Agri-Drones

Abstract

The world-wide farming system faces tremendous challenges. The United Nations Food and Agriculture Organization (UN FAO) expects that food production must be raised by 70% throughout the following 40 years to meet increasing demand due to rising economic welfare and population growth. The main challenge of global agriculture is providing a food to the growing population, which is predicted to increase from seven billion people today to approximately nine billion around the year 2050**.** Where as India's population, currently estimated at 1.34 billion, is projected to rise to 1.51 billion by 2030 and further to 1.66 billion by 2050. India is categorised by small-scale farmers. Furthermore 80% of the total land in the country is divided into pieces of less than 5 acres. So drone being a modern technologies can be solution for farming to reduce drudgery and with less time lots of data for research can be reported for easiness to bring sustainability in futuristic agriculture.

Introduction

The majority of the crops are dependent on rain, with around 45% of the land irrigated. It determines that around 55% of the total population in India depends on farming which is dependent on rain. Due to the acute labour shortage and high labour cost, changes in the climatic conditions, crop losses due to pests, poor availability of the funds and agricultural inputs, wastage of inputs, terrible support price structure these are all the problems which are limit the access for good quality of food for the people. Even though agriculture is the major sector of our economy, but still it is far short of western countries when it comes to adapting latest technologies for better farm output. In order to keep with the challenges, there is need to find ways to improve our current farming practices and processes with improved technologies.

Agricultural drones provide relief for the modern day farmer, which are helping to increasing productivity level and declining expenses by reducing the need for human labour and other input resources.

COVID-19: IIT Guwahati students develop drones to spray disinfectants

Students at Indian Institute of Technology (IIT) Guwahati have developed a drone with an automated sprayer to spray disinfectants to sanitise large areas and prevent the spread of COVID-19.

The students, who also have a startup company, RACERFLY, have approached the Assam Government offering to join the fight the coronavirus pandemic with their sprayer system.

Considering that fighting COVID-19 involves social distancing, the sprayer system can be deployed and operated by just one operator sitting and monitoring at one spot, eliminating the need of many cleaners manually spraying disinfectants. Also, these drones can also be used to record videos as as well.

How drones operate

The drones can spray disinfectants over large areas like parks, roads, highways, and foot-paths with a high degree of efficiency. The roads and areas can be selected on Google maps and the drone can be automated to perform the task within a signal range of 3 km. A drone can cover more than 1.2 hectare in one flight, and more than 60 hectares in a day.

Also the students claim that the drone “can be used to spray disinfectants over vehicles on highways when things start to normal again.” It can also be “used simultaneously as an announcement tool for police when spraying.”

The drone can be controlled using a mobile app and it is crash proof. The drone is equipped to adjust itself to terrain height and avoid obstacles.

The drone's efficiency

A drone can spray two to four litres per minute and can be filled twice for one charge. The drone is highly efficient and can accomplish the task in 15 minutes which would otherwise take a person 1.5 days of work. In this manner, a single drone system can replace around 20 workers, which is what is really needed in the present COVID-19 situation as maximum people are required to stay within the safety of homes. The drone system is very effective for sanitizing and disinfecting especially during the ongoing health crisis when doing so manually may be highly risky to the health of manual workers. It can be used at night as well.

These drone systems have been designed to spray disinfectants in public areas including agricultural fields and have already been tested and are ready for use immediately.

Drishyam 4.0

Drishyam 4.0 is a project conceived by HITS and Orient Flights in association with Aeronautical Society of India to support Police Department in crowd monitoring, surveillance and control during the COVID-19 lockdown period. The project headed by Mr. C.S. Karunakaran, Assistant Professor, School of Aeronautical Sciences, HITS began on started on 5 April 2020

Twelve Professional Aerial Photographers and 8 Drone Pilots based in Chennai City were inducted for the project. DJI Inspire, DJ Mavic pro 2, DJI Mavic Mini and DJI Phantom 4 are the drones used for this project. Project 'Drishyam' started with 6 drones that could cover 0.5 – 1km radius and fly for 5-6 hours a day with support to power supply. It is capable to cover 5 km range with low frequency disturbance. The drone pilots worked in hands with Chennai City Police during the lockdown to monitor the streets to avoid crowd gathering. Crowd monitoring by drones were very helpful for Chennai City Police as they could monitor a wide area by not roaming into streets. Sealed places are susceptible to be infectious; hence personal inspection in those areas are harmful for authorities. Our support through drone monitoring helped in easing such inspections. People began to realize that they are being monitored when a drone is spotted which resulted in reduced crowd gathering.

The 9-day mission witnessed a total of 53 hours and 30 minutes drone flying

hours covering approximately 33 places in Chennai city. In a country like India, Project Drishyam 4.0 can play a pivotal role in crowd monitoring by inducting more drone pilots across India

Drone

A Drone, commonly known as Unmanned Aerial Vehicle (UAV) is essentially flying ROBOT (The air vehicles that do not carry a human operator). The aircraft may be remotely controlled or can fly autonomously through software-controlled flight plans in their embeded system working in conjunction with onboard SENSORS and Global Positioning System **(**GPS).

It carry lethal or nonlethal payloads

Compared to manned aircraft, UAVs were originally used for missions too "dull, dirty or dangerous" for humans.

Types of drones

1. **Fixed wing drones:** Fixed wing drones consists of a rigid wing (Non movable wing), fuselage (main body of the aircraft) and tails which use a motor and propeller as their propulsion system. They have the advantage of being able to fly at higher speeds for longer duration and that can cover wide range of possible environments (ex: jungle, desert, mountain, maritime etc.). But these drones have the disadvantage of requiring runway or launcher for take-off and landing and not being able to hover
2. **Rotary wing drones:** These drones will have the rotary blades or propeller- based systems they are called rotatory wing drones. Unlike the fixed wing models these drones can fly in every direction, horizontally, vertically, and also have the ability to hover and have a high maneuverability. These characters make them perfect drones for surveying hard to reach areas (pipelines, bridges). They are similar to helicopters generate lift from the constant rotation of the rotor blades. But these too have disadvantage of low speed and short flight range
3. **LTA & tethered systems drones:** Rarely used in agriculture and these have management troublesome

Classification of drones

According to size

1. **Very small drones:** They can be designed with a common size range varying from a large sized insect to a 50 cm long unit. Two most

common designs in this category are: Mini Drones and Nano/ Micro Drones. The nano drones are widely used due to their tiny structure and light weight construction and can be used for spying and biological welfare

2. **Mini drones or small drones:** They have a size little bigger then micro drones that means will go above 50 cm but will have maximum 2m dimension. Many of the designs in this category are based on the fixed wing model, whereas few can have rotary wings. Due to their small size they lack in power
3. **Medium drones:** This category of drone's presents that are too heavy to be carried by one person but are smaller than the light aircrafts. These drones can carry weight up to 200Kgs and have average flying capacity of 5 to 10 minutes. One of the most popular designs under this category is UK watch keeper
4. **Large drones:** Large drones are somewhat comparable to size of aircraft and are most commonly used for military applications. Placed that cannot be covered with normal jets are usually captured with these drones. They are main device for surveillance applications. Users can also classify them further into different categories depending upon their range and flying abilities

According to altitude

1. **Low altitude system:** They can fly up to 105-200m height, with in the site of the pilot and its limits the area with a single mission
2. **Medium altitude systems:** Operate in same space as in air traffic little use for civil or scientific community
3. **High altitude systems:** Mostly fixed wing aircraft and Sun is the power source

Components of a drone

Various multicopter come with components that provide power and endurance. Components of a multicopter define the quality and type of a multicopter. Here is a list of essential components that make up an unmanned aerial vehicle:

Frame

The frame is the basic layout upon which the rest of the structure is built. It is considered as the skeleton of the UAV. It must be light as possible to save power while flying but strong enough to tolerate accidents and crashes and to increase the payload of the UAV. The frame supports the motors and various

other devices in a way that they maintain stability during the flight and keep the vehicle levelled. There are several frame types that define the multicopter. The most common frame types include tricopter, quadcopter, hexacopter, singlecopter and octocopter.

Propellers

Propellers are responsible for lifting of the UAV. The propellers have two characteristics i.e. diameter and pitch of the propellers. Pitch of the propellers can be defined as the traveling distance per single revolution. A propeller with lower pitch value is capable of heavy lifting as it generates more torque and the motors do not have to work much harder to carry heavy payloads. As a result the motors will draw less current from the battery and hence the flight endurance time of UAV would increase. Whereas if the propellers with higher pitch values are used then they would not be able to generate much torque and hence would cause turbulence. The flight efficiency of the UAV is dependent on amount of air contacting the surface of the propellers. A large diameter propellers will have more contact with air than the small diameter propellers and hence they are more efficient. Propellers are the motor units that are located on either side of a multicopter. Quadcopters consists of four propellers or motor units, tricopters consists of three propeller units, and hexacopters consist of six propeller units and so on. If you are looking for a UAV for sale or drones for sale, make sure that you check the propellers of a particular drone or quadcopter before investing in it. If you are looking to build your own quadcopter, always seek a low pitch propeller for perfect stability and vibration.

Motor

Motors are the major building blocks of the UAV since the selection of whole power system depends on the selection of motors, therefore it is very important that you consider high quality motors for your drones. The most common type of motor utilized in the making of a multicopter is a brushless motor. The advantage of using brushless DC motor over brushed DC motor is that they are electronically commutated and do not require brushes for commutation. Hence they provide better speed vs. torque characteristics, high efficiency with noiseless operation and very high speed range with longer life.

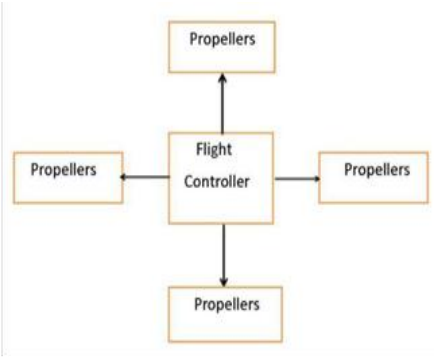
Flight controller

A flight controller is the brain of the UAV. It performs all the mathematical and logical computation based on the input provided to it by the various sensors and user commands and sends signal to the ESC (electronic speed controllers used for controlling the speed of motors) which in turn

makes adjustment in the speed of the motor such that the UAV is balanced and is in control. Many multicopter aficionados refer to the flight controller as the brain of the aerial vehicle. There are various types of flight controllers, namely Naza, KK, WKM, Ardupilot and Rabbit. However, for starters, these flight controllers may be too much. For your own DIY quadcopter project, you can use a gyro sensor instead of a flight controller. Once you are fully acquainted with the features and functions of a flight controller, you can upgrade your old quadcopter.

Power source

It is the power source for UAV that can be of any form such as petroleum, gasoline and electrical power system. Most multicopter experts recommends batteries that too Lithium batteries over petrol and gasoline because they require larger area for storage and are very costly. Whereas electrical power systems like batteries do not require much space and comparatively less costly and provide more energy than the other batteries.



Structure

The common properties of these systems are the freely distributed and modifiable software and hardware and the self- established community around them. The developing process can be really fast in this way , because in some cases (e.g. bad weather conditions for flying) the testing of a new feature is not possible by the programmer but other people can install this feature, test it in real conditions and give feedback to the programmer.

It contains following component-

Description of block diagram and components

In order to make the operation more reliable, more efficient, and less noisy the recent trend has been to use brushless D.C (BLDC)

Sr.No.	componant	Quantity	Specification
1.	Brushless	4	1000 KV Rating
	DC Motors		
2.	Electronic	4	12 A with 1A
	Speed		BEC
	Controller		
	(ESCs)		
3.	Propellers	4	8”x4.5”
4.	Battery	1	11.1 V, 2800
			mAh
5.	Power	1	
	Distribution		
	Board		
6.	Flight	1	Atmega32
	Controller		Microcontroller
7.	Flight	1 each	Gyrometer,
	Sensors		Accelerometer
8.	4-Channel	1	2.4 GHz
	Transceiver		Channel
9.	VGA	1	
	Camera and		
	SD Card		

motors. They are also lighter compared to brushed motors with the same power output. This article gives an illustrative introduction on the working of BLDC motors. Brushless DC electric motor (BLDC motors, BL motors) also known as current does not imply a sinusoidal waveform, but rather a bi-directional current with no restriction on waveform. Additional sensors and electronics control the inverter output amplitude and waveform (and therefore percent electronically commutated motors (ECMs, EC motors) are synchronous motors that are powered by a DC electric source via an integrated inverter/ switching power supply, which produces an AC electric signal to drive the motor. In this context, AC, alternating of DC bus usage /efficiency) and frequency (i.e. rotor speed).

II. Electronic Speed Controller

An electronic speed control or ESC is an electronic circuit with the purpose to vary an electric motor's speed, its direction and possibly also to act as a dynamic brake[30-35]. ESCs are often used on electrically powered radio controlled models, with the variety most often used for brushless motors essentially providing an electronically generated three-phase electric power low voltage source of energy for the motor[36-40].

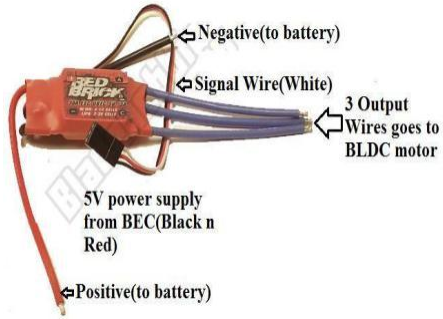


fig3. Electronic Speed Controller

III. Propellers

Propeller is a type of fan that transmits power by converting rotational motion into thrust. A pressure difference is produced between the forward and rear surfaces of the airfoil-shaped blade, and a fluid (such as air or water) is accelerated behind the blade.

fig4. Propellers

IV. Battery

An electric battery is a device consisting of two or more electrochemical cells that convert stored chemical energy into electrical energy. Each cell has a positive terminal, or cathode, and a negative terminal, or anode. The terminal marked positive is at a higher electrical potential energy than is the terminal marked negative. The terminal marked positive is the source of electrons that when connected to an external circuit will flow and deliver energy to an external device. When a battery is connected to an external circuit, Electrolytes are able to move as ions within, allowing the chemical reactions to be completed at the separate
terminals and so deliver energy to the external circuit. It is the movement of those ions within the battery which allows current to flow out of the battery to perform work. Although the term battery technically means a device with multiple cells, single cells are also popularly called batteries

V. Power Distribution Board

A distribution board (also known as panel board or breaker panel) is a component of an electricity supply system which divides an electrical power feed into subsidiary circuits, while providing a protective fuse or circuit breaker for each circuit in a common enclosure. Normally, a main switch, and in recent boards, one or more residual-current devices (RCD) or residual current breakers

with overcurrent protection (RCBO), are also incorporated.

fig5. Power Distribution Board

VI. Flight Controller

The most important component of a multi rotor is its flight controller board. Flight control board has IMU sensors with a microcontroller to perform control task. Now what does it control?

A UAV needs to be stable on 3 axis i.e. pitch, roll and yaw axis so it can hover in midair. The IMU sensors sense the orientation of the aircraft and send the data to micro-controller, microcontroller processes the raw data to estimate the angles and provides error compensation to bring back aircraft to its initial position.

And it does this with amazing speed and accuracy that's why we need a controller for UAVs. UAVs can run both on AVR as well as Arduino based systems. For our drone, we'll be using AVR based ATmega 32 micro-controller.

VII. Flight Sensors

There are two types of flying sensors are being used in our project viz., accelerometer and gyrometer.

Accelerometer:- An accelerometer is an electromechanical device for measuring the acceleration of a moving body. The device measures acceleration force. These forces may be static or dynamic.

By measuring the amount of static acceleration due to gravity, you can find out the angle. The device is tilted with respect to the earth. By

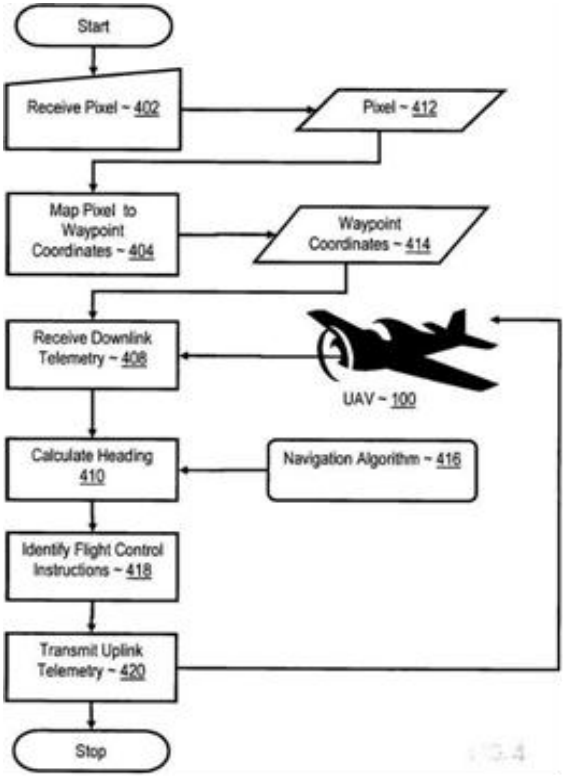
sensing the amount of dynamic acceleration you can analyze the way the device is moving.

Gyrometer:- A gyrometer is a device that uses earth's gravity to help determine orientation. Its design consists of a freely rotating disk called a rotor, mounted on to a spinning axis in the center of a larger and more stable wheel. As the axis turns, the rotor remains stationary to indicate the central gravitational pull, and thus, which way is "down"

WORKING OF DRONE

A typical unmanned aircraft is made of light composite materials to reduce weight and increase manoeuvrability. This composite material strength allows military drones to cruise at extremely high altitudes. Drones are equipped with different state of the art technology such as infra-red cameras (military UAV), GPS and laser (military UAV). Drones can be controlled by remote control system or a ground cockpit. Drones come in a wide variety of sizes, with the large drone mostly used for military purposes such as the Predator drone, other smaller drones which can be launched by hand, to other unmanned aircraft which require short runways. An unmanned aerial vehicle system has two parts, the drone itself and the control system.

The nose of the unmanned aerial vehicle is where all the sensors and navigational systems are present. The rest of the body is complete innovation since there is no loss for space to accommodate humans and also light weight. The engineering materials used to build the drone are highly complex composites which can absorb vibration which decreases the noise produced.
We can see from this above diagram that this work in any type of environment without taking too much time and also without creating noise .it can work in night and day both. And there is no use of any pilot in it also. That's why it is also known as Unmanned Aerial Vehicle



Algorithm of Drone

The electromagnetic spectrum and spectral sensors

Much of the success we have seen in cameras and photography in the last century can be traced back to our understanding of how light properties work. Light interacts with the earth's atmosphere, its plants, and its many diverse surfaces. It is this interaction that spectral sensors and cameras try to capture. Being able to capture these interactions has proven valuable in multiple areas of agriculture.

Light & Electromagnetic Radiation

In the early years of photography, people only had a limited understanding of light and the dimensions involved. The most fundamental understanding came from Sir Isaac Newton's work with light in the 1670s. Newton's work stated that light was composed of

different colors like red, orange, yellow, green, blue, and violet. Newton proved this by splitting white light into those colors by the use of a prism (Newton, 1671). Newton's Theory about Light and Colors was really only the tip of the iceberg when considering the properties of light. One particular advancement in photography came when the connection between James Clerk Maxwell's theory of electromagnetic radiation (EMR) from 1865 was more fully understood and combined with Newton's theory about light .

To understand how photography and modern cameras work, it's imperative to have a basic understanding of Maxwell's theory. Electromagnetic radiation refers to how light emitted from the sun acts more like a wave instead of individual energy particles (Physics University, 2019). The energy of a wavelength, determines how much is absorbed or reflected by our atmosphere, plants, and the earth's surface. Electromagnetic radiation occurs across the electromagnetic spectrum. This spectrum is classified by the characteristics of the different frequencies. These wavelengths or frequencies have been more clearly identified in the last century and have been given mathematical values. Today we often specify a particular region of the electromagnetic spectrum by identifying a beginning and ending wavelength (or frequency) and then attaching a description (Jensen, 2007). Sections of the spectrum are referred to as a band, channel, or region (Jensen, 2007). Additionally, names of these wavelength regions have been assigned and are more commonly referred by their wavelength strength: radio, microwave, infrared, visible, ultraviolet, X-ray, and gamma ray (Figure 1)

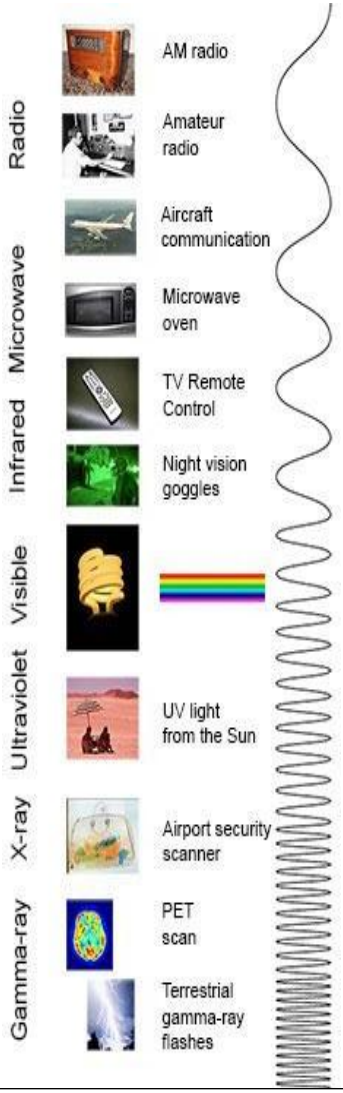


Figure 1. The electromagnetic spectrum from the lowest energy/longest wavelength (at the top to highest

Another important concept to the electromagnetic spectrum is the absorption, scattering, and reflectance of the light wavelengths when they come in contact with the earth's atmosphere and its surroundings. Depending on how much light is absorbed, scattered, or reflected by Earth's elements, determines how certain objects are viewed by the human eye, on film, or as a digital image.
For instance, chlorophyll in vegetation absorbs much of the incident blue and red light for photosynthetic purposes. Most vegetation doesn't absorb the green light, and it is reflected back into the earth's atmosphere (Jensen, 2007). This reaction and combination of absorption and reflectance is what makes most vegetation appear to be green to the human eye. By understanding the basics of the electromagnetic spectrum, a better comprehensive analysis of the types of cameras and sensors used today can be attempted.

Types of Cameras & Sensors

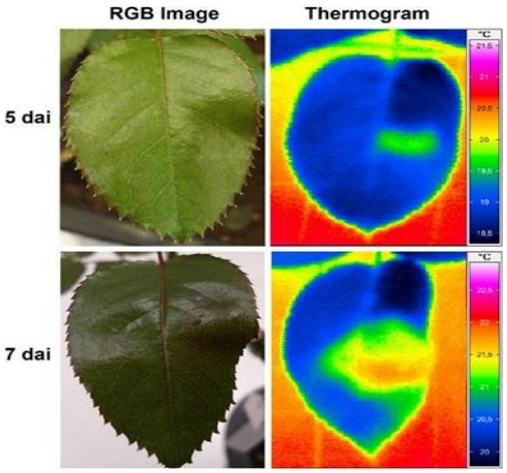
Spectral cameras and sensors are able to view and capture very broad or narrow bands within the electromagnetic spectrum. Combining these spectral sensors with drone technology, a new visual perspective of agriculture can be achieved. In this chapter, examples of different cameras and sensors that have the ability to be attached to a drone will be discussed.
Thermal Sensors

Thermal technology was first developed and used in Britain for anti-aircraft defenses (Monash, 2004). Unfortunately, the development of the images were too slow, and this technology didn't see too much use (Kruse and Skatrud, 1997). Thermal imaging utilizes electromagnetic energy. Any object that has a temperate above absolute zero (0

K) , will emit energy that's detectable in the thermal field (Jensen, 2007). Fortunately, today's engineers have developed thermal cameras and sensors that are sensitive enough to detect thermal infrared radiation (Jensen, 2007). These thermal cameras and sensors now make it possible

to monitor and view what was once invisible to the human eye. Today there are two main types of thermal imaging devices, cooled and uncooled. An uncooled thermal imaging device is the most common. The infrared detector elements are contained in a unit that operates at room temperature. They are less expensive, but their resolution and image quality tend to be lower than the cooled thermal device. In the cooled thermal imaging device, the sensor elements are contained in a unit which is maintained below 0 °C. They have a very high resolution and can detect a temperature difference as low as 0.1 °C, but they are expensive pieces of equipment (Vadivambal and Jayas, 2001). Thermal technology for drones also comes with a hefty price tag. A consumer can expect to pay upwards of $3,500 to $10,000 for some of the popular thermal cameras and sensors available for drone use (MicaSense 2019; and FLIR, 2019).

An issue with many foliar pathogens is that by the time it's detected, the pathogen has already inoculated other nearby plant tissue or has completed its life cycle. This becomes problematic for any disease management plan. With the use of thermal imaging a grower could potentially catch a pathogen early enough to treat, remove, or isolate the infected plant. Caro (2014) attempted just that by monitoring the infection and spread of downy mildew (Peronospora sparsa) on different Rosa cultivars using thermal imaging



Multispectral Sensors

This study is one of many examples that demonstrated the improvements that drone technology and multispectral analysis has seen in last decade. As more research is conducted, additional applications and uses for drone and multispectral sensors will be recognized.

One of the issues with hyperspectral information is how often the term hyperspectral and multispectral becomes interchangeable. The field of spectral imaging is plagued with inconsistent use of
terminology

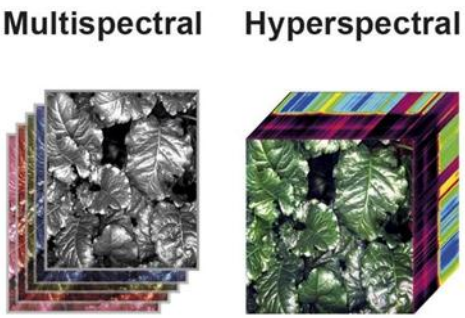


Figure 3.
Difference between Multispectral (Left) and Hyperspectral imaging (right)
Image from: Oerke et al, 2014 (modified image)

Many herbicides, pesticides and fertilizers are used to improve the overall crop yield. Excessive use of these materials should be avoided to minimize environmental impacts. Hyperspectral imagery is helping to reduce the amount of products being used in the environment (OSU, 2003). Cilia et al (2014) used airborne hyperspectral imagery to develop variable rate nitrogen fertilizer maps. Multiple corn fields were analyzed using hyperspectral sensors in hopes to reduce or to better utilize the nitrogen fertilizer. The study proved that airborne hyperspectral imagery can be used to detect N deficient areas in corn crops (Cilia et al, 2014).

LiDAR

Agricultural land comes in all shapes and sizes and is topographically diverse. Being able to accurately map these agricultural fields is a challenge. As technological advancements have improved, our abilities to more accurately create and map different ecological regions of agriculture has also improved. With the development of Light Detection and Ranging (LiDAR), the
ability to map and digitize topographic changes became possible. LiDAR technology can be used to provide elevation data that is accurate, timely, and increasingly affordable in hospitable or inhospitable terrain (McGlone, 2004). Additionally, LiDAR offers an

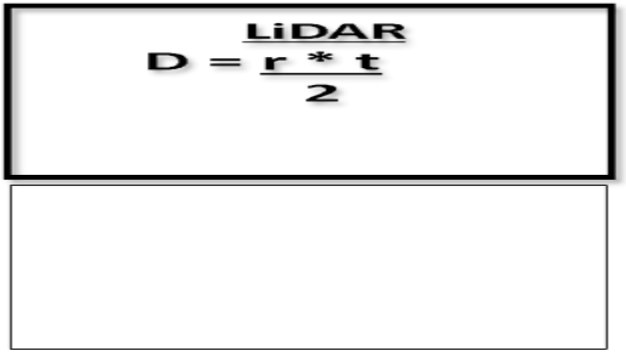


Figure 4.
D = Distance from the sensor to the target r = rate of speed (speed of light = 3x108 m/s)
t = time is takes for laser to return Note: time is divided by 2 because the laser light must travel to the object and

Drone applications

Drones are used in many areas and what's more, there is no end when it comes to their possibilities. Therefore, the areas of applications are numerous today and there is the growing use of drones all around the world.

Main areas of applications

1. **Search and rescue:** One of the important applications of drones is using them in search and rescue missions. In search and rescue operations, every second is vital. In order to function as efficiently as possible, it is important to be able to obtain a rapid overview of the situation. While manned airplanes and helicopters need time to be ready for doing the mission, drones can be put into action immediately without any loss of time. Because of the important role of drones in search and rescue missions, they attracted the attention of many researchers. To this end, several drones were designed and fabricated for performing this type of missions. Drones are very useful in searching and rescuing operations. For example, they are used in fire fighting to determine the amount of the certain gasses in air (CO, CO_2, and the like) using the special measuring equipment.
2. **Security:** Many authorities use drones to protect people during various emergencies. For instance, they are able to help coordinate a variety of security operations and can preserve evidence alike
3. **Inspections:** Many systems such as power lines, wind turbines, and pipelines can be checked by drones

4. **Surveillance:** A drone allows recording and monitoring from the sky, and therefore, they are suitable to monitor public events, protests, or any suspicious happening without being heard and seen. A great tool for the police!
5. **Science & research:** They help scientists a lot in research works to observe different occurrences in nature or a particular environment from the sky. For example, drones are used to document the archaeological excavations, in nuclear accidents, in glacier surveillance, to observe a volcanic eruption, etc.
6. **Aerial photography & video (recreation):** With a drone that is equipped with an HD camera, you can take the fascinating photos and shot footage of great quality from the sky
7. **Surveying & GIS (mapping):** Using multi-spectral cameras and laser scanners, drones are able to create high-quality 3-D maps. Therefore, they found applications in various areas, including remote sensing, surveying & mapping, photogrammetry, precision agriculture, etc.
8. **Unmanned cargo system (commercial):** Drones also serve in delivering of lightweight packages and bundles of all sorts. This way, you can have a safe, environmentally friendly and fast transport of goods by air
    - **Real estate:** Real estate professionals want to use UAS to enhance the marketing of properties
    - **Journalism:** Journalism schools have explored using UAS to cover stories where access is hazardous, such as a natural disaster
    - **Filmmaking:** The Motion Picture Association of America wants filmmakers to be able to use UAS to more safely and efficiently capture difficult shots
9. **Environmental protection:** Although drones are considered as a vital part of military missions, they are also being increasingly used for performing environmental actions, such as managing national parks and agricultural lands, tracking wildlife in different areas, observing the effects of climate change, and monitoring the biodiversity of different ecosystems from rainforests to the oceans [195]. These drones can be used for recognition and investigation of natural disasters including forest fires, avalanches on mountains, etc.

Agricultural drones

Agricultural drones are drones applied to farming in order to help increase crop production and monitor crop growth. Through the use of advanced sensors and digital imaging capabilities, farmers are able to use these drones to help them gather a richer picture of their fields. Information gathered from such equipment may prove useful in improving crop yields and farm efficiency.

Agricultural drones allow relief for the modern day farmer. Drone technology can cut down labour requirements and reduce resource requirements. Farmers are also able to use drones to retrieve aerial-view images of their fields. Visualizing its potential, first Japan Govt. deployed drones for pin pointing cause for dwindling of rice farmer in1986. About 35% of Japan's rice fields' pest control is being accomplished with UAV. Now, Ministry of Agriculture, Forestry and Fisheries are focusing vigorously on use of drone in area of agriculture.

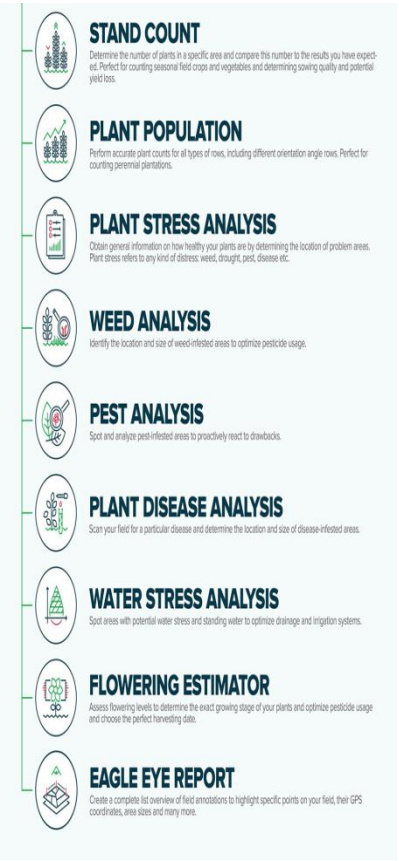
Why one should select drone for farming????

1. The distinct feature of drones like low cost of operation, low elevation operation with hovering ability, light weight, ground station full control, efficient communication and operational ease may be harnessed for agricultural production, management and planning.
2. The autonomous and stabilized flight of drones with navigation sensors and even low cost multi spectral or hyperspectral camera is able to geo decode aerial photographs of higher resolution of 1-2cm, a relatively better image resolution than that of any satellite based images because they covers larger areas like globe and attaining up-to date information is expensive and having low resolution power (63cm) and it is affected by cloud cover.
3. Whereas drones are giving very high pixels resolution, independent of cloud cover factors during critical periods of growth and instant information communication to the user. UAV can be operated at lower height and knitting with modern cost effective sensors can gather more precise information with lesser complexity. In this way, this platform may be resourceful for generating reliable agricultural statistic of site and time specific.
4. The data can generate firm base for precision agricultural technologies e.g. variable rate application of fertilizer, pesticide, irrigation and other agricultural inputs. In turn, it may be proven

effective tool for enhancing input use efficiency, profitability as well as protecting ecosystem.

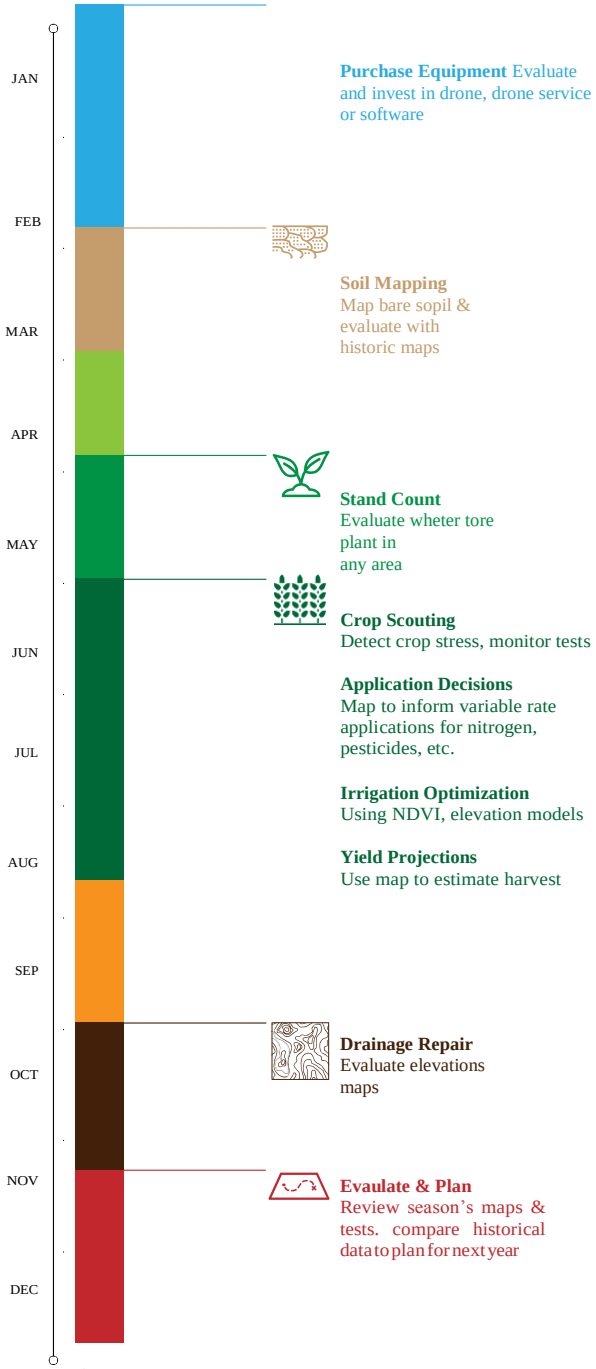
5. Apart from generating information of crop and land the UAV platform has potential for application of pesticides and fertilizers more judicious and safe manner. Tall crop canopy of sugarcane, pigeon pea, horticultural crop etc. has proven problematic for efficient spraying operation with conventional farm machines. In wet land condition, ground moving machines also induces adverse impact such as hardpan development. 6.
6. Impact assessment data through drone of natural clematises e.g. drought, flood, hailstorm etc. may be useful for crop insurance or policy planner as it can provide data more precise and reliable.
7. The innovative UAV platform for farming may lure to rural youth which diminishing, as it having the comfortable working environment. Along with that the spectral reflectance and thermal emittance properties of soils and crops to their agronomic and biophysical characteristics may be exploited for non-destructive monitoring of plant growth and development and for the detection of many environmental stresses which limit plant productivity through remote sensing methods. Apart from this
8. Drones are affordable, requires a very modest capital
9. They can pay for themselves, and start saving money within a single growing season.
10. Operation is relatively simple.
11. They are easy to integrate into the regular crop-scouting workflow; while visiting a field to check for pests or other ground issues, the drone can be deployed to collect aerial data.
12. It's hard to beat the immediacy and convenience of planning the mission, collecting the data, and getting near real-time results; only drones offer these benefits.

The most compelling reason for using drones is that the results are on-demand; whenever and wherever needed, the drone can be easily and quickly deployed



Prepare for the Busy Season with a Flight Calendar

Flying at regular intervals creates a consistent record of what a field looks like over time and gives you more information to work with when it comes to making those big, mid-season decisions. How often you fly is going to depend on your crops, the size of your fields, their distance from your central location, and your specific data needs. But regardless of how often you plan to fly, if you head into the busiest months with a pre- established calendar, you'll be more likely to stay consistent even when things get busy. We've included a sample flight calendar below.



Prepare for year-round drone mapping with a pre-established seasonal flight calendar. That way, you'll be more likely to stay consistent even when things get busy

There are currently three different types of view provided to the farmer through a drone, they are as follows

a) **Birds' eye view:** drones are capable of seeing a crop from a bird's eye view. This particular view can reveal many issues such

as irrigation problems, soil variation, and of course, pest and fungal infestations in the field.

b) **Multispectral images:** These images are used to show an infrared view as well as a visual spectrum view. When these views are combined, the farmer is able to see the differences between healthy and unhealthy plants. This difference is not always clearly visible to the naked eye, so having the ability to see the crops from these views can assist the farmer with assessing crop growth, as well as crop production.

c) **Multitemporal analysis:** Drone can survey the crops for the farmer periodically to their liking. From a choice of weekly, daily, or to each hour, the farmer is able to use this information to show the changes in the crops over time, thus showing where there might be some "trouble spots". This proves to be a key benefit because by identifying these trouble spots, the farmer can then attempt to improve crop management and improve the overall production of their crop.

Working of drone

At first we have to mark the field in which drone should operate on our PC or mobile or tablet. Then drones will start its work in the field and capture the images of the target areas with the help of Multispectral camera sensors. The images obtained is to be analysed using software in order to get the precise information. Here we can see the major patrollers are the cameras, sensors and software's, which give detailed information about the field.

Technology used in agricultural drones

1. **Low altitude remote sensing technology (LARS):** A relatively new concept of acquiring earth surface images at a low altitude using unmanned aerial systems (UAS) is promoted platform to monitor crop growth, crop stress, and to predict crop yield.
2. **Multispectral camera remote sensing imaging technology:** This technology use Green, Red, Red-Edge and Near Infrared wavebands to capture both visible and invisible images of crops and vegetation.

- Multispectral images are a very effective tool for evaluating soil productivity and analyzing plant health. Multispectral sensor technology allows the farmer to see further than the naked eye.

Sensors used

Multi-spectral: plant health assessment, water quality assessment, estimation of vegetation index, estimating plant population.

Thermal: Heat signature detection, livestock detection, surveillance and security, water temperature detection and water source detection.

LIDAR: Surface variation detection and flood mapping, plant height measurements from plant canopy and ground below.

Hyperspectral: Plant health measurement, water quality assessment, estimating vegetation index, spectral research and development, mineral and surface composition surveys.

Some of the major sensors using in agriculture drones are,

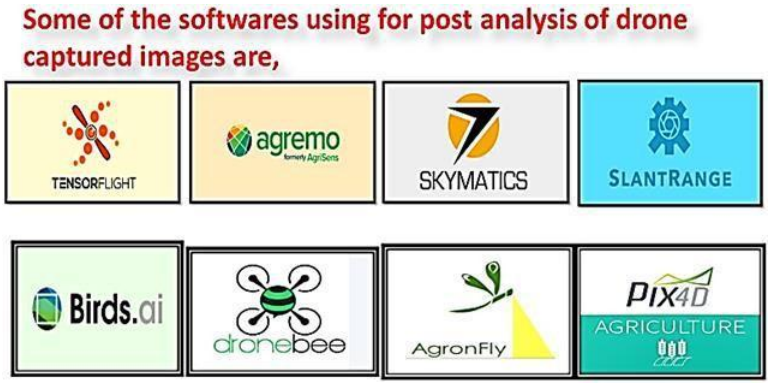
SENTERA | ADC Lite Mica sense red-edge | ARINOV multi SPEC | Parrot sequoia

Note:

Sentera: Generates map, process sensor data and gain NDVI insights.

Mica sense: Produce chlorophyll and weed detection map, identify diseases and highlights stress variations.

Integrated specialized software's: Software is the key component to get the Result by a drone. Which perform pre-processing and Post-analysis.



Applications of drones in agriculture

1. Soil and field analysis

Drones can be used for soil and field analysis. They can be used to produce accurate 3-D maps that can be used for early soil analysis on soil property, moisture content, and soil erosion. This is very important in planning seed planting patterns. Even after planting, drone-driven soil analysis provides data for irrigation and nitrogen-level management in the soil.

2. Planting

Though not quite prevalent just yet, some manufactures have come up with systems able to shoot pods with seeds and plant nutrients into the already prepared soil. These drone-planting systems will decrease planting costs by 85 percent.

3. Crop spraying

Distance-measuring equipment's like ultrasonic echoing and lasers drones can adjust altitude with a change in topography and geography. Their ability to scan and modulate its distance from the ground enables them to spray the correct amount of the desired liquid evenly in real time. This results in increased efficiency with a reduction in amount of chemicals penetrating into groundwater. In fact experts estimates that spraying using drones will be proven 5 times faster than the traditional methods.

4. Crop monitoring

One of the largest obstacles in farming is inefficient crop monitoring of vast fields. Monitoring challenges are made worse by the rise of unpredictable

weather patterns which leads to increased risk and maintenance cost. Previously, satellite imagery offered the most advanced form of monitoring. But there were drawbacks. Today drones equipped with surveillance technology, creating time series animations that can show the precise development of a crop and reveal production inefficiencies, enabling better crop management.

5. Irrigation

Drones with hyper spectral, multispectral, or thermal sensors can identify which parts of a field are dry so water resources can be allocated much more economically i.e. more water for the dry areas and less for the wetter once. Additionally, once the crop is growing, drones allow the calculation of the vegetation index, which describes the relative density and health of the crop, and show the heat signature, the amount of energy or heat the crop emits.

6. Health assessment

It's essential to assess crop health and spot bacterial or fungal infections on trees. By scanning a crop using both visible and near-infrared light, drone-carried devices can identify which plants reflect different amounts of green light and NIR light. This information can produce multispectral images that track changes in plants and indicate their health. A speedy response can save an entire orchard. In addition, as soon as a sickness is discovered, farmers can apply and monitor remedies more precisely.

7. Mid-field weed identification

Using NDVI sensor data and post flight image data we can create weed maps that will help the farmers in easily differentiate the high weed intensity areas from healthy crop areas which are growing alongside them.

8. Cattle herd monitoring

Drones with thermal sensors are the solid option for monitoring herds from overhead, they see whether animals are missing, injured or birthing. Thus drones give livestock farmers a new way to keep an eye on their livestock at all the times resulting greater profits.

9. Crop insurance

Aerial imagery can be used to quickly classify surveyed areas into cultivated and non-cultivated land, and to assess how much damage has been caused by natural disasters. Crop insurers and insurance policy holders also benefit from readily-available and easily repeatable drone imagery. In India, insurers are planning to use UAVs to conduct assessment of crop losses after

natural disasters, allowing them to more accurately and quickly calculate pay-outs. They can use the same data to construct statistical models for risk management, based on historical yield, pest, and weather data. Drone data might also be useful for the early detection and prediction of pest infestations, data that insurance companies could share with farmers. Finally, drone data can be used to detect insurance fraud, preventing fraudsters from insuring the same piece of land multiple times, or claiming damage where there is none.

Drones and precision agriculture

Precision agriculture

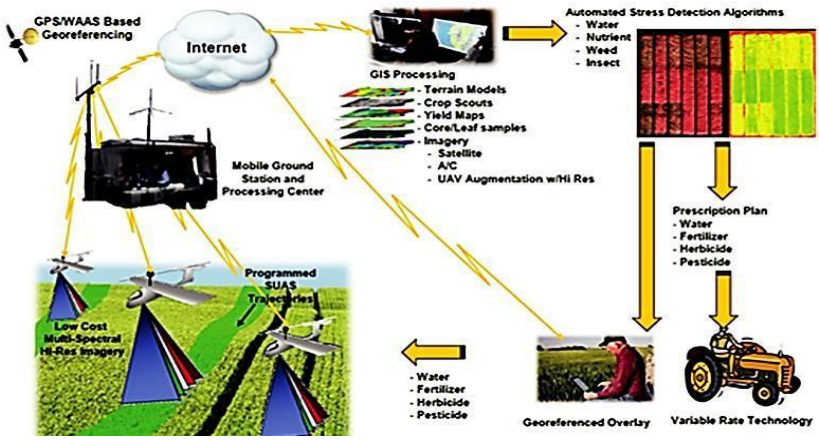
Precision agriculture is an agricultural production system based on the information and technology which is used for the purpose of determine, analyze and manage of the factors such as temporal and spatial variability in the field to obtain maximum profit, sustainability and environmental protection (Unal *et al*., 2013).

Need of advanced technologies in precision farming

India is categorized by small-scale farms. Furthermore 80% of total agriculture land in the country is divided into pieces of less than 5 acres. The majority of the crops are depends on rain, with just around 45% of the land irrigated. It determines that around 55% of total population of India depends on farming which is dependent on rain. Due to poor availability of funds, agriculture inputs like fertilizers, irrigation, seeds and pesticides, no farm insurance, terrible support price structure for the mass- produce, most of the farming is un-remunerative and more than half of the farmers in India are in debt. This is the vital basis behind the more farmer suicides. Again in some part of the country, due to intensive production and mechanization in the latter half of the last century it was not possible to take care of the within field spatial variability. So these developed area required advanced PF technology to be applied. Wealth and security of the nation come from its land and hence its need to be sustainable, innovative and high- productivity agriculture which will be profitable and provide both food and energy security for the country. Hence, it is believed that some advance farming technologies will help to promote the next green revolution to Indian agriculture.

- Agricultural drones are used for precision agriculture, which is a modern method of farming that uses big data, aerial imagery and other means to optimize efficiency
- By generating detailed insights, farmers can make data-based

decisions that will optimize yield and boost revenue while minimizing expenses and the chances of crop failure.



Drone based PA process

These UAV's leverage the precision agriculture approach that includes crop monitoring which provide farmers real time data about the plant health and crop spraying chemicals over the field. This innovative approach can help the farmers to save their crops from the threats like weeds, insects or diseases and helps in increase the yield quality.

Precision agriculture-advantages by using drones

- Optimization of the treatments
- Reduction and prevention of waste
- Reduction of labour and material costs
- Reduction of pollution
- Reduction of the risks

Benefits of drones in agriculture

- Automatic piloting and operations
- Automatic analysis for real-time decisions
- Increase of precision in remote sensing
- Advanced integration with sensor networks and robots on the ground
- It can be deployed quickly and repeatedly thus it saves the time
- can obtain imagery at sub-decimetre resolution
- Highest economic benefit (improve the yield and profitability)
- Spot disease/problems faster
- Reduces waste of water, chemicals other inputs

- They could limit the amount of pesticide sprayed
- Environmental friendly
- We can plan for the future because it generates maps accurately for better crop planning and land management
- Cost effective
- Drones are ethical, as they are used for their predetermined motive, and are not used to cause any kind of harm to the plants and animals
- UAVs have several advantages over satellites and piloted aircraft: they can be deployed quickly and repeatedly; they are less costly and safer than piloted aircraft; they are flexible in terms of flying height and timing of missions; and they can obtain imagery at sub-decimetre resolution. This hyper spatial imagery allows for quantification of plant cover, composition, and structure at multiple spatial scales

Limitations

Weather dependencies: weather is constantly changing and drones are vulnerable to these conditions. Severe weather interrupts drones.

- Wind speed-they may cause turbulence
- Very low and very high temperatures affect the sensors
- Precipitation-heavy rain intercepts radio signals

a. Flight time and flight range

There are some problems with drones in agriculture. Most of the drones have a short flight time of between 20 minutes to an hour. This makes limits the acreage that it can cover for every charge. The flight range also limits the radius that can be cover during every flight time. Drones that can offer longer flight time and longer range are relatively costlier.

b. Initial cost of purchase

Drones with the features that qualify them for use in the agricultural are quite costly. This is mostly so for fixed wing drones which could cost up to $25000 (Precision Hawk's Lancaster). For some drones, the heavy cost is inclusive of hardware, software, tools and imaging sensors. Buying drone that does not come equipped with the necessary equipment could be cheaper. However, the desired cameras and the processing software are quite costly making it equally capital intensive. Purchasing drones equipped for use in agriculture could prove costly in the short run but worthwhile in the long run.

c. Federal laws

The use of drones for agriculture purposes is considered commercial. This means the farmer needs to undergo FAA operator training so as to acquire a remote pilot certificate or hire an operator with such qualifications. FAA also demands that drones be flown at an altitude of not more than 400 feet.

d. Interference within the airspace

Agricultural drones share the same airspace with manually manned aircraft. Hence they are prone to interference. It's, therefore, advisable the farmer files his/her flight plan with the local airport or the FAA before the flight.

e. Connectivity

Most of the arable farmlands have very little online coverage if any. This means that any farmer intending to use drones has to invest in connectivity or buy a drone capable of capturing and storing data locally in a format that can later be processed.

f. Knowledge and skill

The images require analysis by a skilled and knowledgeable personnel for them to translate to any useful information. This means an average farmer without these skills may need training or may be forced to hire a skilled personnel conversant with the analysis software to help out with the image processing.

g. Personal privacy encroachment fears

Farmers fear that their personal privacy is jeopardized when they start using Drones. They believe Drones expose their lands to the general public space. The primary reason is the Drones' link to the internet. When people see Drones above the bottom, they presume they are watched. Other individuals document issues when they see Drones because they feel threatened. Even if the FAA mandates guidelines to modify every resident's privacy, there are still violators that continue to invade other's personal space.

Drone technology keeps improving every day. With many manufacturers entering the industry, it's hoped that the cost of the drones and the accompanying equipment will reduce. Limitations like flight time and range are also expected to be solved by an improvement in technology. These improvements will ensure that farmers reap more from the use of drones.

Drones in India

SENSAGRI: sensor based smart agriculture: Drone technology based unmanned aerial vehicle (UAV) has ability for smooth scouting over farm fields, gathering precise information and transmitting the data on real time basis. This capability could be used for the benefit of farming sector at regional/local scale for assessing land and crop health; extent, type and severity of damage besides issuing forewarning, post-event management and settlement of compensation under crop insurance schemes.

The Indian government has launched a collaborative research project involving use of drone technology in farming sector for assessing quality of soil and compensation for losses due to flood, the Ministry of Agriculture said in a Lok Sabha query. The project aims to implement Hyperspectral Remote Sensing using drone systems and developing a locally researched prototype for soil health monitoring and integrating it with satellites for large scale agricultural applications in the future. This technology could also be integrated with satellite-based technologies for large scale applications Drones will soon be seen scouting over farm fields in India, gathering required geographical data using sensors, pictures, etc. and transmitting such information in real time. This technology will be used primarily in farming sector at regional/local levels for assessing land and crop health; extent, type and severity of damage, issuing forewarning, and settlement of compensation under crop insurance.

Drones regulations in India

The Directorate General of Civil Aviation (DGCA) has come up with draft regulations on civil use of drones which will also enable commercial use of drones for tasks like photography, agriculture, doorstep delivery and even passenger transport.

The government has designed the rules according to the size of the drone being flown

Classification	Size
Nano	less than 250gm
Micro	250gm to 2kg
Mini	2kg to 25kg
Small	25kg to 150kg
Large	greater than 150kg

Nano drones-those that weigh under 250 grams and can't fly at higher than 50 feet-all others must be registered with the DGCA and acquire a Unique Identification Number. Drones that weigh over 2kgs will require an air

defence clearance. And the remote pilot for any drone must be at least 18 years old and have gone through a prescribed training process.

Following are the regulations given by directorate general of civil aviation (DGCA)

- Every drone sold in India must have a unique identification number
- Every person flying a drone must have a permit
- Flying a drone below 200 feet from ground level, a permit from local administration is required
- If the flying is above 200 feet, permission from the DGCA is needed
- An remote pilot for any drone must be at least 18 years old

No drone zone area

- Area within 5 km from an airport
- Within 50 km from international border
- Beyond 500 metres into the sea along the coastline
- Within 5 km radius from Vijay Chowk in Delhi
- Over eco sensitive areas like national parks and wild life sanctuaries.
- Several other countries have allowed the use of drones, US announced its rules in June 2016
- Number of African nations-Kenya, Uganda, Rwanda, Malawi, and more have make use of drones to alert farmers
- In China, using drone in crop-spray is already a reality
- India, predicted to be one of the most promising economies in the next few years, gears up to bring affordable technology to its farmers
- The rules will come as a relief for Indian e-commerce companies who can potentially skip the country's crowded roads and traffic jams to make timely deliveries
- Flipkart has been convincing the government in this regard since 2015
- Amazon, which made its first public drone delivery in the US in March 2016, filed a patent application for certain markers that it will deploy to facilitate deliveries using drones in India

Drone market

- A report published by the Association for Unmanned Vehicle Systems International (AUVSI) indicates agricultural drones are expected to capture 80% of the commercial UAV market
- The worldwide market of drones for civilian use: $609 million in 2014 and forecast to reach $4.8 billion in 202 (Bybordi and Reggiani, 2015)

After viewing the information acquired by the drone, the grower made four key decisions

- The grower will be planting the variety of potatoes from the northern section of his field
- He has identified that his planting machine needs an upgrade
- His planting machine's settings need to be updated and recalibrate
- The aerial NDVI imagery provided by drone deploy enabled him to make very accurate yield projections for himself and the wash house

Reasons Why the Utilities Industry Should Be Employing Drones

One of the fastest growing sectors in the U.S.,1 Unmanned Aircraft Systems (UAS), or drones, are being used across commercial industries as a more efficient and cost-effective option.

1. Cost-effective Inspections

Until recently, methods of surveying, detecting and locating leaks and repair issues have been inefficient and costly to conduct. Drones can help reduce the expense of carrying out inspections, especially in the case of hard to reach equipment, power lines, gas lines, railroads and highways. It has been estimated that drones could cut aerial inspections costs up to 50 percent.2

2.Worker Safety :

UAS applications allow for safe 3D mapping of drill sites, gas pipelines, landfills and other hazardous municipal operations. Researchers have concluded

that the use of drones could improve worker safety for routine inspections ranging from remote areas to dense cities, and for surveying damage to

energy networks after natural disasters, etc.3

3. Data Collection Efficiency

Drones offer speedier data retrieval than traditional ground or air (i.e.

helicopter) observation. A single drone provides a much quicker way to capture the same type of data

and photos that two or three workers would take several hours to produce. Moreover, drones can digitize that data and turn it into something operators on the ground can analyze almost instantly.

4. Improved Inspections

Drone functions like imagery, mapping and LIDAR, a surveying technology that uses a laser light to measure distances, could help reduce the difficulty of inspecting hard-to-reach areas. UAS equipped with cameras can access difficult to reach areas for closer visual inspections than humans have been able to previously, due to visual line of sight and safety reasons.

5. Accurate Data

The innovative things that utilities do with the data they capture will create a competitive advantage for their organization. Drones can glide over rugged terrain, where it's hard for utility workers to get around, and send back images showing the condition of power lines and pipelines to flag major issues to the ground team. UAS can also obtain more detailed images because they're able to hover in the air longer than standard helicopter fly-bys.4

6. Scale Down Environmental Footprint

UAS applications can significantly reduce the environmental impact of certain utility operations, from wind turbine inspections to long-range deliveries. Methane sensors, for example, can be used to detect and measure methane gas leaks and reduce methane emissions.5

7. Develop Better Use of Resources

Effective use of resources is an essential part of business sustainability. For staying on schedule, making quick and accurate decisions or assessing an important situation, drone services may be the solution your organization needs.

Drone Certification :

Conclusion

Over the past decade there has been a growing number of examples of applications of drones in farming. However, there are still some crucial limitations related to drones including high initial costs, sensor capability, strict aviation regulations and lack of interest from the farmers may impede adoption of drones. Hence it is clear that the application of drones in farming is still in its early stage and maybe there is a considerable amount of room for further development concerned to both the technology and the various applications. Providentially, it is expected that with the development of drone technology, improved image processing techniques, lower costs and may allow drones to hover like tractors in future farms.