt the application of drones in the agriculture can transform the traditional method of farming into smart farming. Drones technology implications in agriculture not only improve the crop production but also transforms the farmer to protected scenarios. According to the various reports and documents, in the Indian context, these technologies have very limited application. But this may be increased day by day for various application such as efficient water management, characterizing water bodies, planting, livestock monitoring, soil health monitoring, disease and pest control and vice versa, from farm to household for multiple uses. It has numerous advantages; save about 80% of operating time, 90% of water consumption, 50% of pesticide use, decreasing fertilizer costs and increasing yield, decrease planting costs by 85% and so on. In Indian context, government is trying to popularize this advance technology through various policies and scheme in agriculture through SAUs, KVKs, government and private institutions and agri-industries.

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