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Application of drones in Indian agriculture

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Application of Drones in Indian Agriculture

ICT India Project Working Paper #73

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Abstract

Different prospects are offered by drones (small unmanned aerial vehicles) for the agricultural sector; typical drone applications being pesticide spraying, soil sampling and fertilizing, farm animal surveillance, real-time aerial imagery and sensor data collection etc. The Indian federal government is actively promoting drones for agriculture spraying. These 'Kisan drones' are primarily intended to cut down time, increase efficiency and efficacy of resource utilization in agriculture sprays (pesticides etc.) and mitigate adverse effects of manual pesticide spraying on human health. Going ahead, drones are also expected to help in transportation, surveying, and aerial imagery aspects in agriculture. This review finds that the government is actively pursuing a liberalised policy to promote drones and also offering substantial financial incentives to institutions, individual farmers as well as entrepreneurs to procure and use or manufacture drones as the case may be. Drones save time and are reported to be efficient in resource utilization with substantial water savings. Unit economics of drone spray cost per acre vis-à-vis manual labour cost is also catching up. Drone flying for agricultural operations can also be a good opportunity for rural youth. If drones are able to achieve confidence of farmers for spray related operations, there is a good chance their use can also be expanded to other advanced use cases, benefitting Indian agriculture.

1.0 Introduction:

In recent times, multiple pronouncements by the government of India have stated the focus of the government on promoting drones in the Agricultural sector. As per the Indian federal budget of 2022-23, the government is keen to use 'Kisan' (Hindi for farmer) Drones to boost the agricultural sector in the country. Kisan Drones will be promoted for crop assessment, digitization of land records and spraying of insecticides and nutrients. Kisan Drones can usher in a revolution as high capacity drones can be used to carry vegetables, fruits, fishes to the market directly from the farms. "These items will be supplied directly to the market with minimal damage, consuming lesser time, resulting in more profits to farmers and fishermen," ('What is kisan drone? Five things you should know', Livemint, Feb 19, 2022)

'The prospects offered by drones for the agricultural sector are constantly expanding. Some typical drone applications are soil sampling and fertilizing, pesticide spraying, animal population surveillance, real-time imagery and sensor data collection, and field management.' (Costopoulou C. et al., 2022). Moreover, market researchers forecast that the drone services market is estimated to grow approx. 3-fold in 5 years from 2021-2026 from USD 5.48 Billion to USD 15 Billion by 2026 (Research and Markets, April 2022). The application of drones in agriculture offers a lot of potential and hence it is important to study drones from an Indian agricultural perspective.

The Centre for Sustainable Development (CSD) at Columbia University, New York along with The Energy and Resources Institute (TERI) has been undertaking a multi-sector project titled: "A New Indian Model of ICT-led Growth and Development." The project's objective is to better understand the role of ICTs in the key sectors: agriculture, health, education and infrastructure among others. The project is hence interested in documenting latest developments in cutting edge technologies in the field of agriculture. This paper is part of such efforts. In this paper, first, we review relevant recent literature around unmanned aerial vehicles (UAVs) popularly called drones, in agriculture and list the potential use cases of application of drones in agriculture. After this, recent policy initiatives of the government of India to promote and popularise drone use have been listed. Next, practical aspects of drone use in the Indian agricultural context have been detailed. Some challenges and the way forward for usability of drones in Indian agriculture conclude the paper.

Crop in a farm being sprayed using Agricultural drone (image for illustration purpose only)

Image source: Blog by Princy A.J., Research Dive, Pune, India (September 2021)

2.0 Literature around UAVs/ drones in Agriculture:

Maddikunta Reddy P.K. et al (2021) have studied applications, requirements and challenges of UAVs (drones) in smart agriculture. Their study lists that primarily fixed wing and multi rotor UAVs are used for agricultural purposes among the different categories of UAVs like fixed wing, multi rotor, single rotor and hybrid vertical take-off and landing UAVs. Multi rotor UAVs are easy to manufacture and are the cheapest of all kinds of UAVs and fixed wing are ideal for long distance operations and more flying time. They have also explored various types of agricultural sensors such as optical sensors, temperature-based sensors, location-based sensors etc., and identified potential applications of UAVs in smart agriculture. They are listed below:

- UAVs as sky farmers enabling a birds eye view of the entire cultivation field or a livestock herd
- UAV use in precision agriculture providing superior quality images with the help of the hyperspectral and multispectral cameras to derive vegetation indices like NDVI
- UAV in Irrigation Monitoring
- UAV in Aerial Mustering
- UAV in Artificial Pollination

The study finds key enabling requirements of UAVs in smart agriculture including network availability, data storage, acceptance of technology by farmers, accuracy of results and regulation of UAVs etc.

Rahman M.F.F et al (2021) have done a comparative study on application of UAV Systems in Agriculture. They state that due to their low cost and small size, UAVs have the ability to help agriculture in developing countries with economic prosperity particularly by reducing health related risks associated with manual pesticide spraying and the number of workers. Farmers can use UAVs for agricultural spraying, pest control, aerial mapping, irrigation and livestock farming. Their review also finds that fixed-wing UAVs are already being implemented for field mapping and livestock activities; and multi rotor UAVs, particularly quadcopter is the most fitting type for agricultural purposes because of their excellent aeronautics. UAVs are thus lessening the incredible amount of wastage of fertilizer and pesticides and help in keeping the labourers aside from chemical side-effects and make their job comfortable and fast. However, UAVs for agriculture also have a few limitations. Accurate data interpretation, privacy risk, complex spraying environment and long-distanced positioning are some prime examples of their disadvantages.

Rana V. and Mahima (2020) in their review of Impact of Drone Technology in Agriculture discuss various applications of different technologies in Agriculture like Unmanned Aerial Vehicles (drones), Artificial Intelligence etc. They list different applications of drones:

- Soil and pasture examination
- Planting (Drones can fire nutrient pods containing a seed into the soil, at just the right depth and help with reduced cost and effort in planting trees on scale)
- Monitoring Crops
- Health Evaluation of Plants

Mogili U.M.R. and Deepak B.B.V.L. (2018) have reviewed Application of Drone Systems in Precision Agriculture. They state that drones are used to spray the pesticides to avoid the health problems of humans when they (humans) spray manually. Also drones can operate in areas where it may be difficult for human beings to operate. They describe crop monitoring through a multispectral camera mounted on a drone. This camera captures pictures in one flight and based on the analysis of these pictures, is is easy to find the area where to spray the pesticides. The drone sprinkling system then auto navigates with the GPS coordinates to spray the pesticides on the infected areas where no vegetation has been indicated by the NDVI. They conclude that these are early developments of drones in precision agriculture and there is scope for further development in both the technology as well as the agriculture applications.

PIX4D, in their report, Drones in agriculture: Seeing beyond the surface with smart farming (2021) list different use cases of drones in Agriculture. As per them, Drones (at work) can be used in the following different stages of the crop cycle:

1. Planning stage and emergence: Drones can be used for soil surveying and help reveal soil properties to plan for crop treatment and optimized farming. Analysis of changes in soil pH, texture and salinity etc. can help farmers in making better seeding decisions etc.
2. Nutrient inputs, zonation, and precision spraying: An example of the use of drones is specialized and precise spray treatment by applying exactly where it is needed and with minimal manual involvement.
3. Yield estimations: Drones can employ variety of cameras to capture different types of specialized images to generate vegetation indices which can be analysed to predict yields.
4. Crop monitoring and harvest; drones can be helpful in generating data that can help in optimized scheduling of crop harvest operations.
5. Crop protection and insurance: All above uses of drones can also help various stakeholders related to crop protection and insurance gather relevant and more accurate data faster, thus helping in faster processing of insurance claims etc.

FAO and ITU, in their report (2018), 'Drones for Agriculture' have documented 10 case studies from different countries on using drones in Agriculture. According to this report, drones have a huge potential in agriculture in supporting evidence-based planning and in spatial data collection. Drones are increasingly being used in agriculture in crop spraying, crop production, early warning systems, disaster risk reduction, forestry, fisheries, as well as in wildlife conservation. Drones' imagery, connectivity and transport capabilities can be effectively leveraged in livestock management, surveying, land use planning, humanitarian and emergency relief, stockpile estimation, crop damage assessment, scientific research, inspection of fixed and mobile assets, real estate and tourism marketing, media production, small cargo delivery etc.

'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', notes the report.

These mapping and imaging capabilities of drone platforms with a range of sensors can be used in the whole crop production process in order to better plan production and improve productivity. In fact, to fully leverage drones as a spraying platform, the spraying needs to be paired and synchronized with the imaging, processing and automated analytics capabilities to achieve precision. This would lead to the improvement of dosage in the affected areas, and also achieve rationalization in the overall use of chemicals.

The report also identifies that issues related to privacy, safety and security are the key to the sustainable implementation of drone technologies. Some challenges that have been listed in the report are around Quality software, Acceptability on the farmer front, Legal Aspects, Flight time and flight range, Initial cost of purchase, Interference with the airspace, Connectivity and Weather dependency.

3.0 Recent Government initiatives that support/facilitate drone use in Agriculture:

The government of India, to make drones affordable to the farmers and different stakeholders and promote drone use, has announced a number of subsidies on the purchase of drones. For promoting the use of Kisan Drones, the Indian Agriculture Ministry is providing 50% or maximum INR 0.5 million subsidy to SC-ST, small and marginal, women and farmers of north-eastern states to buy drones. For other farmers, financial assistance will be given upto 40 percent or maximum INR 0.4 million.

100 % of the cost of drone is extended to the Farm Machinery Training & Testing Institutes, Institutions of Indian Council of Agricultural Research, Krishi Vigyan Kendra (KVK) and State Agricultural Universities (SAUs) for drones for demonstration in the farmer fields. Farmers Producers Organizations (FPOs) are provided grants @ 75% for purchase of drones for its demonstration on the farmers' fields. Financial assistance of 40% of total cost of drone upto Rs. 0.4 million is provided for drone purchase by existing and new Custom Hiring Centres (CHCs) under Cooperative Society of Farmers, Farmers Producer Organizations (FPOs) and Rural entrepreneurs. Moreover, agriculture graduates establishing CHCs are eligible to receive financial assistance @ 50% of the cost of drone up to a maximum Rs.0.5 million. Thus, with these subsidies in place drones are free for agri-training and research institutes. Also, implementing agencies are eligible for subsidies per hectare if they hire drones for demonstrations rather than buying them. (PIB, Govt of India)

Elaborating on the various government policies related to drones and potential benefits for Indian farmers, the Civil Aviation ministry listed the following steps that have been taken by the government towards facilitating and easing the policy around drones. (Press Brief, Ministry of Civil Aviation, May 17, 2022 Press Information Bureau, Govt. of India (PRID=1826135))

1. Liberal Drone Rules, 2021 were issued by the Ministry in August, 2021.
2. Drone Airspace Map, opening up nearly 90% of Indian airspace as a green zone for drone flying up to 400 feet, has been published in September 2021.
3. Production-Linked Incentive (PLI) scheme for drones is in force from 30th September 2021.
4. UAS Traffic Management (UTM) Policy Framework was published in October 2021.
5. The federal Agriculture Ministry announced monetary grant program for purchase of agricultural drones in January 2022.
6. Beginning 26th January 2022, all 5 application forms under the Drone Rules, 2021 have been made online on the DigitalSky platform
7. Drone certification scheme was notified in January 2022, making it easier to obtain type certificate by drone manufacturers.
8. Mission 'Drone Shakti' has been announced for supporting drone startups and promoting Drone-as-a-Service (DrAAS) as part of the Union Budget on 1st February 2022.
9. Import of foreign drones has been banned and import of drone components has been freed up via the drone import policy that was notified in February 2022.
10. The drone rules were further amended in February, 2022 to remove the requirement of a drone pilot licence. The remote pilot certificate issued by a DGCA-authorised drone school is now adequate for operating drones.

In fact, as an outreach activity to showcase and promote drones, Bharat Drone Mahotsav (Festival) 2022, India's biggest drone festival was held on May 27 and 28, 2022 in New Delhi. It was inaugurated by the Prime Minister of India Shri Narendra Modi. The Prime Minister interacted with kisan drone pilots, witnessed open-air drone demonstrations and also interacted with startups in the drone exhibition centre. More than 70 exhibitors displayed various use cases of drones at the exhibition. Different product launches, virtual award of drone pilot certificates, panel discussions on drones, drone flying demonstrations and display of a Made in India drone taxi prototype were other highlights of the event. The presence of the Prime Minister in different events related to drones in a short span of 6-7 months makes amply clear the priorities that the government attaches to the development of the drone sector in India, particularly Kisan drones. ('India can become global drone hub: PM Modi at country's biggest drone festival', Hindustan Times, May 27, 2022)

4.0 Drone Operations in Indian Agriculture:

In India, presently, drones are being advocated primarily as an automated spray device that can be tasked with pesticide etc. spraying over crops to reduce health hazards associated with manual spraying and save time, resources and human labour.

The Indian Agriculture Ministry estimates that the service of a drone that has the capacity to carry a 10 kg payload will cost Rs 350-450 per acre. The calculation is based on the assumption that a drone equipped with multiple batteries will be utilised for at least six hours a day, covering about 30 acres of farmland.

Detailed spray operations and metrics around drones are given below. These have been taken from an information sharing webinar conducted by the organisation Iffco Kisan in which an expert, Dr Shankar Goenka shared the details of drone operations from their experiences in rolling out drones sales as well as spray services (on rent/acre spray basis).

According to Dr. Goenka, uniform intensity/spread of spray is achieved through drones even for plants with higher heights like sugarcane, mango orchards etc. Reduction in input costs of spray items (pesticides/weedicides) is estimated at around 25-30% due to automated processes. Citing an illustration of nano urea here, considering a cost of Rs.240/bottle for spray on an acre, if savings are 25%, then input cost is reduced to that extent for the farmer. Consequently around 80-90% reduction in water is also achieved because of tiny droplet sizes of approx. 50 microns as against manual spray droplet size of approx. 500 microns. Drone sprays save time as 1 spray takes around 5-7 minutes/ acre whereas manually typically a person can cover only 3-4 acres in a day.

Among other features of drones, a 10 Litre capacity drone has a tank capacity of 11 litres. Thus it can load 10 litres of water and 1 litre of spray item (weedicide/pesticide/germicide/fungicide) etc. Standalone drone weight is 12-13 kgs and fully loaded 10 litre capacity drone can thus fly with a weight of upto 25-27 kgs. The drone has a flying range of 5 kms but it is freezed at 500m and it can fly to a height of 120 feet but it has been freezed by manufacturers to 30 feet height to take care of security concerns. Going ahead, innovators are trying to equip drones to be also able to spray pellets, powdery matter and even seeds also.

The camera in the drone allows it to capture images and the obstacle radar in the drone allows it to manoeuvre any obstacles like wires, poles etc. that may appear in the drone flight path. Automatic height adjustment through terrain radar allows the drone to adjust its spraying height as per the height of the plant and terrain etc. Flow meter in the drone ensures an automatic return to the launch point in case battery/spray liquid/water is exhausted. Night vision light is also available to allow spray at night. Krishi Viman drone Made in India

From the point of view of farmer safety and health concerns owing to spraying and other activities in the field, drones provide a good solution. Around 58000 farmer deaths are reported due to snakebite in India. Around 0.3 million farmers suffer from respiratory diseases due to spraying pesticides etc. Drones offer a potential to mitigate these sufferings of farmers significantly because farmer doesn't have to venture extensively inside crops for spray purposes.

Coming to the economics of drones, as captured from the webinar, a typical drone costs around 0.7-0.9 million INR. If renting a drone for spray, the present renting cost is around INR 600- 700/acre.

(Source of information in section 4: Above information has been transcribed from a webinar conducted by IFFCO Kisan with their partner organisation which was addressed by Dr. Shankar Goenka, Managing Director of the partner entity of IFFCO. The recording of the webinar is available at https://m.facebook.com/iffcokisan/videos/533186745002351/?_rdr)

5.0 Startups in the Indian drone sector:

Some startups (along with their websites) active in the Indian drone sector are listed* below:

- Asteria Aerospace Limited: https://asteria.co.in/
- AUS-Aarav Unmanned Systems: http://www.aus.co.in/
- Garuda Aerospace Pvt Ltd: https://www.garudaaerospace.com/

- General Aeronautics Pvt Ltd: https://www.generalaeronautics.com/
- ideaForge: https://www.ideaforge.co.in/
- Indrones: https://www.indrones.com/
- IoTechWorld Avigation: https://www.iotechworld.com/
- NeoSky India: https://rttn.in/neo-sky/
- SankhyaSutra Labs: https://sankhyasutralabs.com/
- Skylark Drones: https://skylarkdrones.com/
- Throttle Aerospace Systems Pvt Ltd: https://www.throttleaerospace.com/
- WOW Go Green: https://krishiviman.com/

*(list in alphabetical order, these names have been sourced based on simple internet searches and media reports etc. with no preference or criteria and are listed for information of the readers only. No endorsement etc. is intended or should be assumed)

6.0 Prospective challenges with drone sprays and the way forward:

It is common knowledge that cost of labour of manually spraying an acre is around INR 350-400 and it is possible to spray around 2 acres for a person in a day but with difficulty. Thus the spray cost in case of renting drones for spray is presently on the higher side considering the going average rate of approx. INR 700 an acre. However, the time savings while using drones for spray is substantial. Among other potential benefits of drones, crop choice/intensity may be positively affected due to convenience offered by drones. Hence if drone spraying costs go little lower, they may really capture the market of spraying and farmers would perhaps be willing to rent drones on a pay per use basis and shift to drones for their spraying requirements.

There are some concerns also that the low volume spray (less water use compared to conventional spraying) that drones use may make the spray more concentrated. This aspect needs to be taken care of along with other commercial advantages of drone spraying because after all most important thing in case of food production is safety and more concentrated chemicals in sprays may pose a question here.

Given the fact that drones are a relatively novel technology as far as Indian agriculture is concerned, going ahead, implementation should be accompanied by robust efforts towards documentation also to understand factors enhancing or restricting uptake. For instance,

younger aged farmers may be more willing to adapt to drone sprays and farmers with fields in challenging terrains/ cultivating crops which are difficult to spray may also prefer drones. Farmers may also like to experiment with drone use in parts of their farms to test both economics as well as efficacy of drone use. Such documentation and research efforts would also help to produce a crop wise drone spray guide to help farmers take an informed decision.

Requirement of trained manpower for operations and maintenance/services of drones present both a challenge as well as an opportunity. The challenge is to create a pool of well trained personnel in the rural areas, near the farms, who can operate and deliver the drone services at an economic price to the farmer. At the same time, given the huge number of farms in India (145+ million), this is also an employment opportunity for aspirational youth.

If drones are able to capture the imagination of Indian farmers for crop spraying to begin with, then other advanced use cases possible with drones can also be gradually explored. This can lead to more efficient resource utilisation in Indian agriculture while leading to better health and economic outcomes for Indian farmers.

References:

- 'What is kisan drone? Five things you should know', Livemint, Feb 19, 2022 https://www.livemint.com/news/india/what-is-kisan-drone-five-things-you-should-know-11645248791806.html

- Costopoulou C., Karetsos S., Ntaliani M. and Rizakos I. Intention to Use Drones in Agriculture: Evidence from Greece. Mod Concep Dev Agrono. 10(3). MCDA. 000736. 2022. DOI: 10.31031/MCDA.2022.10.000736

- Drone Services Market Research Report by Function, Application, End User, Region - Global Forecast to 2027 - Cumulative Impact of COVID-19. Research and Markets. April 2022. https://www.researchandmarkets.com/reports/5337726/drone-services-market-research-report-by#rela0-5441269

- Ebook-'Drones in agriculture: Seeing beyond the surface with smart farming'. November 2021. Pix4D S.A. , Switzerland Available at https://www.pix4d.com/drones-in-agriculture-seeing-beyond-the-surface-with-smart-farming

- https://economictimes.indiatimes.com/industry/transportation/airlines-/-aviation/bharat-drone-mahotsav-2022-pm-modi-to-inaugurate-indias-biggest-drone-festival/articleshow/91805895.cms

- https://economictimes.indiatimes.com/news/economy/agriculture/who-will-pay-for-the-kisan-drone/articleshow/89530562.cms

- https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1757850#:~:text=No%20restriction%20on%20foreign%20ownership,reduced%20to%20INR%201%20lakh.

- https://pib.gov.in/PressReleasePage.aspx?PRID=1804978

- https://pib.gov.in/PressReleasePage.aspx?PRID=1806231

- https://pib.gov.in/PressReleasePage.aspx?PRID=1826135#:~:text=Drone%20(Amendment)%20Rules%2C%202022,of%20a%20drone%20pilot%20licence

- https://pib.gov.in/PressReleasePage.aspx?PRID=1833750

- https://pib.gov.in/PressReleseDetailm.aspx?PRID=1822070

- https://static.pib.gov.in/WriteReadData/specificdocs/documents/2022/jan/doc202212810701.pdf

- https://static.pib.gov.in/WriteReadData/specificdocs/documents/2022/mar/doc202231124201.pdf
- https://www.businesstoday.in/opinion/columns/story/india-as-a-global-drone-hub-wishful-thinking-or-realistic-scenario-318690-2022-01-11
- https://www.equinoxsdrones.com/blog/10-major-pros-cons-of-unmanned-aerial-vehicle-uav-drones
- https://www.equinoxsdrones.com/blog/importance-of-drone-technology-in-indian-agriculture-farming
- https://www.facebook.com/iffcokisan/videos/533186745002351/
- https://www.facebook.com/watch/?v=533186745002351
- https://www.financialexpress.com/industry/drone-segment-gets-off-to-a-flying-start-in-india/2558061/
- https://www.fortuneindia.com/enterprise/kisan-drone-makers-have-a-business-model/107619
- https://www.hindustantimes.com/india-news/indias-biggest-drone-festival-inaugurated-by-pm-huge-enthusiasm-for-tech-101653630409251.html
- https://www.indiabudget.gov.in/doc/Budget_Speech.pdf
- https://www.researchdive.com/blog/agriculture-drones-a-skilled-tool-for-conserving-and-improving-agricultural-needs-for-future
- https://www.youtube.com/watch?v=VGm4L4daR70
- Increasing efficiency of Application of crop protection chemicals and saving drift to environment and reducing exposure to human beings to hazardous chemicals.
- Maddikunta Reddy P.K., Hakak S., Alazab M. et al (2021). Unmanned Aerial Vehicles in Smart Agriculture: Applications, Requirements, and Challenges. IEEE Sensors Journal. PP. 1-1. 10.1109/JSEN.2021.3049471.
- Mogili U.M.R. and Deepak B.B.V.L. Review on Application of Drone Systems in Precision Agriculture. 2018. Procedia Computer Science. 133. 502-509. 10.1016/j.procs.2018.07.063.

- Pasquale Daponte et al 2019 IOP Conf. Ser.: Earth Environ. Sci. 275 012022
- Press Brief, Ministry of Civil Aviation, May 17, 2022 Press Information Bureau, Govt. of India https://pib.gov.in/PressReleseDetail.aspx?PRID=1826135
- Rahman, Mohammad F.F., Shurui Fan, Yan Zhang, and Lei Chen. 2021. "A Comparative Study on Application of Unmanned Aerial Vehicle Systems in Agriculture" *Agriculture* 11, no. 1: 22. https://doi.org/10.3390/agriculture11010022
- Rana V. and Mahima. 2020. Impact of Drone Technology in Agriculture. Int.J.Curr.Microbiol.App.Sci. 9(01): 1613-1619. doi: https://doi.org/10.20546/ijcmas.2020.901.177
- Sylvester G. (2018) E-agriculture in action: drones for agriculture. Food and Agriculture Organization of the United Nations (FAO), Rome, Italy.