ISSN: 2347-4688, Vol. 10, No.(3) 2022, pg. 352-365

Current Agriculture Research Journal

www.agriculturejournal.org

The Application of Drone Technology for Sustainable Agriculture in India

VISHAL KATEKAR* and JEEVAN KUMAR CHERUKU

Department of Public Policy, Law and Governance, Central University of Rajasthan, Bandarsindri, Ajmer, Rajasthan.

Abstract

Agriculture in India faces challenges from multiple fronts, decline in productivity, climate change and sustainability. Using drones in farming contributes to sustainable agriculture in terms of social, economic and environmental dimensions. This article discusses the advantages of adopting drone technology in India. The drones are useful in multiple ways, such as, soil analysis for field planning, plant establishment, precision application of agrochemicals, crop monitoring, irrigation management, crop health assessment, livestock monitoring, and disaster management, geo-fencing, crop biomass and damage estimation, locust control, and transporting goods in agriculture. The paper also describes the initiatives of Government of India towards promoting drone technology. Challenges in use of the drone technology have been discussed. The study found that the application of drone technology saves time, labour, water, and cuts spending on chemicals. It also reduces use of chemicals and eliminates the chemical exposure to human. The paper concludes that the government should effectively adopt and leverage the potential of drone technology for transforming the agriculture sector and life of millions of farmers in India.

Article History
Received: 27 August 2022
Accepted: 21 October 2022

Keywords
Climate Change;
Drone;
Sustainable Agriculture;
and Technology.

Introduction

India is an agrarian country with a good amount of agricultural land for cultivation (nearly 155 million hectares).[1] Even after the seven decades of independence agriculture remains a major source of income, employment and livelihood for rural households. Agriculture sector's share of employment is just 45.6%,[2] although it contributes 20.2% to India's Gross Domestic Product (GDP).[3,4] The Indian economy is growing but a share of the agriculture sector in GDP has not improved over the past decades. The agriculture sector is generating low income and is still technologically backward compared to the industry and service sector.[5]

CONTACT Vishal Katekar 2019phdpplg05@curaj.ac.in Department of Public Policy, Law and Governance, Central University of Rajasthan, Bandarsindri, Ajmer, Rajasthan.

Doi: http://dx.doi.org/10.12944/CARJ.10.3.19

Agrarian Distress

Agriculture sector is suffering from age-old challenges such as low productivity, decreasing landholding size, unplanned resources allocation, sub-optimal input use efficiency, frequent crop failure, farmers' suicide, low-income generation, high biotic losses, low level of mechanization, more uses of chemicals, unsustainable use and lack of efficient management of resources, more dependency on labour and minimum linkage to extension system and market. The existing challenges are preventing the agriculture sector from realizing its maximum potential and farmers to raise their income levels.[6] According to the 2003 National Sample Survey Organization (NSSO) 59th assessment, 40% of Indian farmers are not interested in pursuing their profession. They will leave farming if they get alternative employment opportunities.[7] The frequent protest by the farming community highlighted the agrarian distress in the country. As has been said, agriculture is the major profession in rural regions of India, which also consists of the majority of the poor population. The lower living standard and low income of individuals employed in the agriculture sector underline the need for transformation in this sector.

Transforming Agriculture Through Digital Technologies

Use of available advanced technologies may be the first choice in front of policymakers to enable sustainability and transformation in Indian agriculture. Agricultural sector has to increase efficiency and productivity to realize its maximum potential. There is a need to identify the challenges in existing practices and their possible sustainable solution with the help of advanced technologies. In the current agricultural practices, there are many unsustainable methods related to irrigation, chemical spraying, crop monitoring, pest management, etc. FAO suggested that the potential of different emerging technologies needs to leverage for solving the existing challenges faced by the agriculture sector.[8] Now the new technologies such as Artificial Intelligence (AI), Big Data, Satellite Technology, Drone Technology, Internet of Things (IoT), Digital Dashboards and Portals, Climate Smart Advisories, Information Technology (IT), Geographic Information System (GIS), Global Positioning System (GPS), Remote Sensing (RS) and Cloud Computing are used in solving the traditional challenges and advancement of the agriculture sector.[4] These emerging digital technologies are contributing to making food production and supply chain more predictable, sustainable, and seamless.

Drones also known as Unmanned Aerial Vehicles (UAVs) is a multipurpose flying robotic vehicles that can be operated by an operator from the ground or can work autonomously based on a predetermined algorithm. Drone technology has many applications ranging from military purposes, disaster management and relief, remote surveillance, construction, mineral exploration and in various agricultural activities.

During the COVID-19 pandemic time, the relevance of application of drone technology has increased due to the acute shortage of labour for agricultural activities. The social norms in pandemic such as physical distancing measures also favour the use of drones for agricultural-related activities as the continuation of farming is essential for ensuring the food security of citizens. The various studies highlighted the opportunities for the use of drones in agriculture during the lockdown and the situation of labour deficit.[9]

In the post-COVID-19 period, the adoption of digital technologies has been accelerated in almost every field including agriculture. The pandemic and climate change are forcing farming communities to become more resilient in feeding the people continuously during uncertain time. Digital technologies are providing opportunities not only for addressing the traditional challenges in agriculture, but also supporting in achieving of the globally accepted Sustainable Development Goals (SDGs).[8] To achieve the target of doubling farmers' income, the Indian agriculture sector needs to adopt cutting-edge digital and precision agriculture technologies. Digital technologies can transform Indian agriculture toward sustainable agriculture by improving farm productivity and increasing the access of market information to all types of farmers.[6] Drone in agriculture is useful to meet the food demand of the growing population. This technology has the ability to assist farmers in overcoming the challenges posed by their profession.

Drone technology has the potential to transform agriculture by providing an alternative to manual activities. At the global level, this is the most used

digital technology to modernize the agriculture sector. The farming community is showing a positive approach towards the use of drone technology in agriculture because of two reasons that are the absence of labour and the increasing importance of precision farming.[10]

The researchers conducted a field study to explore the application of drone technology in agriculture. Figures 1 and 2 are the pictures captured from the field.

Fig. 1: Farmers with a drone in their agriculture field.
Source: Captured from the field.

Fig. 2: Chemicals spraying on cultivated crops using drone technology.
Source: Captured from the field

Application of Drone Technology in Agriculture

Nowadays, researchers from different organizations including public research institutes and private companies are exploring different applications of drone technology ranging from tracking rhino poachers in dense forests, for searching and rescuing in disasters and natural calamities, and delivering medicine to remote areas during health emergency.[11] In agriculture, drones can be used for a variety of activities ranging from crop production to agro-forestry which includes seeding large and difficult terrain, to monitor crop growth along with soil and water management.[12] Figure 3 explains different applications of drone technology in agriculture.

In agriculture, drones have been used for different activities as discussed below.

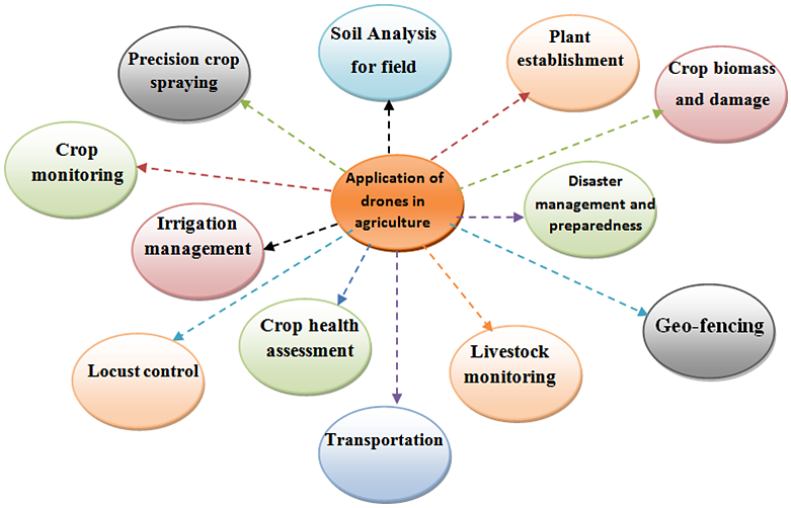

Fig. 3: Application of drone technology in agriculture.
Source: Authors' self conceptualization.

Soil Analysis for Field Planning

To increase crop production it is necessary to check the soil condition, soil type, and presence of micro and macro-nutrients before selecting a suitable crop for plantation.[13] Field and soil assessment before the cultivation of crops and after the plantation is essential for decision-making regarding the selection of different inputs and their quantity.[10] Drones can be used to analyse soil and fields for irrigation, crop planning, and nitrogen levels.[9] The FAO's case studies related to drone technology in agriculture also highlighted the use of drone in soil analysis for field planning. Drone can collect data and helps in taking accurate decision regarding the cultivation of crop suitable to soil condition and the amount of nutrition and water required to use from time to time manner.[8]

Plant Establishment

At the time of crop sowing activities, it is observed that there used to be a shortage of labour. The drone technology can address this challenge by planting crops on a large field in very less time with maintaining maximum accuracy.[10] Drone planting systems involve the planting of seeds and spraying of nutrients on the agricultural field with a specific pattern. It is observed that the use of drone technology increases the consistency and efficiency of crop management along with cost reduction.[13] Some innovators have developed extra attachments for drone systems that can shoot pods holding seed and plant nutrients into already prepared soil. This contributes to lower planting expenses.[9] Such a method of crop sowing has reduced the cost of plantation by nearly 85% in addition to the elimination of labour work.[10,13]

Precision Crop Spraying

Pests, weeds and plant diseases leads to crop loss approximately 15-25% of the entire food produced in India.[14] According to the Food and Agriculture Organization (FAO), if farmers stop using crop protection technologies, they will lose approximately 40 % of their yield due to pests and plant diseases. The traditional way of spraying chemicals in agriculture is very labour intensive and poses a health risk to labour due to the exposure of toxic chemicals to the eyes, lungs and skin.[16] Nearly 0.3 million farmers suffer from respiratory diseases due to spraying pesticides.[17] Different studies highlighted that pesticide use killed 183 farmers in Maharashtra between 2013-14 and 2017-18, and 442 across the country.[18] The snakebite is also major cause for the deaths of farmers in India. Approximately 58000 farmer losses their life.[17] The drone technology has the potential to address these challenges in agriculture.

It is difficult to ensure the application of chemicals in a prescribed dosage and it is hazardous in difficult geographical regions such as hilly area with slopes. The drone technology can solve these challenges

by combining it with AI, machine learning and the Normalised Difference Vegetation Index (NDVI) for getting proper insight into soil conditions, plant health and yield predictions.[6,9] High-quality camera and sensors mounted on the drone enables it for site-specific spraying. The drone can scan the crop area for spraying and also it ensures the spraying of a precise or fixed amount of liquid nutrients and pesticides on the scanned crops. The various studies on spraying using drones found that drones can spray five times faster than the traditional method of agricultural spraying, thus saving time and reducing the input cost. The studies show that map-based optimized nitrogen application results in a 20 % reduction in nitrogen input.[19]

Reduction in input costs of agrochemicals (pesticides/weedicides) is estimated at around 25-30% due to automated processes. For instance, in the application of nano urea, considering a cost of Rs.240/bottle for spray on an acre, if savings are 25%, then it contributes in overall reduction of input cost. Furthermore, drones have the ability to save up to 90 % of agricultural water usage, which is because of tiny droplet sizes of approx. 50 microns as compared to manual spray droplet which has size of approx. 500 microns. Spraying by drone save time as it takes around 5-7 minutes/ acre whereas traditional spraying required whole day for covering 3-4 acres.[17] Figure 4 depicts the benefits of drones for pesticide application in agriculture.

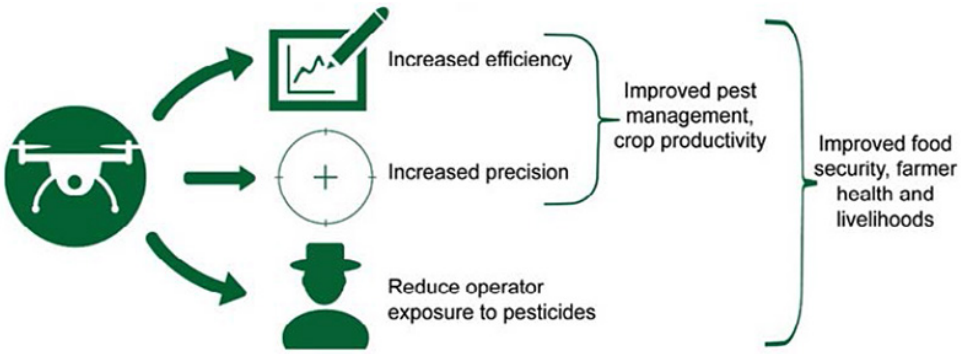

Fig. 4: Benefits of drone for pesticide application.
Source: FICCI (2020, p.1)

Crop Monitoring

Crop monitoring is a major source of concern not only for farmers but also for a variety of other stakeholders involved in agricultural activities. This difficulty has been aggravated by the growth of unpredictable weather patterns, which has resulted in increased crop loss risks and maintenance expenses. Frequent crop monitoring is required for the assessment of crop damage and pest attack to take measures accordingly. Drones can be used to plan monitoring routes by collecting multispectral geospatial and temporal datasets at predefined scales relating to crop development and health. Data analytics can provide insights on crop health that are not visible through manual field scouting.[9] With the help of drones' farmers can conduct agricultural field surveillance at their own convenience.[1] Such frequent crop monitoring enables farmers to take preventive actions within a short time. Accurate and frequent crop monitoring can provide the actual condition of the cultivated crop, which helps in the detection of any problems at an early stage.[10]

According to Mogili and Deepak (2018) crop monitoring through a multi-spectral camera mounted on a drone is more effective. This camera captures crop images in a single flight and based on the analysis of these images, it is easy to find the pest infected area. The drone can precisely spray the required chemicals with the help of GPS coordinates.[20]

Irrigation Management

In the majority of drought-prone areas, providing sufficient water to cultivate crop is a challenging task. At present, available irrigation techniques provide the water to a field in a uniform manner. However,

it is required to provide the water where it actually needs for rational and optimum use of available water resources.[21] Water is the critical input for crop growth, inadequate or excess amount of water creates problems in proper growth of the plant. Farmers need to do proper irrigation management based on the cultivated crop in a large agricultural field. The drone can assist farmers to take accurate decisions for precise irrigation management with the help of thermal digital cameras. The drone can capture the soil moisture stress condition and excess water at particular area in the agriculture field.[10,21] The field survey conducted using drone helps in achieving the water use efficiency and identification of leaks in irrigation through frequent irrigation monitoring.[13]

Drones equipped with sensors, thermal and multispectral imaging camera that can capture the heat and water stress in the crop of particular area in the agriculture field. Using it, irrigation may be applied to crops based on their needs. This will stop water from being wasted and ensure that irrigation water is used effectively.[22] Drones were used in Colombo by the International Water Management Institute (IWMI) to observe rice farming in the water-scarce Anuradhapura region. The institute took pictures of the paddy fields using near-infrared and red, green, and blue sensors. In Africa's rain-fed agriculture system, water is the determining factor. UAV technology is assisting in the planning and development of a feasible irrigation infrastructure.[23]

Crop Health Assessment

Frequent crop monitoring is essential for the identification of any disease at its early stage. Early disease identification and timely preventive measures can reduce crop failure and production loss by a substantial amount.[13] The early detection of bacterial, fungal and pest-related diseases can prevent the spread of infection. The drone can help in crop health monitoring by scanning cultivated crops using green visible light and near-infrared light. The crop health assessment by using the drone can boost crop production and cut the expenditure on chemicals such as pesticides.[10] According to FAO "UAVs equipped with special sensors can collect multispectral images that are stitched to generate spectral reflectance bands. These bands allow users to calculate indexes such as a Normalized Difference Vegetation Index (NDVI), a Leaf Area Index (LAI) or a Photochemical Reflectance Index (PRI), allowing farmers to view crop changes or stress conditions that are otherwise invisible to the human eye".[8]

Livestock Monitoring

Farmers used to engage in economic activities other than farming such as animal husbandry to generate additional income. Managing livestock is somewhat complex as animals used to move from one place to another and also need extra labour which increases the expenditure. It can take a lot of time to keep an eye on sheep and cattle while grazing in large open area. There are a number of technologies for keeping an eye on animals such as wearable Radio Frequency Identification (RFID) tags or remote devices to capture physiological or behavioral parameters and sound alerts when the information is out of the ordinary. Continuous monitoring is made possible by automatic equipment, which may also provide more information than manual monitoring.[24] The drone can easily monitor the animals which are tagged with RFID tags. Using the RFID tags the drone can provide the exact location of the individual animal, which makes farmer easier to monitor livestock and reduce the expenditure on dedicated personnel.[10] The drones with thermal sensor technology can find out lost animals and also helps in the detection of injury and sickness in animals.[13] With the presence of high-quality cameras and sensors, drone can detect predators before an attack and animals with any disease can be identified and treated in a short time.[1]

Drones are useful if the animals reached in places where the herder might find it hazardous to travel, such as on water reservoirs with slopes or in difficult and steep terrain.[24]

Disaster Management

Favourable weather conditions can support crop growth, however, extreme weather events may prove disastrous for cultivated crops. The weather cannot be accurately predicted and it is very difficult to handle the sudden change in weather. Drones can help the farmers to detect real-time weather conditions and the information collected by the drone can be interpreted by farmers to prepare an advance plan for risk mitigation. Advance information can help in planning the different types of agricultural activities and rational allocation of available resources.[5] In disaster management, the risk is mitigated by

the prediction of possible disaster events based on the collection of real-time data from the ground with the help of drones. Data collections through drones have advantages over the satellite-based Remote Sensing (RS) as it is less expensive, flexible, more timely and accurate. This drone-enabled data is helpful for increasing agricultural productivity and supply chain management through precise prediction and required interventions.[13]

Geo-Fencing

Wild animals are used to destroy the cultivated crops in many regions of the country. In day time farmers can provide attention to the entry of animals or human beings, however during night time monitoring the field and preventing crop loss due to wild animals is very difficult. The drones with attached thermal cameras can detect animals during the day as well as at night and alerts the farmers. Thus, with the help of drones farmers can avoid crop damages due to external animals.[5] Similarly, birds are a serious issue when numerous crops have been sown. Extra labour is required to protect the field. A few drone flights can scare the birds away from the field.[9]

Crop Biomass and Damage Estimation

The density of crop/tree canopy and distance from the ground surface can be detected using ultra-compact LIDAR sensors mounted on drones. This allows for the assessment of the tree/crop biomass change obtained from differential height measurements, which serves as the foundation for calculating timber output in forests and crop production estimations in crops such as sugarcane.9Detection of weeds, infections and pests can be easily done by using a drone with the help of multispectral and Red-Blue-Green (RBG) colour sensors. On the basis of acquired information, farmers can plan the chemical spraying with more precision and efficiency. The high-quality aerial images of crop captured by drones can provide information related to post-disaster crop damage with more accuracy compared to a manual survey. Such application of drone technology can increase the accuracy and reduce the delay in the crop damage assessment activities, which helps the farming community to settle the insurance claim of the crop in a very effective manner.[13] This aspect of crop surveillance and crop health assessment is also the foundation for using drones to improve agricultural insurance instruments for cross-verifying farmers' insurance claims.[9]

Locust Control

In addition to the natural vulnerabilities attack of locust on crop is becoming new challenge for farmers. The cultivated crop destroyed by army of locust resulted into the disaster and the economic loss for farming community. To address this challenge, many states in India are using the drones for spraying insecticides to eliminate the locust, which otherwise is very difficult task for human labour.[1]

Transporting Goods in Agriculture

The drones can also carry and transport the goods related to agriculture from one place to another as per the farmer's requirement. The drones can provide the service type operation, they can park in a field and use during different types of work such as spraying, monitoring and shifting goods.[13]

Drone Technology and Sustainability in Agriculture

Sustainable agriculture can be realized with the help of drones as it enables farmers to acquire continuous real-time information, crop production parameters and other insights on the agricultural field management. The drones can help farmers increase production through prevention of environmental degradation, effective monitoring of crop health; getting insights into the soil health, planning irrigation and the proper use of available resources.[7] Drone technology is such a revolutionary technology which can transform the farming profession with improving the three dimensions of sustainability in agriculture.

Environmental Dimension

The use of drone helps in achieving the resource optimization by increasing the input use efficiency. Minimum use of chemicals and efficient use of water will prevent pollution and degradation of the surrounding environment.[6] Crop sowing or planting with drone can reduce the need for tractors and helps in saving labour, costs, and fuel which leads to the sustainable farming. Low consumption of petroleum fuel will help in achieving the environmental dimension of sustainability.[1]

Economic Dimension

The optimum and precise application of input resources will reduce the requirement and increase the level of crop production which ultimately resulted into increase in farmers' income.[6] Reduction in requirement of labour and cost of production promotes the economic dimension of sustainability.

Social Dimension

The accomplishment of agricultural activities with the help of drones required less amount of time, less labour intensive and increase the farmers' safety while working. The time saving, improved level of safety and reduction in labour requirement in profession along with the respect in society will help in achieving the social dimension of sustainability in agriculture.[6]

Fig. 5: Dimensions of sustainability in agriculture
Source: Authors' self conceptualization.

Initiatives to Application of Drone Technology in Indian Agriculture

The drone technology in Indian agriculture is at an initial stage, however, due to the possible benefits of this technology, government is trying to promote the adoption of drones in agriculture by working with agri-tech start-ups, private sector, academicians and farmers. Through the NeGP-A and Union budget 2022-23, government is trying to provide policy backup for speed up the adoption of such advanced digital technologies in agriculture.

Specifically, Union budget (2022-23) is very important in post-pandemic situation, it announces the following.

i. Scheme based on Public Private Partnership (PPP) model for delivery of digital and advanced technology enabled services to farming community. The scheme will involve and seeks collaboration among the multiple stakeholders including public research sector and extension institutions (Example: Indian Council of Agricultural Research (ICAR), Agricultural Universities, Krishi Vigyan Kendras (KVKs), private sector and agri-tech startups).
ii. 'Kisan Drones' for using drone technology in agricultural activities such as crop assessment, digitization of land records, spraying of insecticides and nutrients. The initiatives like Kisan Drones can transform the agriculture sector by improving efficiency and accuracy. It will also promote the ease of doing business in farming profession and attracts the young educated people towards agriculture sector.
iii. The 'Drone Shakti' and Drone-As-A-Service (DrAAS) will be realized through the promotion and supporting the startups related to application of drones in different fields.[25]

India- Israel Collaboration in Drone Technologies

Israel is a world leader in the development of drones, unmanned aircraft, and autonomous vehicles.. Government of India collaborated with Israel for development of drone ecosystem in different sectors including agriculture. Agriculture is one of the most fascinating and possibly most relevant sectors for collaboration between Israel and India. With currently available cutting-edge technology, Israelian enterprises can offer solutions and services based on drones that are better, cheaper, and safer. The technological transfer enables civilian use of previously perfected technology for military purpose. However, it is a challenging task to actually develop highly technological solutions in a practical or economically viable manner. Furthermore, it is more difficult to 'translate' the importance of it to end users, such as small and marginal farmers.[26]

In order to promote indigenous development and adoption of drone technology Indian government initiated the online platform i.e. "Digital Sky Platform" for registration and operation of drones in India.

The central government established the two task forces particularly for the designing and making aircraft and drones in the country. This initiative will promote the development of indigenous drone technology and its adoption in different sectors including agriculture.[7]

India has enacted rules and regulation for drone operation, Standard Operating Procedures (SOPs) for spraying pesticides and liquid fertilizers using drones.[27]

To promote the development and adoption of drone technology in India, the Union government has initiated the Production Linked Incentive (PLI) to drone manufacturers and proposed to give 20 % incentives for any value addition in drone technology.[28]

The high cost of drones is the major hurdle in adoption of this beneficial technology by farmers. As the 86 % of the farmers in India are small and marginal, the cost of new technology must be low and affordable to Indian farmers for its maximum adoption in India. There are certain initiatives taken by government and private sectors to address this challenge. For instance, recent initiatives by Ministry of Agriculture for providing subsidy in purchasing agricultural drones by research institutions and the farmers' cooperative organizations.

The central government has permitted the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) to introduce the drone technology in Indian villages and its use for agricultural research activities.[1]

Many states in India started exploring the opportunities related to application of drones in different sectors. Different state governments are providing policy support for leveraging potential of drone technology in agriculture sector. For instance, the Maharashtra government using agricultural projects and schemes (Maha Agritrch, PoCRA), whereas Tamil Nadu government is collaborating with academic institutions (Eg: Anna University) for using drones in agricultural activities applications like crop monitoring and pesticide spraying. Farmers are receiving expert advisories based on the government initiatives related to crop health monitoring using drone and satellite technology.[12,29]

Government of Maharashtra has collaborated with the World Economic Forum (WEF) centre for the 4th Industrial Revolution to harness potential of drone technology for the government initiatives. The case study of farmers from Dahanu-Palghar tribal villages in Maharashtra highlighted that drone technology has applications in organic farming, fish farming, and rotation of crop and also in other related activities such as hydroponics, bio-waste management and in fruits gardens.[1] The TN government is working on the policy and institutional setup (i.e: Drone Corporation) for regulation and promoting the adoption drone in the State. The Tamil Nadu Aerospace and Defence Policy (ADP) also have the provision of setting up a Drone Testing Facility (DTF).[28] In case of Maharashtra, wilt disease in sugarcane crop is successfully detected by using drone based crop monitoring, where NDVI and RGB sensors were used. The North-Eastern (NE) part of India has difficult terrain due to the presence of hilly areas. The crop is cultivated in such area with the step-farming technique. It is very difficult for human beings in performing the agriculture activities in hilly areas. In this context, the drone technology has been exploited by state governments for the purpose of crop monitoring.[29]

The data collected by using drone technology has brought new opportunities for ensuring the timely settlement of crop insurance claim after the crop damage or loss due to any natural uncertainty. Such evidence based crop estimation will also reduce the dispute between different stakeholders.[30] Getting financial assistance in less time and minimum document process will help farming community to cope up with the disaster like situation and continue their profession with more job satisfaction.

The central government scheme such as Pradhan Mantri Fasal Beema Yojana (PMFBY) incorporated the use of advanced technologies - including remote sensing and drone technology to detect fraud, false claims and inconsistencies.[7] The Ministry of Civil Aviation (MoCA) and the Directorate General of Civil Aviation (DGCA) have granted

approval to the Ministry of Agriculture & Farmers Welfare (MoAFW) to deploy drones in agricultural areas of 100 districts across the country for Remote Sensing (RS) data collection and yield calculation at the Gram Panchayat (GP) level, as part of the PMFBY.[31]

Similarly, the central government and Insurance Regulatory and Development Authority of India (IRDAI) are exploring the use of combination of drone technology, satellite imagery and big data analytics to address the issue of fraud in crop and industrial insurance, which is estimated up to Rs. 45,000 crore.[27]

The fertilizer company IFFCO, involved in the development of nano urea, has been demonstrating the spraying of Nano-Urea by using drone in the paddy field of Kerala and Maharashtra. The company is also working on launching of full fledge Drone-Nano Urea project in different states of the country.[32] In the presence of a large number of farmers IFFCO also conducted a practical field trial of drone spraying of nano liquid urea in Bhavnagar. According to an IFFCO study, spraying nano urea by drones is more effective on crops and would increase yield.[33]

Drone use in Svamitva Scheme

Under the SVAMITVA (Survey of villages and mapping with improvised technology in village areas) scheme the Government of India is aiming to conduct aerial mapping of villages by Survey of India (SoI). This will help in developing accurate digital land record system, solving land and property related disputes in rural areas, panchayat level planning and resource management and Direct Benefit Transfer (DBT). The targets associated with this scheme (mapping of 1 lakh villages by Dec 2020 and mapping of 6.6 lakh villages by Dec 2024) will promote the adoption of drones in rural areas as it will generate the demands for local drones and employment.[34]

Locust control in India using drone: India has been praised by the FAO for becoming the first country in the world to employ drones for anti-locust operations.[26] In recent times, Indian agriculture faces problems due to the huge quantity of swarms of locusts as they entered into the Indian territory and started destroying crops, particularly in Rajasthan, Delhi, Madhya Pradesh and Maharashtra. In the anti-locust operation run by different States found that the use of drone is very helpful particularly in areas where transportation of spraying equipment is difficult. For controlling the pest like locust, spraying at the height is required, which is only possible with the help of drones. Drones can also spray chemicals on the locust located at high trees where manual spraying is not possible. By using drone the speed of operation has been enhanced at much level as drone can complete spraying 2.5-acre area within 15 minutes.[35] Drone can provide trustworthy data related to crop damage. Drone can capture images of the infected region, which helps in providing financial assistance for farmers by accurate and efficient estimation of crop damage.

Challenges in Adoption of Drones in Agriculture in India

There are several challenges which hinder the adoption of drone technology in agriculture. There is need to be addressed this challenges for effective adoption.

These challenges include

Internet Connectivity Issue / Internet Access

The low level of internet connectivity creates the trouble in operation of digital technologies such as drones.

Weather Dependency

In normal weather condition, drones are used to perform well and more efficiently than human labor. However, during the extreme weather condition the flying of drones is not advisable as it increase the risk of falling or less precise operation.

Knowledge and Skill

Leveraging new technology is encouraging, but using a drone on a regular basis demands necessary skill set and expertise.

Regulatory Uncertainty

The regulations for drone usages are still being developed. Drones for pesticide spraying in farmer fields will be adopted more quickly if standards are set for permitted pesticides.[6]

High Cost

Drone technology, training, and deployment in agriculture are more expensive.[10] Manufacturing is

carried out on a small scale, with substantial fixed costs. It is not economically viable for a village entrepreneur to purchase/rent one and use it for surveys/farm applications.[36]

Limited Flight Time and Range

Due to their larger payloads, drone flights often last 20-60 minutes. This limits the amount of field coverage per charge and raises the drone's operational costs.

Scarcity of Trained Pilot

Aside from technical know-how and price, a scarcity of trained pilots is a major impediment to the UAV market's expansion in India. Farmers can purchase agri-drones, but maintaining them is costly in terms of battery technology.[1,7]

Techno-Economic Feasibility

The proliferation of drone applications in India, where farmers are primarily marginal and land holdings are fragmented, may be hampered by their techno-economic feasibility.[7]

Safety and User-Friendliness

Due to safety concerns, drones cannot be operated publicly without prior approval from the government. Significant concerns about national security, criminal actions, safety, and privacy issues.

Dependency on Imports

Huge reliance on imported drone components due to the inadequate startup finance and insurance along with the lack of adequate investment on drone research and development.[26]

Issue of Long Term Profitability and Operational Cost

From a business standpoint, the profitability of drones in the agriculture sector is difficult to justify. Replacement of destroyed UAVs, procurement of high-resolution picture lenses, as well as accompanying technical solutions and other maintenance costs, are all possibilities for compensation. This makes it harder to reach out to farmers and agricultural entrepreneurs.[10]

Privacy Issue

Many people are concerned that the use of unmanned aerial vehicles (UAVs) for tracking and surveillance would breach their privacy. A key difficulty is the lack of defined operational and technical norms for UAVs to operate safely. There is the potential for misuse to infringe on people's privacy and to transfer information illegally.

Conclusion

The agriculture sector needs revolutionary changes to meet the demands of ever-growing population, farmers' welfare and the emerging uncertainties at national and international level such as COVID-19 pandemic. Drones technology is rapidly emerging technology because of its diverse applications. Drones not only improve the overall performance in agriculture but also motivate farmers to adopt precision agricultural practices and provide opportunity to transform farming from labour intensive to technology intensive profession. It will help in reducing the human error and inefficiencies in conventional agricultural practices by providing accurate and reliable information about situation on agricultural field. The drone act as "an eye in the sky" brings the new revolution in the agriculture sector. The combination of software, sensors, camera and different analytical tools can autonomously capture and interpret the data and images to actionable information and insights which helps in reducing the human error at large extent. The drone technology can help farmers in two ways, first by assisting the farmers in decision making and second is to replace the human labour by performing different tasks in field with more accuracy and in less time. There are several challenges which hinder the adoption of drone technology in agriculture. There is need to address this challenges for effective adoption and leveraging the potential of drone technology for transforming the agriculture sector and life of millions farmers in India.

Acknowledgement

Authors are grateful of Department of Public policy, Law and Governance, Central University of Rajasthan.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

Conflict of Interest

The authors do not have any conflict of interest.

References

1. Shukla, P. How farmers can benefit using drones. Retrieved from www.agritimes.co.in: https://agritimes.co.in/livestock/how-farmers-can-benefit-using-drones. Accessed August 30, 2021.
2. Sharma, Y. S. Share of agriculture sector in employment sees steady increase-CMIE. Retrieved from economictimes.indiatimes.com: https://economictimes.indiatimes.com/news/economy/indicators/share-of-agriculture-sector-in-employment-sees-steady-increase-cmie/articleshow/85266073.cms. Accessed August 12, 2021.
3. Ministry of Agriculture & Farmers Welfare. Contribution of Agriculture Sector towards GDP Agriculture has been the bright spot in the Economy despite COVID-19. Retrieved from www.pib.gov.in: https://www.pib.gov.in/PressReleasePage.aspx?PRID=1741942. Accessed August 03, 2021.
4. Borkar, S. How Agritech is Changing the Face of Sustainable and Industrial Agriculture in India. Retrieved from inc42.com: https://inc42.com/resources/how-agritech-is-changing-the-face-of-sustainable-and-industrial-agriculture/. Accessed November 21, 2021.
5. Tropogo. Application of Drones in Agriculture in India. Retrieved from tropogo.com: https://tropogo.com/blogs/application-of-drones-in-agriculture-in-india. Accessed February 06, 2022.
6. Thota, P. Precision farming and drones can help India make the big leap. Retrieved from www.thehindubusinessline.com: https://www.thehindubusinessline.com/opinion/farming-the-potential-of-drones/article34573234.ece. Accessed May 17, 2021.
7. Singh, A. Agricultural drones: The shape of Indian agriculture to come. Retrieved from smefutures.com: https://smefutures.com/agricultural-drones-shape-indian-agriculture-come/. Accessed January 10, 2019.
8. Sylvester, G. E-Agriculture in action: Drones for agriculture. 2018. Bangkok: FAO.
9. Pathak, H., Kumar, G., Mohapatra, S. D., Gaikwad, B. B., & Rane, J. Use of drones in agriculture: potentials, problems and policy needs. Baramati, Maharashtra, India: ICAR-National Institute of Abiotic Stress Management. 2020.
10. Mrunalini, K., & Deb, C. K. Chapter 16 : Drones in Agriculture. In S. Rathore, V. B., & V. S. Kumar, Digital technologies in agriculture (pp. 171-182). New Delhi: Biotech Books. 2021.
11. World Economic Forum. (2022, October 11). How drones delivering vaccines are saving lives in India. Retrieved from www.weforum.org: https://www.weforum.org/impact/drones-delivering-vaccines/
12. Government of Maharashtra. Harnessing drones and other disruptive technologies in agriculture. Government of Maharashtra. 2021.
13. Banerjee, A. Drone Technology in Agriculture : A Viable Solution to Address Food Security Issue. Retrieved from krishijagran.com: https://krishijagran.com/agriculture-world/drone-technology-in-agriculture-a-viable-solution-to-address-food-security-issue/. Accessed January 30, 2021.
14. The Hindu. (2016, July 19). Pests destroying almost one-fourth of crops. Retrieved from https://www.thehindu.com: https://www.thehindu.com/news/national/Pests-destroying-almost-one-fourth-of-crops/article14497608.ece
15. FICCI. Technical Discussion Paper on Drone usage for agrochemical spraying . New Delhi: Croplife India and FICCI. 2020.
16. Employment News. Making India a global drone hub. New Delhi, India: Ministry of Information and Broadcasting. Accessed February 05, 2022.
17. Beriya, A. (2022). Application of drones in Indian agriculture, ICT India Working Paper, No. 73. New York: Center for Sustainable Development (CSD), Earth Institute, Columbia University.
18. Hindustan Times. (2018, March 18). In three years, pesticides killed 183 farmers in Maharashtra. Retrieved from www.hindustantimes.com:

https://www.hindustantimes.com/mumbai-news/in-three-years-pesticides-killed-183-farmers-in-maharashtra/story

19. The Print. Ministry of Agriculture backed Startup IG Drones is helping farmers to boost income using Drone Geospatial Data. Retrieved from theprint.in: https://theprint.in/ani-press-releases/ministry-of-agriculture-backed-startup-ig-drones-is-helping-farmers-to-boost-income-using-drone-geospatial-data/767604/. Accessed November 17, 2021.
20. Mogili, U. R., & Deepak, B. B. (2018). Review on Application of Drone Systems in Precision Agriculture. Procedia Computer Science, 502-509.
21. Debanjan, B. Rise of Precision Farming Driving Agriculture Drone Market Growth. Retrieved from techbullion.com: https://techbullion.com/rise-of-precision-farming-driving-agriculture-drone-market-growth/. Accessed November 02, 2021.
22. Rani, A., Chaudhary, A., Sinha, N. K., Mohanty, M., & Chaudhary, R. S. 2019). Drone : The green technology for future agriculture. Harit Dhara, 2(1).
23. Chamuah, A., & Singh, R. (2020). Securing sustainability in Indian agriculture through civilian UAV: a responsible innovation perspective. SN Applied Sciences, 10(2). doi:doi.org/10.1007/s42452-019-1901-6
24. Herlin, A., Brunberg, E., Hultgren, J., Högberg, N., Rydberg, A., & Skarin, A. (2021). AnimalWelfare Implications of Digital Tools for Monitoring and Management of Cattle and Sheep on Pasture. Animals, 11(3). doi:doi.org/10.3390/ani11030829
25 Ministry of Finance. Highlights of the Union Budget 2022-23. Retrieved from www.pib.gov.in: https://www.pib.gov.in/PressReleasePage.aspx?PRID=1794165. Accessed February 01, 2022.
26. Zadka, J. India, Israel need to collaborate in drone technologies. Retrieved from www.thehansindia.com: https://www.thehansindia.com/hans/opinion/news-analysis/india-israel-need-to-collaborate-in-drone-technologies-705843. Accessed September 10, 2021.
27. The Financial Express. An eye in the sky: Drones, satellite imagery to fight farm insurance fraud a good idea. Retrieved from www.financialexpress.com: https://www.financialexpress.com/opinion/an-eye-in-the-sky-drones-satellite-imagery-to-fight-farm-insurance-fraud-a-good-idea/2326725/. Accessed September 09, 2021.
28. Kumar, N. R. ICAR to deploy drones, sensors to study crop loss. Retrieved February 25, 2022, from www.thehindu.com: https://www.thehindu.com/sci-tech/agriculture/icar-to-deploy-drones-sensors-to-study-crop-loss/article8403030.ece. Accessed March 28, 2016.
29. Indian Academy of Drones. Drones in Indian Agriculture. Accessed November 30, 2019.
30. The Times of India. For timely settlement of insurance claims, DGCA allows agri dept to fly drones. Retrieved from timesofindia.indiatimes.com: https://timesofindia.indiatimes.com/business/india-business/for-timely-settlement-of-insurance-claims-dgca-allows-agri-dept-to-fly-drones/articleshow/80686081.cms. Accessed February 04, 2021.
31. Department of Agriculture & Farmers Welfare. Standard Operating Procedure (SOP) for use of drone application. Department of Agriculture & Farmers Welfare. New Delhi: Ministry of Agriculture & Farmers Welfare, Government of India. 2021. Retrieved from https://agricoop.nic.in/sites/default/files/SOP%20for%20Drone_2.pdf. Accessed February 10, 2022.
32. Jha, A. IFFCO employs drones for paddy fields. Retrieved from Indiacooperative.com: https://www.indiancooperative.com/iffco/iffco-employs-drones-for-paddy-fields-catches-netizens-fancy/. Accessed August 24, 2021.
33. Tribune India. IFFCO conducts field trial of spraying of nano urea by drone at Gujarat's Bhavnagar. Retrieved from www.tribuneindia.com: https://www.tribuneindia.com/news/nation/iffco-conducts-field-trial-of-spraying-of-nano-urea-by-drone-at-gujarats-bhavnagar-318812. Accessed October 01, 2021.
34. Ministry of Civil Aviation. Media interaction by Hon'ble Minister for Civil Aviation: Drones for mass benefit. Retrieved from www.civilaviation.gov.in: https://www.

civilaviation.gov.in/sites/default/files/Presentation_on_Drones.pdf. Accessed July 16, 2020.

35. Iqbal, M. Drones deployed for controlling locusts in Rajasthan. Retrieved from www.thehindu.com: https://www.thehindu.com/news/national/other-states/locust-attack-about-90000-hectares-hit-in-20-rajasthan-districts/article31694494. Accessed June 02, 2020.

36. National Conference on e-Governance. Emerging Technologies: Digital Agriculture & Drones, The PoCRA quandary. Technology for Accelerating Development 2018 , 13-14. Hyderabad: Department of Administrative Reforms and Public Grievances. Retrieved from https://www.nceg.gov.in/sites/default/files/29%20Drones%20in%20Digital %20Agriculture.pdf. Accessed July 12, 2021.