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Role of drones in sustainable development of agriculture: Indian perspective

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Abstract
Indian Agriculture faces numerous challenges; decline in productivity, climate change, global warming and loss of natural resources, labour shortage, and pandemics situations. The mechanization and IoT gaining is huge importance nowadays and there is huge potential for IoT to replace human labour in farming. The drone contributes to sustainability in agriculture in terms of social, economic and environmental proportions. Here, it is elaborated about status of market of drone and applications of it in many fields. The drones are useful in soil analysis for farming, growth and establishment of plants, precision application of agro-inputs, crop disease scouting, irrigation monitoring, crop health assessment, livestock nursing, and disaster supervision, geo-fencing, crop biomass and damage estimation, locust control and transporting materials. Drone saves time, labour, water, and cuts expenses on chemicals as shown by research accomplishments across the world. The paper concludes that the government must efficiently adopt and switch the potential of drone technology for transforming the livelihoods of agriculture labours and improving the lives of millions of farmers in India.

Keywords: Climate change, drone, sustainable agriculture, technology

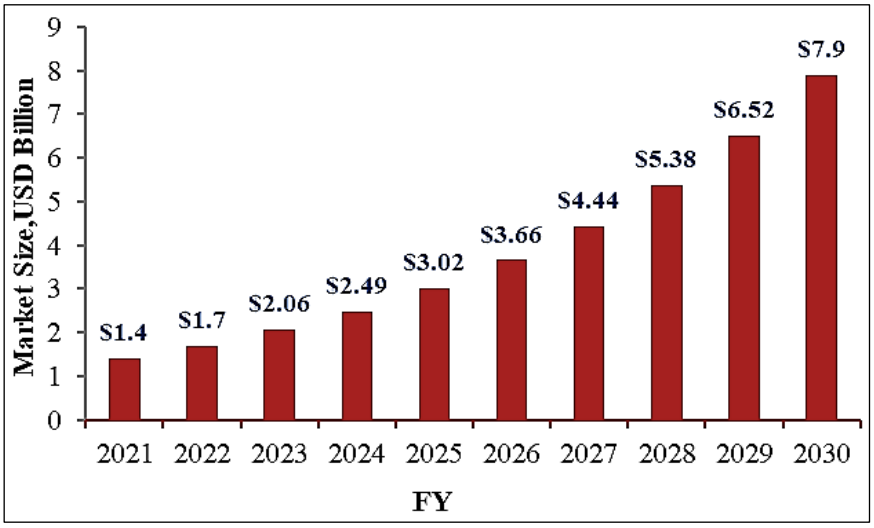
Introduction
India is an agrarian country with a decent agricultural land for cultivation (approx. 155 mha) (Shukla, 2021) [1]. Even after the seven decades of independence, agriculture has been a major source of income, employment and livelihood for rural households. Agriculture sector's share of employment is just 45.6%, although it contributes 20.2% to India's Gross Domestic Product (GDP) (Shukla, 2021, Sharma, 2021) [1, 2]. 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. The service sector is acknowledged to be the most considerable contributor to India's GDP. Our country reigns the world as the most prominent producer of pulses, milk, rice, wheat, sugarcane, spices, etc. These also add substantial value to the economy with their activities in the agrarian sector. The agricultural sector contributes a tremendously (18%) to the India's GDP. It is considered to be the prime source of livelihood for approx. 58% of the country's population, mainly for rural areas. Indian agriculture sector, along with forestry and fishing, results in a Gross Added Value of around Rs 18.55 lakh crore as of 2019. The agricultural sector expands with parallel industries at a growth rate of 2.1% (2019-20). Regardless of Indian agriculture's contribution to the GDP, our country is yet to augment productivity and efficiency in the sector to reach the maximum potential. Several dimensions and apprehensions need to be identified, supported, and equipped with resolutions. Unsuitable methods for monitoring crops, water irrigation, using pesticides, and many other necessary farming activities are currently adopted. These hindrances have granted multiple opportunities for growth and development in the world of technology. The influence of technology in the agricultural sector has been consistently positive since its commencement.
Drone technology has become most of the appreciation in the industry because of its diversity and considered as the future for the agrarian country. The military started using them initially. However, other sectors quickly and gradually embraced unmanned aerial vehicles (UAVs) when they learned about its adaptability with respect to applications. Drones don't simply enhance overall performance but also encourage the farmers to solve other various barriers and receive plenty of benefits through precision agriculture. With the market for agricultural drones reaching a whopping $1.3 billion, UAVs (unmanned aerial vehicles) fill the gap of

human error and inefficiency by traditional farming methods. The purpose of adopting drones is to eliminate any guesswork or ambiguity and instead focus on accurate and reliable information. External factors like weather, soil conditions, and temperature play a critical role in farming. Agriculture drone allows the farmer to adapt to specific environments and make watchful choices accordingly. The gained data helps normalize crop health, crop treatment, crop scouting, irrigation, and carry out field soil analysis and crop damage assessments. The drone survey helps boost crop yields and minimize time and expenses.

According to one estimate, the world population is predicted to be 9 billion by 2050. Agricultural consumption is also said to upsurge concurrently by nearly 70%. Drone technology, armed with artificial intelligence (AI), machine learning (ML) and remote sensing features, is rising in demand because of its advantages. The central government has endorsed and approved the significance of unmanned aerial vehicles (UAVs), machine learning and artificial intelligence with '*Digital Sky Platform'* online. Drone start-ups in India have used this opportunity to achieve better technological potential. Transforming crop production through digital platforms and use of novel methods is prime choice before the policymakers to ensure sustainability in Indian agriculture. Agriculture sector must enhance its efficiency to prove its potential in using novel techniques in order to augment the food production to meet demands of ever-growing population of India. It is mandatory to identify the challenges in current practices and their possible alternate solution with the support of advanced technologies. Currently, there are many unsustainable farming practices related to irrigation, chemical spraying, crop monitoring, pest management, etc. FAO recommended that the potential of different emergent technologies needs to leverage for solving the current challenges being faced by the agriculture sector (Sylvester, 2021) [5]. 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 (Thota, 2021) [6]. 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) are the multipurpose flying robots that can be operated by an operator from the ground or can work autonomously based on a predetermined algorithm in linkage with global positioning system (GPS). Drone technology has many applications *viz*. military, disaster management and relief, remote surveillance, construction, mineral exploration and in various agricultural activities.

Agriculture drone market

The global agricultural drone market size was demonstrated at USD 1.7 billion in 2022 and is estimated to hit about USD 7.9 billion by 2030, growing at a CAGR of 21.2% during the forecast period 2022 to 2030. An agricultural drone used in agriculture can aid with crop monitoring, crop production and other aspects of optimizing agricultural operations. Drones are being used in precision agriculture for a variety of tasks, including the application of pesticides, planting and the examination of agricultural fields and soil.



***Source*:** Precedence Research

Fig 1: Global market size of drones

Key Market Drivers: The use of small drones in agriculture is at faster rate. Numerous technological advancements have positively impacted farming production during the past few years in the agriculture. UAVs are one of these key innovations, and they are presently widely used in agricultural operations with the assistance of cutting-edge technology and software. Small, autonomous and unmanned rotor-craft are successfully developed. This is one of the key elements that experts' thoughts will fuel market expansion.

Key Market Challenges: The creation of drone usage restrictions in response to data privacy issues. Due to farmers' lack of expertise, drone manufacturers find it challenging to contact their potential clients. Moreover, because people lack the skills to use the tools (software programs) that assess and improve efficiency, they find it undesirable to purchase agriculture drones, which hinder the market's growth. Another reason is that, the impeding market expansion is cyber security worries; if these are resolved, the industry may increase in the near future.

Key Market Opportunities: The growing use of sustainable farming methods to promote the use of agriculture drones. Information and communication technologies (ICTs) are being used by agriculture more and more to address environmental problems. In order to feed the world's expanding population, farming communities must be able to adapt and become resilient in the face of significant challenges brought on by climate change. Utilizing the development and transformational power of ICTs offers a great platform for not only solving some of these problems but also accelerating the achievement of the 2030 Sustainable Development Goals (SDGs). When cutting-edge technology is used, traditional agricultural techniques will see changes in production and efficiency. Farmers that adopt sustainable agricultural practices may be able to expedite their production operations utilizing enhanced data analytics. The market for agricultural drones will also benefit from increased investment in auxiliary equipment and agricultural drones.

Future drone technology

Drone technology is constantly developing, so future drone tech is currently undergoing ground-breaking progressive improvement. According to air-drone-craze, an Amazon Services LLC affiliate advertising program website, drone technology has seven potential generations, and the majority of current technology sits in the fifth and sixth generations. The drone technology generations can be break down as below (Business insider report, 2022) [19]:

Generation 1: Basic remote-control aircraft of all forms.

Generation 2: Static design, fixed camera mount, video recording and still photos, manual piloting control.

Generation 3: Static design, two-axis gimbals, HD video, basic safety models, assisted piloting.

Generation 4: Transformative designs, Three-axis gimbals, 1080P HD video or higher-value instrumentation, improved safety modes, autopilot modes.

Generation 5: Transformative designs, 360° gimbals, 4K video or higher-value instrumentation, intelligent piloting modes.

Generation 6: Commercial suitability, safety and regulatory standards-based design, platform and payload adaptability, automated safety modes, intelligent piloting models and full autonomy, airspace awareness.

Generation 7: Complete commercial suitability, fully compliant safety and regulatory standards-based design, platform and payload inter-changeability, automated safety modes, enhanced intelligent piloting models and full autonomy, full airspace awareness, auto action (take-off, land, and mission execution).

Over the past few years, drones have become more relevant to people's lives. The technology has matured and during the pandemic, there was a urgency about finding new ways of accessing goods and services. In Ghana, drones delivered about 13% of the country's initial shipment of COVID-19 vaccine in just 3 days. In the United States, the Alphabet-owned drone delivery company Wing saw demand for its services double as people looked for contactless ways to get access to consumer goods. In response, many regulators across the globe have demonstrated interest in helping this industry to expand its operations. They are granting more approvals under current frameworks, and also adopting more comprehensive frameworks to enable larger scale drone operations. During the COVID-19 pandemic, the significance of application of drone technology was increased due to the acute scarcity of labour in agriculture. The social distancing measures also favoured the use of drones for agricultural-related activities as the continuation of farming was essential for safeguarding the food security of citizens. The several studies emphasized the prospects for use of drones in agriculture during the lockdown and the situation of labour deficit (Singh, 2019). In the post-COVID-19 period, the adoption of digital technologies was 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) (Sylvester, 2021) [5]. 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 (Thota, 2021) [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 (Mrunalini & Deb, 2021) [8]. The researchers conducted a field exhibition to explore the application of drone technology in agriculture. Figures 2 is the picture captured from the field of UHS Bagalkot Totagarika Mela.

Fig 2: Field exhibition of drone in Horticultural Mela

Fig 3: Chemicals spraying and Arial photography in exhibition

Hitherto, drones were only capable of transporting light packages. But a new technology are emerging which can carry 70 kg to 500kg of payloads, depending on the aircraft. This means that new delivery models can be more efficient and cost-effective than existing helicopter, truck, or ferry-based infrastructure, especially for goods that are of high social or economic value in areas that are not well served by current infrastructure. Remote, rural and off-shore communities can receive essential goods via autonomous aerial systems, if the right regulations can be put in place. Heavy-lift drone delivery has recently reached a level of technical maturity and the systems are ready for certification by civil aviation authorities.

One can gain in-depth knowledge about agriculture drones only after complete recognition of drones characteristics and specifications. Usually, drones include a navigation system, GPS, multiple sensors, high-quality cameras, programmable controllers, and tools for autonomous drones. The DJI is one such familiar drone utilized by the industry. Most farmers currently use satellite imagery as an introductory guide for farm management. Furnished with modern technology, Un-manned aerial vehicles (UAVs) can get more precise data than satellites for precision agriculture. They then process the data captured into agri-tech software to produce beneficial knowledge. Capturing data from agriculture drone takes place as in the following stages:

Analysing the area: This identifies the territory being tested. Therefore, the first step includes establishing a boundary, analyses of the area, and then finally, uploading the technical GPS information into the drone's navigation system.

Using Autonomous Drones: Since Un-manned aerial vehicles (UAVs) are independent, they enter flight patterns into their already established system to collect required data.

Uploading the data: After capturing all the required data through sensors such as the multispectral sensor/RGB sensor, it is processed through numerous software's for further analysis and interpretation.

Output: After collecting the data, they format it so that farmers can understand the data with no hassle, bringing them a step closer to precision farming. 3D mapping or Photogrammetry are popular methods to display extensive data collected.

Application of drone technology in agriculture

Nowadays, researchers across the world are discovering different applications of drone and UAVs ranging from tracking & scouting drones in dense forests, for searching and rescuing in disasters and natural calamities and delivering drug to remote areas during health emergency (World Economic Forum, 2022) [9]. 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 (Drone Report, 2021) [10]. In agriculture, drones are being used for different activities as discussed below.

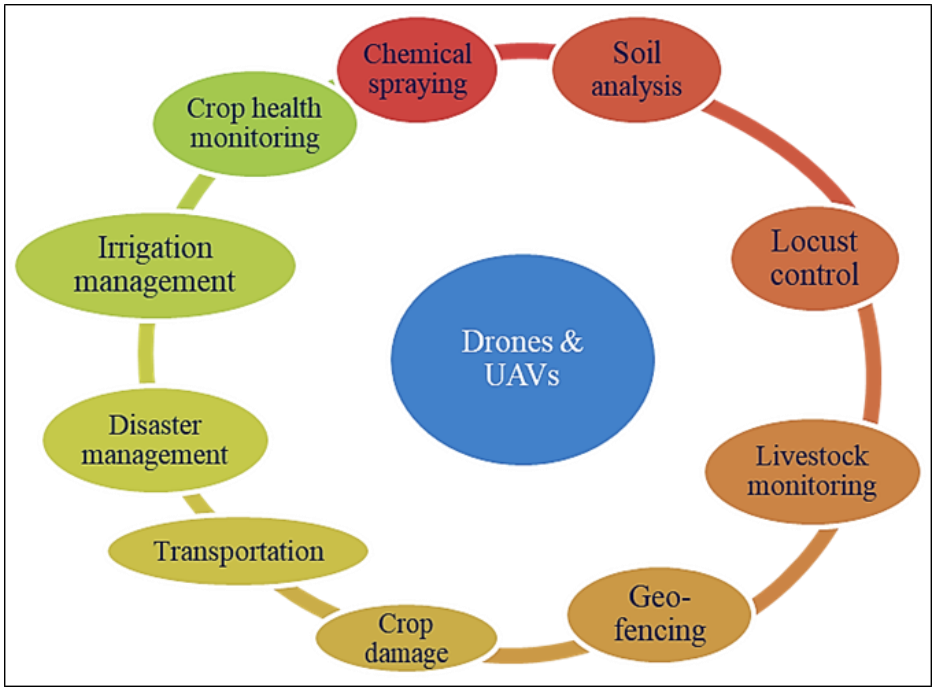


Fig 4: Application of drone technology in agriculture

Soil Analysis

Soil environment plays a key role in achieving higher crop yields. To enhance the production and productivity, it is essential to give attention towards the soil conditions, soil textural class, and status of micro and macro-nutrients before choosing a crop are grown (Banerjee, 2021) [11]. The soil analysis before the cultivation of crops and during growth is essential for decision-making which helps in selection of different inputs and their quantity (Mrunalini & Deb, 2021) [8]. Drones can be employed to analyse soil for irrigation, crop planning and nitrogen levels (World Economic Forum, 2022) [9]. The case studies of FAO related to use of drone in agriculture also emphasized its potential for soil analysis. Drone can gather data and supports in taking precise decision about the cultivation of crop suitable to soil condition and extent of nutrition and water required from time to time. The multispectral sensors allow seizing data useful for seed planting patterns, thorough field soil analysis, irrigation and nitrogen-level management. Precise Photogrammetry/3D mapping permit farmers to analyse their soil conditions thoroughly.

Growth and Establishment of crops:

In most of the time during sowing period, there is a scarcity of agricultural labour. The drones can address this issue by sowing seeds over the large field in a quick time with high accuracy (Mrunalini & Deb, 2021) [8]. Sowing of seeds with drones involve the scattering of seeds and spraying of nutrients on the agricultural field with a specific pattern. It is witnessed that the use of drones increases the consistency and efficiency of crop management along with cost reduction (Banerjee, 2021) [11]. Some visionaries have designed extra attachments for drone systems which can shoot pods holding seed and plant nutrients into seedbeds, which reduces costs of sowing and planting (Pathak *et al*., 2020) [12]. Such a method of crop sowing has reduced the cost of plantation by nearly 85% in addition to the elimination of labour work (Mrunalini & Deb, 2021; Banerjee, 2021) [8, 11]. Precision Crop Spraying Pests, weeds and plant diseases leads to crop loss approximately 15-25% of the entire food produced in India (The Hindu, 2016) [13].

Crop Monitoring and Surveillance

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. It is crucial to track the health of the vegetation and spot bacterial/fungal plagues in the early stages. Frequent crop monitoring is required for the assessment of crop damage and pest attack to take measures accordingly. Agriculture drones can see which plants reflect different amounts of green light and Near-infrared spectroscopy (NIRS) light. This data helps produce multispectral images to track crop health. Quick monitoring and discoveries of any defects can help save crops. In circumstances of crop failure, the farmer can also document the damages for accurate insurance claims. Such crop monitoring allows farmers to take defensive arrangements in a quick time. Accurate and frequent crop monitoring can deliver the actual condition of the crop, which helps in the detection of any problems at an early stage (Mrunalini & Deb, 2021) [8]. Crop monitoring over a multi-spectral camera mounted on a drone is more effective which 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 essential chemicals with the help of GPS coordinates (Mogili & Deepak, 2018) [14].

Crop damage assessment

Agricultural drones built-in along with multispectral sensors and RGB sensors also detect field areas caused by weeds, infections and pests. As per this data, the careful amounts of chemicals required to fight these infestations are known and this helps reduce the costs inflicted by the farmer.

Irrigation management

In the drought-prone regions, facilitating the adequate water to crops is a challenging task. Currently, existing irrigation techniques deliver the water to a field uniformly. However, it is necessary to supply the water where it actually required for rational and optimum use of available water resources (Debanjan, 2021) [15]. Water is the critical input for crop growth, inadequate or excess amount of water creates problems in proper growth of the plant. Farmers sometimes go wrong in irrigation planning. 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 moisture stress in soil and waterlogged areas in the agriculture field (Mrunalini & Deb, 2021; Debanjan, 2021) [8, 15]. The field survey conducted using drone helps in attaining the water use efficiency and documentation of irrigation leakages over frequent irrigation monitoring (Banerjee, 2021) [11].

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 (Banerjee, 2021) [11]. 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 (Mrunalini & Deb, 2021) [8].

Livestock monitoring

Farmers engage themselves in activities other than farming such as animal husbandry to generate added income. Managing livestock is somewhat difficult as animals used to move from one place to another and also need additional labour which escalates the expenses. Its time consuming one as one has to keep an eye on sheep and cattle during grazing in large area. There are a number of technologies for livestock monitoring such as wearable Radio Frequency Identification (RFID) tags or remote devices to capture physiological or behavioural parameters and sound alerts when the information is out of the ordinary. Continuous monitoring is made possible automatically, which may also provide more information than manual monitoring (Herlin *et al*., 2021) [16]. The drone can effortlessly 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 (Banerjee, 2021) [11]. The drones with thermal sensor technology can find out lost animals and also helps in the detection of injury and sickness in animals (Banerjee, 2021) [11]. With the existence of high-quality cameras and sensors, drone can sense predators before an attack and animals with any disease can be identified and treated in a short time (Shukla, 2021) [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 (Herlin *et al*., 2021) [16]. The drone survey allows the farmers not to keep track of their crops only but also monitor the movements of their cattle. Thermal sensor technology helps find lost animals and detect an injury or sickness. Drones can carry out this function favourably and this adds comprehensively to the production of vegetation.

Disaster management

Favourable weather conditions may support the crop growth, however, adverse weather conditions may prove devastating for cultivated crops. The weather cannot be precisely forecasted and it is very hard to handle the spontaneous 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 (Beriya, 2022) [18]. This drone-enabled data is helpful for increasing agricultural productivity and supply chain management through precise prediction and required interventions (Banerjee, 2021) [11].

Agricultural spraying

Through drone crop spraying, human contact with such harmful chemicals is limited. Agri-drones can carry out this task much quicker than vehicles/airplanes. Drones with RGB sensors and multispectral sensors can precisely identify and treat problematic areas. Professionals say that aerial spraying is five times faster with drones when compared to other methods.

Prospects of drone sector in India

Certainly, drones have evolved from defence-only equipment to multi-purpose equipment, which can be used for several sectors like governance, farming, logistics and so on. The finance minister of India proposed extensive use of drones in agriculture, including spraying insecticides and nutrients (Prabhat Sinha, 2022) [20]. The proposed drones-as-a-service (DRaaS) model said to be associated with capabilities to revamp and boost India's fragmented drone industry for new business and employment avenues. Under the '*Drone Shakti'* scheme, Start-ups will be encouraged to facilitate Drone Shakti with its application in multiple sectors. In selected IITs, the required courses for skill development will be started in all states in coming days. Incorporating the drone in the IITs syllabus will enable a robust foundation for a drone-based ecosystem. Though drones have existed for the last two decades, the last few years have been very significant in the evolution of Unmanned Aerial Vehicles. Drones are built using IOT technology, which includes a controller from which launch, navigation, and landing activities are controlled either with the help of remote controls, mobile apps, or automated. The controllers communicate with the service of radioactive waves such as WiFi. Like any other active device, drones also need a power source like a battery or fuel. Drones are also equipped with propellers, rotors, and a frame. The drones are made up of composite and lightweight materials so that their weight is considerably low with better transportability. The drones not only help military, but they are also helping businesses with complex activities normally undoable by humans in a timely and effective way. The adoption of drone by businesses is quick as companies across the globe have identified the infinitive potential of drones. It boosts speed, productivity, and efficiency and improves accuracy. Drones are majorly used for express shipping and delivery, unmanned cargo transport, aerial photography for journalism and film, gathering information for effective disaster management, thermal sensor drones for search and rescue operations, geographic mapping of inaccessible terrain and locations, building safety inspections, crops monitoring and assessments, Border control surveillance and; aw enforcement, Weather forecast for storm tracking, hurricanes, and tornadoes. Drones can reach remote areas with little or no human interference and within the least required effort, time, and energy. Consequently, drones are getting adopted worldwide, specifically by military, commercial, personal, and future technology. Recently, the Ministry of Civil Aviation approved a project of the Telangana state government to use drone technology to deliver vaccines in remote areas. A lot depends upon drone technology for the growth of the agriculture sector. Drones will spray pesticides and micronutrients evenly in farms and be used extensively to monitor crops and identify the challenges faced by farmers. *SVAMITVA* scheme launched by the government has helped millions of village residents with property cards. Drones can be effectively used for emergency services like fire protection, healthcare, and flood relief where human intervention risks life. Police departments of several states use drones for law enforcement activities like-search and rescue, crime scene analysis, surveillance, crowd monitoring, etc. Recently, Bihar police have started using drones to trace liquor manufacturers and distributors located in remote and densely populated areas to enforce the liquor ban. Lockdown was imposed during COVID 19 grew the growth of drone technology as companies, and government organizations started using it exponentially. Major companies like Amazon Prime Air, Zomato, FedEx, Boeing, DHL International GmBH, Drone Delivery Canada Corp, Airbus have already started their drone delivery services. The drone sector has become a lucrative career option for youths with rapid growth opportunities. It has the potential to grow and penetrate several other industries with ample employment opportunities. The growing use of drones in multiple sectors has several associated risks like drone attacks, delivery of weapons, increased terrorism, to name a few. Drones are comparatively cheaper than conventional weapons but still can be destructive with a far better reach.

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

Weather irregularities/dependency: In normal weather condition, drones are used to perform well and more efficiently than human labour. 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 requirement: Leveraging new technology is encouraging, but using a drone on a regular basis demands necessary skill set and expertise.

Regulatory un-certainty: 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 (Thota, 2021) [6].

High capital cost of drones: Training and deployment in agriculture are more expensive (Drone Report, 2021) [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 (NC, 2018) [21].

Limited Flight Time and Battery 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.

Shortage of pilots: 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 (Shukla, 2021; Singh, 2019) [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 (Singh, 2019) [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 start-up finance and insurance along with the lack of adequate investment on drone research and development (Zadka, 2021) [22].

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 (Drone Report, 2021) [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 necessitates a revolutionary change to meet the demands for food production to meet the requirement of ever-growing population. The cost of agricultural operations are reaching at its highest level and scarcity of labours is escalating which forces the Indian farmers to think ahead and adopt the new technologies coming their ways to get maximum benefits from agriculture activities. Drones technology is quickly evolving one, because of its varied applications. Drones not only improve the overall performance in agriculture, but also inspire farmers to adopt precision agricultural practices. It will help in decreasing the human error and in-efficiencies in conventional agricultural practices by providing precise and reliable information about different aspects of agricultural activities. 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 could help reducing the human errors at large extent. The drone can help farmers in two ways, first by assisting the farmers in decision making process and second is to substitute the human labour by performing different jobs on field with more precision and in short time. There are numerous challenges which delay the acceptance of drone technology in agriculture. There is necessity to address these challenges for effective adoption and leveraging the potential of drones for renovating the agriculture sector and lives of millions farmers in India.

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References

1. Shukla P. How farmers can benefit using drones; c2021. https://agritimes.co.in/livestock/how-farmers-can-benefit-using-drones.
2. Sharma YS. Share of agriculture sector in employment sees steady increase-CMIE; c2021. https://economictimes.indiatimes.com/news/economy/indicators/share-of-agriculture-sector-in-employment-sees-steady-increase-cmie/articleshow/85266073.cms
3. Ministry of Agriculture & Farmers Welfare. Contribution of Agriculture Sector towards GDP Agriculture has been the bright spot in the Economy despite COVID-19; c2021. https://www.pib.gov.in/PressReleasePage.aspx?PRID=1741942
4. Borkar S. How Agritech is Changing the Face of Sustainable and Industrial Agriculture in India; c2021. https://inc42.com/resources/how-agritech-is-changing-the-face-of-sustainable-and-industrial-agriculture/
5. Sylvester GE. Agriculture in action: Drones for agriculture. Bangkok: FAO; c2021.
6. Thota P. Precision farming and drones can help India make the big leap; c2021. https://www.thehindubusinessline.com/opinion/farmingthe-potential-of-rones/article34573234.ece.

7. Singh A. Agricultural drones: The shape of Indian agriculture to come; c2019. https://smefutures.com/agricultural-drones-shape-indian-agriculturecome/
8. Mrunalini K, Deb CK. Drones in Agriculture: Digital technologies in agriculture. Biotech Books, New Delhi; c2021. p. 171-182.
9. World Economic Forum. How drones delivering vaccines are saving lives in India; c2022. https://www.weforum.org/impact/dronesdelivering-vaccines/
10. Drone Report. Harnessing drones and other disruptive technologi es in agriculture. Government of Maharashtra; c2021.
11. Banerjee A. Drone Technology in Agriculture: A Viable Solution to Address Food Security Issue; c2021. https://krishijagran.com/agriculture-world/drone-technology-in-agriculture-a-viablesolution-to-address-food-security-issue.
12. Pathak H, Kumar G, Mohapatra SD, Gaikwad BB, Rane J. Use of drones References in agriculture: potentials, problems and policy needs. Baramati, Maharashtra, India: ICAR-National Institute of Abiotic Stress Management; c2020.
13. The Hindu. Pests destroying almost one-fourth of crops; c2016. https://www.thehindu.com/news/national/Pestsdestroying-almost-one-fourth-of-crops/article14497608.ece
14. Mogili UR, Deepak BB. Review on Application of Drone Systems in Precision Agriculture. Procedia Computer Science; c2018. p. 502-509.
15. Debanjan B. Rise of Precision Farming Driving Agriculture Drone Market Growth; c2021. Tech-bullion.com: https:// techbullion.com/rise-of-precision-farmingdriving-agriculture-drone-market-growth/.
16. Herlin A, Brunberg E, Hultgren J, Högberg N, Rydberg A, Skarin A. Animal Welfare Implications of Digital Tools for Monitoring and Management of Cattle and Sheep on Pasture. Animals, 2021, 11(3). Doi: doi.org/10.3390/ani11030829
17. Tropogo. Application of Drones in Agriculture in India; c2022. https://tropogo.com/blogs/application-ofdrones-in-agriculture-in-india.
18. Beriya A. Application of drones in Indian agriculture, ICT India Working Paper. New York: Center for Sustainable Development (CSD), Earth Institute, Columbia University; c2022. p. 73.
19. Business Insider Report. Market Forecasts, key players and use cases, and regulatory barriers to the proliferation of drone. Business Insider: India; c2022. https://www.businessinsider.in/tech/news/in-a-rare-move-apple-amazon-and-google-just-announced-a-major-partnership/articleshow/72873563.cms
20. Prabhat Sinha. Prospects of Drone Sector in India. Analytics Insights, Market Trends; c2022. https://www.analyticsinsight.net/prospects-of-drone-sector-in-india/
21. National Conference. Emerging Technologies: Digital Agriculture & Drones, The PoCRA quandary. Technology for Accelerating Development Department of Administrative Reforms and Public Grievances; c2018. Hyderabad: https://www.nceg.gov.in/sites/default/
22. Zadka J. India, Israel need to collaborate in drone technologies; c2021. https://www.thehansindia. com/hans/opinion/news-analysis/indiaisrael-need-to-collaborate-in-dronetechnologies-705843.