Use of Drones in Agriculture:
Potentials, Problems and Policy Needs

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Contents

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1. Introduction

Drone technology is a phenomenal innovation with potential to transform the way the routine manual activities are carried out in agriculture. Agricultural industries globally are increasingly using drone technology to modernize farming. Drones are the remotely piloted aircraft systems (RPAS), having a propulsion system, a programmable controller with or without the satellite navigation system, automated flight planning features and capable of carrying payload such as cameras, spraying systems, etc. for accomplishing a given task. Several other acronyms, namely UAV/UAVs (Unmanned Aerial Vehicle/Systems), UAS (Unmanned Aircraft Systems) are interchangeably used; however, RPAS is the most formal and international way of addressing such systems. The drone used for agricultural activities is known as agriculture drone. Drones are designed to carry the sensors that can provide real-time information about the crop status or livestock movement, so that decision on cultural operations and management is made efficiently and precisely. The drone can be either remotely controlled over wireless communication or can be programmed to travel the predefined path using complex navigation algorithms running on onboard controllers. It can be retrofitted with different configuration of payloads of sensors with digital imaging capabilities such as multi spectral, high-resolution camera systems and actuators, for field survey, crop scouting, spraying and spreading applications and surveillance in livestock and fisheries. Using the data captured through cameras mounted on drone and data analytics, farmers can precisely calculate their land sizes, classify crop types and varities , develop soil maps along with pest management and properly plan the harvesting of their crops. These drones can be fully automated to help further improve the scale of operation and productivity. Drones have found several applications in agriculture, however is limited by the country policies on its use context.

Use of drones can be advantageous in the case of pesticide spraying, replacing labour intensive and hazardous conventional methods particularly in difficult areas such as hills. Artificial intelligence and machine learning can be combined with NDVI (Normalised Difference Vegetation Index) imaging technology-based high resolution images captured by drones to develop understanding of soil conditions, plant health and crop yield prediction.Every individual plant can be located separately and analyzed using image processing algorithms, if it is stressed. Using this result, farmers can take preventive action to cease the spread of diseases to other crops. Timely actions can be taken to prevent losses from biotic stresses such as insect-pests and diseases, optimize fertilization, rationalize irrigation and reduce the impact of climate change and unpredictable weather using analyzed insights from data collected by drones and satellite-based remote sensing. The agricultural labour shortage in exceptional times of COVID-19 pandemic that has necessitated adoption of physical distancing measures has opened up several opportunities for the use of drones in agriculture. An attempt has been made in this article to assess the use of drones for facilitating farming activity amidst lockdown compliance and labour deficit.

2. Status of Drone Applications in Agriculture

Drone applications in agriculture are already widespread across Asia, while elsewhere in the world, drones are allowed to be used for limited and specific trials and, in some cases, commercial operations in horticulture, agriculture and forestry. Spraying for weed, insect-pest and disease management, spreading micro-granular pesticides and fertilizers as well as planting new forests are among the diverse uses now being found for drones. The Chinese government has subsidized the commercial use of drones in agriculture. As a result, DJI Innovation Technology trained more than 10,000 persons to operate the 2015 model drone named as Agras MG-1 series 8-rotor sprayer. Yamaha Motor, which was previously focusing on unmanned helicopters, started selling multi-rotor drones as the demand for such drones increased in Japan. In small paddy fields where the helicopters are not efficient, the spraying quality of 10-litre capacity YMR-08, which uses co-axial rotors is comparable to the RMax and Fazer helicopters. According to Yamaha's report, 2,500-plus manual radio-controlled or fully autonomous helicopters are rented by operators who use it to spray nearly 42% of the country's paddy fields. Nearly 100 manual radio-controlled or fully autonomous helicopters are operating in South Korea and the company recently started rolling out its technology in Australia and New Zealand, and also in the US where Yamaha is permitted by the Federal Aviation Authority to conduct commercial trial services and research[1]. Spraying herbicide to control weeds and unwanted plants in isolated or inaccessible areas is another potential application for example the Bitou Bush Control Programme of Great Lakes Council through helicopter spaying run by Yamaha's Key Aerial Services in Australia. Bracken (Pteridium) is a genus of large, coarse ferns in the family *Dennstaedtiaceae*, which grow on challenging areas of hill sides of upland areas in UK. This is essentially a sheep production area where governing authorities have allowed spraying from drones on a trial basis by a consortium of farm drone owners and other parties.
Similarly, in Denmark drones are used to dispense pest-eating beneficial insects to field crops. As per South Denmark University using bio-control agents within high-value indoor production with a controlled setting and a high-level of infrastructure is easily manageable. However, it has been difficult and expensive to use bio-control in large open fields, but it is now possible with drones. Australian drone retailer Rise Above has developed a drone fitted with grass seed and fertilizer spreader with an electric motor and a hopper extension.

In India, forty drone start-ups are engaged in enhancing the technological standards and decrease the agriculture drone's prices to make it affordable and popular among farmers. The Maharashtra state government has been encouraging drone companies to work with them. Recently, Maharashtra government and World Economic Forum (WEF) Centre for the Fourth Industrial Revolution signed an MoU to explore the possibilities of using drones for several government initiatives. Farmers of Dahanu-Palghar tribal villages in Maharashtra have learned to use drones for organic farming, fish farming, crop rotation, bio-control, hydroponics, bio-waste management, beside also using drone-based technologies on their orchards and farms[2].

However, the cost of drones, operational policy, and limited availability of technically trained pilots are specific blockage in drone market development in India. Hiring an urban drone team to conduct a survey for a remotely located small field is extremely expensive for any assessment & crop planning at the grassroots level. Just like custom hiring of farm implements scheme, farmers should be trained in drone operation and should be encouraged to form a group enterprise and own the drones. Due to the costs involved in purchasing drones, small and medium-scale farmers are reluctant to use drones.

In addition to affordability and technical know-how, the lack of skilled pilots is a major preventive factor for UAV market development in India.

2.1. Demonstrated versions of drone for agricultural operations

1) As per BAYER, a new type of drone called multi-rotor, powered by rechargeable batteries, was launched in China to apply crop protection products in fields. This unmanned aircraft, equipped with only a 5-10 liters tank can treat up to 1 hectare of rice in 10 to 15 minutes. This multi-rotor drone flies and lands autonomously, has an automatic filling tank designed to the exact field size, can trace the terrain and keep a constant height over the crop under a height sensor and recent models can detect and avoid obstacles during flight. Furthermore, these drones can fly individually or in collaborative groups and can fly during both day and night. BAYER also reports that in 2016 already 9000 drones were in use in China, which treated 1.4 million hectares and that China could cover 33 million hectares with 100K units of drones by 2020[3].
2) DJI Agras MG-1 (DJI, 2017) drones are designed for precision variable rate application of liquid pesticides, fertilizers and herbicides. The MG-1's propulsion system allows the aircraft to carry up to 10 kg liquid payloads, including pesticides and fertilizers to cover an areaof 4,000-6,000 m^2 in just 10 minutes, which is around 40 to 60 times faster than manual spraying operations. The intelligent spraying system automatically adjusts its spray according to the flying speed so that an even spray is always applied. This way, the amount of pesticide or fertilizer is precisely regulated to avoid pollution and economize operations.[4]
3) FAO has been using drones in the Philippines, which are equipped with navigation equipment and photogrammetric with up to 3 cm ground resolution. Using this drone, NDVI, water stress or lack of specific nutrients in crops can be detected. Under the FAO's disaster risk reduction and management (DRRM) and climate change adaptation (CCA) strategies, drone-based mapping work in Philippines is being mainstreamed now. These drones can guide when to visit orchards for cultural operation including fertilizer application and pesticide spray[5].
4) Taking the lead from USA, Switzerland, New Zealand and China, Queensland (Australia) granted permission to its farmers to apply pesticides from drones since September 2016.[6]

3.Potentials and Problems of Using Drones in Agriculture

3.1. Potentials[7 & 8]

1) **Soil Analysis for field planning:** Drones can be used for soil and field analysis for irrigation, planting planning, and nitrogen level in soil. Along with this, drone is helpful to produce accurate 3-D maps that can be used to conduct soil analysis on soil properties, moisture content, and soil erosion.
2) **Seed Pod Planting:** Although invented but seldom prevalent just yet, some companies have come up with additional attachment below the drone systems able to shoot pod containing seed and plant nutrients into the already prepared soil. This is helping to reduce planting costs.
3) **Crop Monitoring:** Crop monitoring is the biggest headache not only for farmers, but also various other stakeholders associated in agriculture operations. This challenge has got worse also with rise of unpredictable weather patterns, which lead to rising crop loss risks and maintenance costs. Drones can be used to set its monitoring routes by gathering multispectral geospatial and temporal datasets at pre-defined scales that relate to crop development and

health. Data analytics help in getting insights on crop health much before being visible by manual field scouting.

4) **Crop Spraying:** Drones can carry suitably sized reservoirs, which can be filled with fertilizers, herbicides, or pesticides for crop spraying on large areas in less time. Crop spraying is much safer and cost-effective by its autonomous and pre-programmed run on specific schedules and routes. Drones are also programmed to self-adjust its altitude and speed using ultrasonic echoing, TOF lasers and GNSS signals to achieve uniform and optimum spraying results across varying topography.Smart farms use drones for agriculture spraying, which reduces the contact of humans with fertilizers, pesticides and other harmful chemicals. Drones are also un-comparable when it comes to spot treatment automated with stress detection technology which uses sensors and cameras and work on them while leaving the healthy parts intact. Drones enhances spraying capacity up to five times faster than with traditional machinery..
5) **Irrigation:** Drones loaded with thermal, multispectral or hyper-spectral sensors can identify the parts of the field with moisture deficits using multispectral indices. This helps in planning timely irrigation to the identified areas with precision.
6) **Crop health assessment:** Plants reflect visible & near-infrared light and its intensity varies with health status and stress levels experienced by plants. Drones fitted with sensors capable of scanning crops using visible and near infrared light can be used to track crop health over period of time and also to monitor response to remedied measures.
7) **Crop surveillance:** It is nearly impossible to estimate the overall state of crops in large fields. Drones based agriculture mapping can help farmers remain area-wise updated on the plants status and point out which field areas require attention. Drones inspect the field with infrared cameras and determine light absorption rates to estimate the state of crops. Based on real-time and accurate information, farmers can take measures to improve the state of plants in any spot of the field. This feature of crop surveillance and crop health assessment also forms the basis of the use of drones for enhancing agricultural insurance tools for cross verifying farmers' insurance claims. However, financial implications vis a vis insurance model adopted and practical possibilities will decide the future potential use.
8) **Controlling weed, insect, pest and diseases:** Apart from soil conditions, drones can also detect and inform farmers about field areas inflicted by weeds, disease and insect pests. Based on this information, farmers can optimize the use of chemicals needed to fight infestations, hence reducing the expenses and also contribute to better field health.
9) **Tree/crop biomass estimation: Crop/tree canopy density and distance from ground surface can be measured using ultra compact** LiDAR sensors mounted on drones. This enables estimation of the tree/crop biomass change derived from differential height measurements that forms basis for estimating timber production in forest and production estimates in crops like sugarcane.
10) **Scaring birds:** Birds are the major problem after sowing seeds of many crops. This needs labour to protect the field. A couple of drone flights can scare the birds away from field.

3.1.1. Benefits, Costs and Saving in Using Drone[9]

- **Security:** The agriculture sprayer drones are controlled from a distance by trained pilots. This process eradicates the involvement of farmers or farm labourers in direct contact with poisonous chemicals and adverse operational conditions.

- **High field capacity and efficiency:** Drones have very less turnaround time and other field operational delays. The drone can spray 50-100 acres per day depending upon the capacity of drone which is 30 times more than the traditional knapsack sprayer.
- **Wastage reduction:** Due to a high degree of atomization while spraying, 30% of pesticide is saved. Pesticides in the form of chemical fog can be sprayed at all levels of the crop.
- **Water saving:** Drone utilizes ultra-low volume spraying technology, thus saving 90% of water in comparison to traditional spraying methods.
- **Lower cost:** In comparison to conventional spraying methods, the cost of drone spaying is reduced by 97%.
- **Easy to use and maintain:** The agricultural drone are made rugged. It has low maintenance cost, a long productive lifespan, and its parts replacement is simple, as and when required for the company offering drone services.

3.2. Problems and bottlenecks[10]

1) **Flight Time and Range:** Along with benefits, drones for agricultural use have some limitations. Due to relatively higher payloads, the flight duration of drones used in agriculture is short, ranging from 20-60 minutes. This results in limited coverage of land with every charge. The cost of drones increases significantly with longer flight time.
2) **Initial Cost:** Mostly, agricultural drones used for surveying have fixed wings and may cost up to $25000 (Precision Hawk's Lancaster) based on features and sensors necessary for executing its intended use. Some drones are costlier as it includes cost of imaging sensors, software, hardware and tools. The initial cost is also proportional to the payload and flight duration capacities, apart from sensors and features included.
3) **National Laws:** India's Directorate General of Civil Aviation announced the country's first Civil Aviation Requirements (CAR) for drones on August 27, 2018 to go into effect from December 1, 2018. The operation of drones in India is governed by the Unmanned Aircraft System (UAS) Rules[18] - Part VI, published on June 2, 2020 in the gazette of India which requires obtaining unmanned aircraft operator's permit (UAOP) for piloting UAS, Permission for each flight through Online Digital Sky platform for No Permission No Take off (NPNT) compliance. As of date the current Digital Sky platform only accepts registrations and API's aren't fully open yet. Very limited UAOP have been issued till date and very few Indian OEMs have been provided provisional NPNT compliance, thereby limiting use of drones in agriculture including other general applications. The UAS rules also prohibits a) carriage of any payload as specified by Director General for RPAS, thus restricting spraying and pod planting applications discussed in section 3.1.2 & 3.1.4 to only Model Remotely Piloted Aircraft System (MRPAS) used for educational or experimental purposes only. b) Beyond Visual Line of Sight Operation (BVLOS) thus restricting autonomous operations for better work productivity within unaided line of sight of the authorized UAS operator.
4) **Connectivity:** Online coverage is mostly unavailable in the arable farms. Under such a situation, any farmer intending to use drones has to invest in connectivity or buy a drone with local data storing capability in a format that can be transferred and processed later.
5) **Weather Dependent:** Under windy or rainy conditions, flying drones is not easy, unlike traditional aircrafts. Drones are weather dependent.

6) **Knowledge and Skill:** An average farmer cannot analyze the drone images as it requires specialized skills and knowledge to translate it to any useful information. Under these circumstances, the farmer has to acquire the skills and knowledge of software of image processing or hire skilled personnel conversant with the analysis software.

7) **Misuse:** There is a chance of misuse to infringe the privacy of people and illegal transfer of information.

With the advancement in drone technologies and startups/ manufacturers showing interest in the industry, it has assumed that the cost of the drones and the additional equipment will reduce. Also, flight time and range are expected to increase by advancement in underlying technologies such as battery storage and reduction in payload weights. These developments will ensure that farmers get more benefits from the use of drones in agriculture.

4. Deploying drone technology in agriculture

The modern farming industry is at a turning point. With the development of more advanced farm management techniques, such as precision agriculture, industry professionals now have more tools than ever to improve the accuracy and efficiency of processes. The use of different types of agricultural drones for solving specific tasks of plant growing is being studied for developing SOP and algorithms, particularly for the creation of electronic maps of fields, operational monitoring of crop conditions, evaluation of germination, predicting crop yields, checking the quality of ploughing, maintaining environmental monitoring of agricultural land, etc.

During the last couple of years, drone market for agriculture has expanded considerably. The cost of drones equipped with accessories for spray can range from 3 to 7 lakhs depending on make and capacity of spray tank. In India presently, the firms registered in the DIGITAL SKY platform of DGCA (Director General Civil Aviation, GOI) for manufacture of drones are mentioned in Table 1.

Table 1. Registered Firms of RPAs[19]

RPA Name	Manufacturer name	Max. take-off weight (kg)	Max. height attainable (ft)
LookOut VTOL RPAS	Throttle Aerospace Systems Private Limited	1.99	400
Patang	Skylark Drones Pvt Ltd	1.9	1000
A200	Asteria Aerospace Pvt Ltd	1.9	200
Insight	Aarav Unmanned Systems Pvt Ltd	3.6	400
Ninja	ideaForge Technology Pvt Ltd	1.98	400
Agribot UAV (AGUAV)	IoTechWorld Avigation Pvt Ltd	23.2	33
Prion Mk3	UAVE Limited	42.88	12100
Starlite	Hubblefly Technologies Pvt Ltd	1.92	9842
Freebird Z1 A	Ecom Infotech India Limited	4	13123
DH-Q4	Dhasksha Unmanned Systems Pvt Ltd	5.18	400
WHITE HAWK	EDALL SYSTEMS	1.98	11482
Staredge	Hubblefly Technologies Pvt Limited	4.25	400
Model V	CBAI Technologies Private Limited	3.33	400
A400	Asteria Aerospace Pvt Ltd	3.4	400
NOCTUA DS	Detect Technologies Pvt Ltd	1.85	2624
Insight 2.0	Aarav Unmanned Systems Pvt Ltd	3.6	400

With the aim of integrating competence, flexibility, efficiency, long-term perspective, social interest and accountability, the Public-Private Partnerships (PPPs) approach can be adopted to promote agricultural drone for social and economic development of rural India[11].

Under this approach infrastructure for sizeable spatial data on digital soil maps, hydrology and weather can be supported by government and commercial cloud services. This will encourage private sector investment, especially entrepreneurs, to support agro-ecologically based innovation systems and help to enhance the farmers' income.

Agriculture Skill Council of India's skill development programme and MeitY's PMGDSA (Prime Minister Gramin Digital Saksharta Abhiyan) scheme can consider integrating drone applications in agriculture and make provisions to assist Farmer Friends (Krushak Sathi) in obtaining UAS pilot license or become Remote Piloted Aircraft (RPA) Observer.

4.1. Implementation Plan

1) **Drone manufacturing:** Less than twenty companies are manufacturing drones in India which includes assemblers and suppliers. Start-ups can be encouraged to establish local drone manufacturing/assembling.
2) **Drone service providers:** About 50 start-up service providers have come up recently through incubation centres. There is a need to encourage thousands of such startups to cover 180 million hectares of cultivable land.
3) **Legal and policy instrument:** Though the comprehensive legal and policy framework in form of CAR 3.0 and Digital sky platform have been formulated and partially implemented, its revision for pragmatic and practical implementation should be expedited to encourage applications of drone in agriculture.
4) **Trained human resources:** Capacity development for flying drones is required as it is a skill-based operation. Training institutes should be established in collaboration with organizations equipped with drone know-how.
5) **Ease of doing business:** An enabling ecosystem needs to be developed with a single-window concept for entrepreneurs.
6) **Research in drone application:** Enough studies are not available on use cases of the drone in various crops, animals, fisheries and forests. Various operating parameters need to be studied and standardized for each use case in agriculture.
7) **Extension system:** Field extension functionaries need to be oriented towards popularizing drone usage with field demos of various applications in agriculture.
8) **Custom hiring centers:** Similar to the mechanism of providing several types of agricultural equipment on a hiring basis, custom hiring centers should develop a mechanism to provide single window solution for custom hiring drone application services, by tie-up with startups offering drone services. This will effectively utilize the existing farmer-custom hiring network to bridge the demand and supply chains of drone applications in agriculture.

4.2. Scope for PPP mode operations

The following points need consideration to for use of drone in agriculture under PPP mode.

1) As per the norms of Directorate of Civil Aviation, the Drone operators have to register in Digital Sky platform of DGCA. The digital sky API's aren't fully open yet.
2) Some Indian OEMs have been provided provisional NPNT compliance

3) Provision for drone ports/corridors (i.e., segregated airspace for drones) has been envisaged in the Unmanned Aircraft Systems Rules Part VII, published June 2, 2020

4) The Drone Federation of India (DFI), a not-for-profit, non-government, industry-led body, supports and attempts to build a safer and scalable unmanned aviation industry in India. DFI connects with experts, leaders, visionaries and policymakers to share their knowledge and build a sustainable UAV Industry in India[12].

5) For young entrepreneurs it is a business opportunity to operate drones use in agriculture in compliance to the UAS rules. The current labour migration due to COVID lockdown has provided the unique opportunity perceived to positively affect drone use in agriculture. It is predicted that this technology can engage the new generation in agriculture and will hopefully reverse the trend of deflection from farms. Agriculture inputs suppliers like Bayer is fully engaged in encouraging such technology[11].

6) Some of the private firms have already tested the use of the drone for spraying insecticides in agricultural fields and have tried to commercialize the technologies. For example, Grape Growers Association engaged drone for disease surveillance in vineyards of Nashik district of Maharashtra.

7) Possible mode of realizing the drone usage in PPP mode would be as follows:

- Announcement of drone service for agricultural activities by authorized firms who have registered with DGCA and have appropriately trained pilots to operate the drones from ground as per the norms of DGCA.
- Form block-level hubs for staggered agricultural operations related to drone engagement.
- Select the drone service provider for each hub.
- Agriculture Department at Block level to make essential pesticides available in stock.
- KVKs and Agricultural Department has to use existing farmer database and smart phones to assess demand and synchronize other activities with drone activity.
- Crop Growers' Association, Drone Federation, Drone Institute and Representatives of DGCA can be potential advisors in enabling ICAR to implement drone technology for key agricultural operations like pesticide and herbicide sprays to start with and then for disease surveillance.

5. Rules and Regulations in Drone Use

Countries across the world realise the potential of drones and are investing in the growth of drone innovations. But they also understand the risks posed by unfettered usage of drones and have laid down rules for drone usage. The first body to bring this out was the FAA of the USA. Soon, other countries followed suit. India's DGCA has also brought out its own set of rules to govern the Indian skies via RPAS regulations.

Although drones are used in agriculture for last two decades, rules and regulations about agricultural drone uses are still in its early years in the world. Although drone usage in India is limited in contrast to the US and China, New Delhi took the initiative in forming rules of global governance partly because the evolution of drone technology could have serious security implications for India, but equally because it is advantageous for India to take the initiative and guard its interests. So far, at the multilateral level, the International Civil Aviation Organisation (ICAO) is the leader for formulating rules and regulations for drone operations. Although it began its work on UAVs back in 2007, the first set of rules in the form of Circular 328 was issued

by the International Civil Aviation Organization only in 2011. Let us illustrate some leading countries' policies regarding drone usages.

5.1. Rules and Regulations in different countries

5.1.1. United States of America[13]

- The regulations to operate drones are the most commercial-friendly in US.
- In August 2016, the New Small Unmanned Aircraft (UAS) Rule (107) of the Federal Aviation Administration (FAA) came into existence. It regulates commercial or work purpose operations of drones.
- In case the drone weighs less than 55 lbs, the operator can apply for a waiver of Part 107 rule, however, the applicant must specify the operator plans regarding safety and emergency risk mitigation strategies.
- It is mandatory to register drones weighing 0.55 lbs to 55 lbs with the FAA. It must be ensured that the UAV remains within the visual line-of-sight. The industry, however, demands to relax this rule once the drone sector reaches full automation.
- It is believed that the FAA has relaxed the rules for drone operations in the commercial sector because drone industries are estimated to generate an additional US$82 bn to the US economy. The world's largest drone manufacturer, Pix4D and the DJI Innovations endorse this potential.
- In case of drone use for recreational activities and hobbies, operators are regulated by Public Law 112-95 Section 3 which states that "UAVs must operate within visual line-of-sight, give way to manned aircraft, provide advance notification to the airport and air traffic control tower, when flying within five miles of an airport, and also the UAV must not weigh more than 55 lbs".

5.1.2. Australia[13]

- Australia was one of the pioneering countries who established a drone regulatory framework as early as 2002.
- The Australian Civil Aviation Safety Authority (CASA) is responsible for safety and regulating drone operations under different categories such as drone operations for fun, hobbies or commercial ventures.
- In September 2016, new rules for regulating drone operations were issued, which has focus on safety and risk-reduction.
- Although the new regulations focus on low-risk operations, it's less restrictive from a regulatory and legal point of view.
- Under new rules, small commercial drone operators are exempted from paying regulatory fees (US$1,400) to avoid the lengthy documentation and paper work.
- Moreover, property holders don't need approval to operate drones up to 25 kg on their properties.

5.1.3. Japan[13]

- A small drone was found on the roof of the prime minister's office building in Tokyo in April 2015. This prompted Japan to formulate regulations for drone operations.

- Urgently, the ruling Liberal Democratic Party (LDP) proposed a bill to the Diet (Japanese Parliament) in June 2015. Another bill to amend the existing Aviation Act was tabled in July 2015; subsequently they were passed in the Diet.
- In case drone operator want to fly UAV where there is air traffic such as airports and other approach areas, or areas above 150 metres, it was made mandatory for the operators to obtain authorization from Ministry of Land, Infrastructure and Transportation (MLIT) as per the new regulations.
- In spite of permission, drones can't be used in the hours of dawn and dusk; also one has to maintain more than 30 metres of distance from people and objects due to safety reasons.
- A fine of upto (US$4,000 approximate) 500,000 yen can be imposed for violation of Japan's regulations.
- The law makers of Japan have also considered the scope of drone usages for commercial purposes. On the other hand, terrorism and other security-related concerns have pressed for stringent regulations for drones particularly for recreation and hobbies.

5.1.4. China[13]

- China is world leader in drones manufacturing with industry giants like DJI (Dajiang) Innovations, Zero Robotics, Yuneec, and Hubsan belonging to China.
- Out of eleven international venture-capital funded drone companies, five are in China and many foreign companies have established their drone manufacturing units in the country.
- Even though the legal and regulatory framework is not clearly defined, commercial use of drones in agriculture has picked up to a greater height. In addition, safety issues have also to be dealt with.
- In December 2015, a drone being tested by Alibaba crashed into a landing military jet, indicating the safety issues that need to be settled.
- The existing regulations differ across regions–Beijing and Shanghai. They have far stricter policies regarding when and where drones can be flown – given the dense population of these cities.
- Chinese regulations also differentiate between small consumer drones and large commercial drones.
- After a series of accidents, the Civil Aviation Administration of China (CAAC) placed stringent laws in June 2017 that mandate civilian drones above a certain size to be registered under real names so that the safety measures could be strengthened.
- China is leader in the drone market and the future of large-scale use of drones in non-commercial and commercial segments are significantly high but the legal and regulatory architecture is yet to be established.

5.2. Rules and Regulations of Drone Use in India

In December 2018, the Indian Govt. launched a drone policy, which allows for the application of drones, next to for instance, their deployment in infrastructural works. The DGCA, GOI, regulations implicitly permits the use RPAS i.e., Drone/ UAV for agricultural purpose except to spray pesticides until specifically cleared. The operation of drones in India is governed as of date

by the Unmanned Aircraft System (UAS) Rules[18] - Part VI. The DGCA RPAS Guidance Manual[17] provides procedures pertaining to issue of Unique Identification Number (UIN), Unmanned Aircraft Operator Permit (UAOP) and related activities.

The general laws of using drone are listed below[14].

1) Densely populated areas or large crowds must be avoided.
2) Do not breach the privacy of others
3) Five km from airports or in areas where aircraft are operating are out of bounds for UAVs
4) Fly during daylight hours and under good weather conditions
5) Use of drones or camera drones is prohibited in sensitive areas, including government or military facilities.
6) Drone user must be trained drone pilot and should have attained the age of 18 years.
7) License plate indicating the details of the operator and how to contact them must be placed on the drone.
8) Visual line of sight should be maintained while using RPAS.
9) One person can't fly more than one UAV at the same time.
10) The area within 50 km of the country's border is prohibited for drone flying.
11) Flying drone more than 500 meters into the sea from the coastline is banned.
12) Similarly, it's not allowed to fly the drone within 5 km of Vijay Chowk in Delhi
13) Flying over national parks or wildlife sanctuaries is also barred.
14) All drones must have valid third party insurance policy to cover the liability that may arise on account of mishap.
15) Basic drone laws must be followed while flying a drone over 250 grams weight.

The DGCA RPAS Guidance Manual[17] (Revision 2.0 published 11th March 2020) provides guidelines for obtaining UIN for all types of RPAS except Nano RPAS (weight including payload below 250 grams). Since all agricultural drones falls in category above nano-drones (weight including payload above 250 g) getting UIN is compulsory

The Unmanned Aircraft System (UAS) Rules[18] - Part VI, requires a) obtaining unmanned aircraft operator's permit (UAOP) for piloting UAS, b) Permission for each flight through Online Digital Sky platform for No Permission No Take off (NPNT) compliance, c) prohibits carriage of any payload as specified by Director General for RPAS and d) prohibits Beyond Visual Line of Sight Operation (BVLOS) of RPAS. For Small RPAS (<25 kg) UAOP is compulsory.

The army, naval bases, and airports are several restricted zones where drone operations are not allowed in India. Among popular use of drones in India are photography, videography and shows by the police and also in agriculture. The Directorate General of Civil Aviation (DGCA) refers drone as Remotely Piloted Aircraft System (RPAS). The Digital Sky Platform of Ministry of Civil Aviation is the first-of-its-kind national unmanned traffic management (UTM) platform that implements "no permission, no takeoff" (NPNT) policy. The UTM operates as a traffic regulator in the drone airspace and coordinates closely with the defense and civilian air traffic controllers (ATCs) to ensure that drones remain on the approved flight paths. Regulations 1.0 are intended to enable visual line-of-sight daytime-only and a maximum of 400 ft altitude operations. Air space has been partitioned into Red Zone (flying not permitted), Amber Zone (controlled airspace), and Green Zone (automatic permission)[15 &16].

The issues related to regulation, ethics and implementation need to be carefully addressed, keeping in mind the existing legal and moral principles and adapting them to the fast technological changes to build a helpful governance system for UAVs in India.

India must also study existing policy structures in other countries to adopt their best practices as it formalizes its regulatory architecture. However, guidelines alone are not sufficient; key is guarantying implementation and conformity.

This would essentially mean that guidelines and circulars issued by governments and multilateral agencies like ICAO need to be converted into legal and policy instruments that would have obligatory for governments to implement. Nonetheless, norms and standards of accountable behaviour relating to drones are vital first steps in this regard.

6. Policy Need

Policy challenges associated with drones fall into the following broad categories: personal privacy, public safety, international airspace, and civil rights. The success of using drone in agriculture would depend on achieving a symbiotic integration of law, tax and civil liberties. Operations of drones for agricultural purpose beyond visual-line-of-sight operations is not permitted by the regulations as of date, which would be challenging particularly when whole village has to be covered and such operations being carried out in PPP mode. The following policy reforms would encourage drone use in agriculture.

1) Entrepreneurs providing drone services need to be encouraged by giving priority in registration and trainings on regulation.
2) In the wake of COVID 19 lockdown associated crisis the registration if any for drones in DGCA should be reopened and expedited.
3) Training for drone operators for agricultural purpose should be made easily accessible and affordable for young entrepreneurs.
4) The emergence of drone technology for modern solutions for difficult tasks has led to establishment of educational institute for operation of drones, the Indian Institute of Drones (IID), for example. This type of training has to be part of the new agriculture graduate curriculum and should align with the norms of DGCA.
5) Inclusion of DGCA guidelines for issuing license/certificate to remote pilot for pesticide spraying both for agriculture and public health purpose in the new Pesticides Management Bill, 2017, is the need of the hour.
6) Besides, the existing pesticide formulations with label claim can be integrated into the Drone based pesticide application paradigm. The regulation of drone-based aerial application for uniform canopy coverage of pesticides in major crops also find a part in the new Pesticides Management Bill, 2017.
7) Liability and damage insurance in drone-based pesticide application should find a place in the Pesticides Management Bill, 2017.
8) Formulating BIS standards for benchmarking the specifications of drones for agriculture use and, testing and evaluation standards for identified agricultural applications of drones.
9) Strengthening Farm Machinery Testing Centres with facilities for testing and evaluation of drone applications in agriculture for compliance to BIS standards on formulation.
10) Provision for drone corridors (i.e., segregated airspace for drones) with unmanned traffic management (UTM) systems should be envisaged.

11) Fully autonomous AI based drone operations may be allowed with relaxations for Beyond Visual line of Sight (BVLOS) and night operations beyond 400 ft limit. This will help to increase the number of hours of operation of existing drone inventory to reduce cost of operation as while maintaining positive benefit-cost ratios.

7. Way Forward

Drone technology has got considerable potential in carrying out several agricultural operations very efficiently. It can save labour and also accomplish the norms of social distancing in the time of COVID 19 and national lockdown. However, high initial cost and policy reforms are some of the challenging areas in making it popular and farmers' friendly. There is also a need of conducting research for optimizing operation protocols and calibrating and validating the drone use. For example, research carried out into the impact of the stream of air generated by drone rotors on the distribution of the liquid revealed that the rotational speed of the drone rotors that perform spraying of the plants influences the volume of the drops settled on the different levels of the plants. The stream of air coming from the drone rotors can cause penetration of the stream of drops into the internal structure of the plants. The greater the rotational speed of the rotors is; the lower location is of water deposited on the plants. As a result of this, the rush of air may change the inequality index of the volume of the liquid settled on the different levels of the plants. As there is no detailed knowledge on the quality of the operations performed of depositing pesticides, the organization of the field spraying process is not possible. There are several other issues, which need further research and fine-tuning for effective use of drone technology in agricultural purposes.

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