

**Draft Study Material**



**KISAN DRONE OPERATOR**  
**(Qualification Pack: Ref. Id. AGR/Q1006)**  
**Sector: Agriculture**  
**(Grade XII)**



**PSS CENTRAL INSTITUTE OF VOCATIONAL EDUCATION**  
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## Preface

Vocational Education is a dynamic and evolving field, and ensuring that every student has access to quality learning materials is of paramount importance. The journey of the PSS Central Institute of Vocational Education (PSSCIVE) toward producing comprehensive and inclusive study material is rigorous and time-consuming, requiring thorough research, expert consultation, and publication by the National Council of Educational Research and Training (NCERT). However, the absence of finalized study material should not impede the educational progress of our students. In response to this necessity, we present the draft study material, a provisional yet comprehensive guide, designed to bridge the gap between teaching and learning, until the official version of the study material is made available by the NCERT. The draft study material provides a structured and accessible set of materials for teachers and students to utilize in the interim period. The content is aligned with the prescribed curriculum to ensure that students remain on track with their learning objectives.

The contents of the modules are curated to provide continuity in education and maintain the momentum of teaching-learning in vocational education. It encompasses essential concepts and skills aligned with the curriculum and educational standards. We extend our gratitude to the academicians, vocational educators, subject matter experts, industry experts, academic consultants, and all other people who contributed their expertise and insights to the creation of the draft study material.

Teachers are encouraged to use the draft modules of the study material as a guide and supplement their teaching with additional resources and activities that cater to their students' unique learning styles and needs. Collaboration and feedback are vital; therefore, we welcome suggestions for improvement, especially by the teachers, in improving upon the content of the study material.

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## Module 1

## Drones in Agriculture

### Module Overview

This module consists of two comprehensive sessions aimed at enhancing understanding of both traditional and modern agricultural practices. The first session on principles of crop production and management, demonstrates the essential aspects of effective crop management, including soil fertility, crop selection, irrigation, pest control, and harvesting techniques. You will learn how to optimize resources and implement best practices to improve crop yields while maintaining soil health. The session also emphasizes sustainable practices to ensure long-term productivity and environmental protection.

The second session on applications of drones in agriculture, introduces the cutting-edge role of drone technology in modern farming. This session explores how drones can revolutionize precision agriculture by enabling efficient crop monitoring, disease detection, aerial spraying, and data analysis. You will gain hands-on knowledge of how drone imagery, combined with tools like the NDVI, can enhance decision-making and improve farming efficiency. Together, these sessions provide a well-rounded foundation in both traditional agricultural principles and the latest technological advancements.

### Learning Outcomes

After completing this module, you will be able to:

- Identify the stages of crop growth and understand the factors influencing crop development, including environmental, biological, and management factors.
- Explain the importance of soil health, fertility, and water management in crop production.
- Apply crop production principles to local conditions and stay updated on the latest agricultural advancements.
- Apply techniques for seedbed preparation, planting methods, and sowing times for various crops.
- Explore the use of modern technologies, such as precision agriculture, to enhance crop production efficiency and sustainability.
- Identify and explain the key components of agricultural drones, including sensors, cameras, GPS, and control systems.

- Describe the role of drones in precision agriculture, including site-specific crop management, variable-rate application of inputs, and optimized resource use.

## Module Structure

Session 1: Principles of Crop Production and Management

Session 2: Applications of Drones in Agriculture

### Session 1: Principles of Crop Production and Management

Crop production and management refers to the process of growing crops efficiently and sustainably, involving a set of practices aimed at **maximizing yield, quality, and long-term soil health**. It encompasses various agricultural techniques such as soil preparation, seed selection, irrigation, nutrient management, pest control, and harvesting. The goal is to ensure optimal growth conditions for crops while minimizing resource wastage, environmental impact, and risks to productivity. Effective crop production and management integrates **scientific knowledge and practical methods to achieve sustainable agricultural outcomes**.

In this session, you will study the **core principles of crop production and management**, essential for enhancing agricultural productivity and sustainability. These principles include understanding soil health, crop rotation, pest control, and irrigation practices. By examining how these factors interact, we can influence crop yield and quality, while also emphasizing the importance of adopting best farming practices.

Drones are revolutionizing agriculture, offering farmers new tools to improve productivity and sustainability. With ongoing technological advancements, drones are playing an increasingly vital role in modern farming, enabling more informed decision-making. This session will also help you to understand the growing significance of drones in agriculture and their potential to implement the various principles of crop production and management and shaping the future of farming.

In today's era, drones are transforming agriculture by addressing traditional farming challenges, enhancing efficiency, and enabling sustainable practices. This module will focus on the various applications, benefits, and future potential of drones in agriculture.

The principles of crop production and management are guidelines that help farmers optimize crop growth, productivity, and sustainability. These principles, rooted in both scientific research and practical experience, support decision-making



throughout the crop production cycle. Now let us discuss the key principles, which are illustrated below:

- i. **Crop Selection:** Choosing the right crops for a region based on climate, soil, resource availability, and market demand is crucial for maximizing yields and reducing risks.
- ii. **Soil Management:** Sustainable soil practices improve fertility and long-term productivity. Techniques like ploughing and levelling and creating ideal conditions for crop growth while conserving soil health are important aspects of soil management.
- iii. **Seed Selection and Quality:** High-quality seeds, chosen for purity, viability, and resistance to pests and diseases, are critical for crop success. Farmers should source seeds from trusted suppliers.
- iv. **Irrigation Management:** Efficient water use, tailored to soil type, climate, and crop needs, is essential. Proper irrigation timing helps prevent water stress and ensures optimal growth.
- v. **Nutrient Management:** Balancing organic and inorganic fertilizers based on soil testing helps maintain soil fertility and provides crops with the nutrients they need for healthy growth.
- vi. **Pest and Disease Management:** Integrated Pest Management (IPM) strategies, including biological control and selective pesticide use, minimize pest damage and protect crop quality.
- vii. **Weed Control:** Techniques such as timely weeding, mulching, and herbicides manage weed growth and reduce competition for nutrients.
- viii. **Crop Rotation and Diversification:** Rotating crops helps maintain soil fertility and break pest and disease cycles, promoting long-term agricultural sustainability.
- ix. **Harvest and Post-Harvest Management:** Proper timing and techniques during harvest and post-harvest activities preserve crop quality, minimize losses, and ensure market compliance.
- x. **Environmental Stewardship:** Sustainable farming practices, such as conservation agriculture, reduce soil erosion, preserve water, minimize greenhouse gas emissions, and support biodiversity.

Following these principles helps farmers improve crop production, conserve resources, and support sustainable agriculture. By adapting these practices to local conditions and incorporating new technologies like drones, farming efficiency can

also be significantly improved. Drones enhance these traditional farming methods by providing more precise crop monitoring, targeted pesticide application, and real-time data for informed decision-making. The integration of drones has marked a new phase in precision farming, boosting efficiency and sustainability. These aerial devices provide vital data to help farmers make informed decisions, optimize resources, and increase crop yields. As drone technology evolves, its applications in agriculture will expand, making it an indispensable tool for modern farming.

## Activities

**Activity 1:** Visit to an agricultural farm for studying the various crop production techniques in agriculture, such as, soil testing, crop identification and cultivation, pest identification and control, weed identification and control, harvesting of crops, planting methods, etc. Let us take an example of planting method. Learn about common planting methods and the factors influencing the choice of planting method. Some of the common methods and factors are as follows:

- **Planting methods:** Direct seedling, transplanting, container planting, broadcast seeding, etc.
- **Factors influencing planting method:** Climate and environmental conditions, soil characteristics, resource availability etc.

You can take the help of a search engine or an App on your computer or mobile to identify the pests. Take notes of your observations in the agriculture field and include it in your diary or portfolio.

**Activity 2:** Sustainable farming practices are methods and approaches that aim to minimize environmental impact, promote economic viability, and maintain the long-term health and productivity of the land. Write in brief on the following aspects that the farmers or agricultural enthusiasts should learn:

- Crop management
- Livestock care
- Challenges faced by farmers
- Innovative solutions in agriculture

## Check Your Progress

### A. Multiple Choice Questions

1. How do drones assist in crop health assessment?
  - a) By planting seeds
  - b) By providing real-time aerial imagery for crop health assessment
  - c) By monitoring weather conditions
  - d) By delivering fertilizers

2. What is a significant advantage of using drones for applying fertilizers and pesticides?
  - a) Increased labour costs
  - b) Decreased crop yield
  - c) Enhanced ability to apply fertilizers and pesticides accurately
  - d) Manual application
  
3. In what way can drones identify water stress in crops?
  - a) By measuring soil moisture directly
  - b) By providing weather forecasts
  - c) By using thermal imaging to identify water stress areas in crops
  - d) By monitoring pest populations
  
4. How do drones help in the early detection of pest infestations and diseases?
  - a) By applying pesticides automatically
  - b) By using sensors to detect pest infestations and diseases early
  - c) By conducting soil tests
  - d) By measuring air quality
  
5. What technology allows drones to analyse soil health?
  - a) Manual soil sampling
  - b) Drones can analyse soil health through remote sensing technologies.
  - c) Traditional soil testing methods
  - d) Weather forecasting tools
  
6. How do drones contribute to monitoring soil health and crop performance over time?
  - a) By providing aerial tours of fields
  - b) By monitoring soil health and crop performance over time
  - c) By applying fertilizers
  - d) By planting cover crops
  
7. In what way can drones assist farmers in determining optimal harvest timing?
  - a) By providing weather predictions
  - b) By monitoring crop readiness and optimal harvest timing
  - c) By analysing market prices
  - d) By counting crop yield
  
8. How can AI be utilized by drones in agriculture?
  - a) By sorting and grading crops automatically using AI
  - b) By planting seeds
  - a) By measuring rainfall

- d) By providing pest control
9. What role do drones play in promoting sustainable farming practices?
- a) By increasing chemical usage
  - b) By providing data for sustainable farming practices and resource management
  - c) By reducing crop rotation
  - d) By eliminating all pesticides
10. How can drones aid in targeted nutrient application?
- a) By delivering seeds
  - b) By conducting soil tests and mapping nutrient levels for targeted applications
  - c) By improving crop aesthetics
  - d) By analysing weather patterns

## Session 2: Applications of Drones in Agriculture

In the previous session, we covered the principles of crop production and management, essential for enhancing agricultural productivity and sustainability. We explored key aspects such as soil health, crop rotation, pest management, and irrigation techniques, examining how they influence crop yield and quality. By mastering these principles, you are now better equipped to apply effective crop management strategies that support both productivity and environmental stewardship. In this session, we will focus on the applications of drones in agriculture.

India's economy heavily depends on agriculture, yet the country has been slow in adopting advanced precision agriculture technologies that can optimize input management. Precision agriculture refers to the precise application of inputs to achieve higher yields compared to traditional methods. It aims to increase production efficiency, improve product quality, reduce chemical usage, conserve energy, and protect the environment. By integrating information technology and management, precision agriculture leverages various tools to achieve these goals.

In recent years, India has introduced several new technologies to enhance agricultural productivity through precision farming. These technologies are especially useful when human involvement is limited or skilled labour is scarce. Precision agriculture, with its focus on minimizing external inputs, holds immense potential for increasing yields, particularly for small-scale farmers in developing countries. By using Information and Communication Technologies (ICT), farmers can gather and analyse data from multiple sources, leading to better insights into soil conditions and more efficient crop management. The transformation of agriculture into Farming 4.0 has brought ICT into traditional farming practices. Technologies such as drones, the Internet of Things (IoT), remote sensing, Artificial

Intelligence (AI), Machine Learning (ML), and Big Data Analytics (BDA) are paving the way for a new era in agriculture. Drones, in particular, play a crucial role in precision agriculture, photogrammetry, and remote sensing, especially in more developed nations. They assist farmers in monitoring fields and making data-driven decisions. Drones are highly effective in tracking various agricultural parameters, such as environmental conditions, soil nutrient levels, plant health, and irrigation management. This leads to increased yields, cost reductions, and optimized processes. By easing the workload on farmers, drone technology has the potential to close the gap between current agricultural production and future demands.

### **Drones: A Modern Agricultural Revolution**

A drone, also referred to as an Unmanned Aerial Vehicle (UAV), is an aircraft that operates without a human pilot on-board. Instead, it is controlled remotely or autonomously. Drones are equipped with different components like cameras, sensors, Global Positioning System (GPS), and communication systems, enabling them to execute various tasks such as data gathering, surveillance, mapping, delivery, and recreational flight. Their applications are widespread across industries like agriculture, filmmaking, search and rescue, environmental tracking and defence operations. **Figure 1.1** displays the drone image to recall the drone concept learned in Grade 11.



**Figure 1.1: Components of a drone**

## Agricultural Drones

Agricultural drones, also recognized as Agricultural Unmanned Aerial Vehicles (UAVs), refer to specialized remote-controlled or autonomous aircraft that are designed and equipped for various agricultural tasks. These flying robots have special tools like cameras, sensors and other data collection devices to gather information from farms and crops. They play a significant role in modern precision agriculture by providing farmers and agricultural professionals with valuable insights and actionable data for better decision-making and improved farm management (**Figure 1.2**).



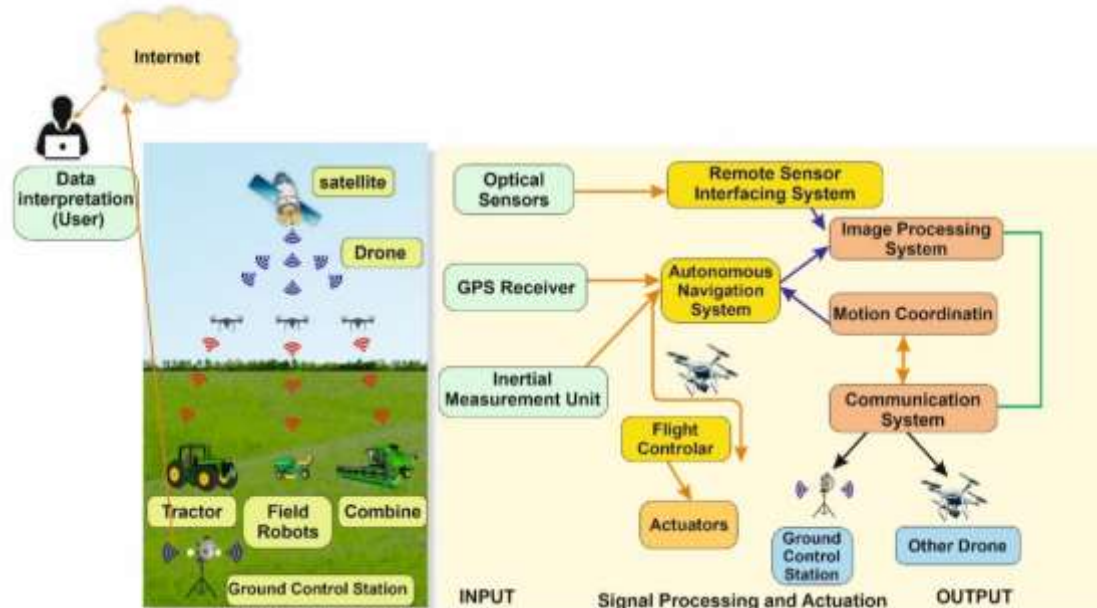
**Figure 1.2: Drone for spraying pesticide and fertilizers**

## Working Principles of Drones used in Agriculture

Drones play an essential role in modern agriculture by collecting data from both GPS systems and sensors integrated into farm equipment. This collected information is then transmitted to a central Ground Control Station (GCS) using satellite communication. Subsequently, this data is relayed to end-users through the internet, enabling them to analyse the information and regulate various farm operations effectively.

The operational framework of utilizing drone in agriculture is graphically depicted in **figure 1.3**. The GCS serves as a hub for collating drone-related data, including geographic positioning, and coordinates the planning and execution of drone missions. These missions involve a fleet of drones, each of which receives directives

from the GCS and collaboratively works to fulfil the assigned tasks. Maintaining a robust connection between the drones and the GCS is imperative for seamless communication, enabling the implementation of drone-assisted wireless instructions and interactions with on-field equipment. Furthermore, drones have the capability to act as autonomous applicators for specific inputs. This means they can precisely dispense substances like fertilizers or pesticides to targeted areas of the field. This feature allows for meticulous management of resources, contributing to enhanced efficiency and sustainable agricultural practices on a site-specific basis.



**Figure 1.3: Real-time application and uses of drone in agriculture**

### **Agricultural Drones Reforming the Farming Industry**

Agriculture is a sector that requires vast monitoring and management of crop fields and livestock, which drones can efficiently provide. Agricultural drones come with numerous sensors and imaging technologies, such as multispectral, thermal, and LiDAR sensors, that allow farmers and researchers to monitor crop growth, identify diseased or stressed plants, assess soil quality, estimate yield, and analyse irrigation needs.

The collected data of drones can help farmers make decisions that are more informed, optimize resource utilization and ultimately increase crop productivity and profitability. Furthermore, drones can access hard-to-reach areas, such as steep terrain, wetlands, or high-altitude crops, which are often challenging for traditional farming machinery or manual labour. The usage of drones in agriculture is presently in its infancy, but it has enormous potential to revolutionize farming practices and contribute to sustainable and efficient food production. The application of drones in agriculture, refers to the utilization of drones to assist and enhance various farming activities. The common applications of agricultural drones

are depicted in **Figure 1.4**.



**Figure 1.4: Applications and uses of drone in agriculture**

### Applications of Drones in Agriculture and Allied Sectors

- i. **Crop Monitoring:** It is the process of regularly observing and assessing the growth, health, and conditions of crops throughout their lifecycle. It involves the use of technologies like drones, sensors, and satellite imagery to collect data on plant health, soil conditions, irrigation needs, and pest infestations. Crop monitoring enables farmers to make timely decisions to improve crop yields, optimize resource use, and prevent potential issues, leading to more efficient and sustainable farming practices.

Crop monitoring refers to the systematic and ongoing observation of crops throughout their growth cycle, aimed at collecting crucial data on crop health, development, and surrounding environmental conditions. This helps farmers improve their farming practices and boost productivity. Drones equipped with cameras and sensors are commonly used to capture high-resolution aerial images of fields, providing valuable insights into crop health, growth patterns, irrigation requirements, and the presence of pests or diseases. By using this information, farmers can efficiently monitor their crops and make informed, data-driven decisions to optimize resource use and improve yields.



- ii. **Crop Spraying:** It is the application of pesticides, herbicides, fertilizers, or other chemical treatments to agricultural crops to protect them from pests, diseases, and weeds, or to enhance growth. This process can be performed using various methods, including manual spraying, ground-based equipment, and aerial applications using drones or aircraft. Crop spraying is essential for maintaining crop health and maximizing yields while ensuring that the application is done in a manner that minimizes environmental impact and adheres to safety regulations.

Crop spraying, whether conducted from the air or at ground level, involves the application of diverse substances like pesticides, herbicides, fungicides, or fertilizers to agricultural crops. The primary objective is to safeguard crops from pests, diseases and weeds; while also fostering their growth and improving overall yield. This application process utilizes specialized equipment, such as airplanes, helicopters, tractors, or handheld devices. Drones equipped with spraying capabilities can efficiently administer chemicals and pesticides onto agricultural fields. This enables precise and targeted application, minimizing waste and reducing environmental impact. Drone-based spraying can be especially beneficial in areas with challenging terrain or hard-to-reach locations (**Figure 1.5**).



**Figure 1.5: Crop spraying in the agricultural field using a drone**

- iii. **Crop Health Assessment:** It is the process of evaluating the overall health and vitality of agricultural crops to determine their condition, growth status, and potential yield. This assessment involves analysing various factors, such as plant appearance, leaf colour, growth patterns, and signs of pests or diseases. Advanced technologies, including remote sensing, drones, and soil sensors, can be used to gather data on crop health indicators. By conducting regular crop health assessments, farmers can identify problems early, make informed management decisions, and implement targeted interventions to enhance crop productivity and sustainability.

Assessing crop health involves a thorough examination of various indicators to evaluate the overall condition and vitality of agricultural plants. This process is crucial for farmers and agronomists, as it helps identify potential issues like diseases, pests, nutrient imbalances, or environmental stress. By recognizing these concerns early, they can take appropriate actions to enhance crop productivity. Drones equipped with multispectral or thermal sensors can gather detailed data on crop health, allowing farmers to spot signs of stress, nutrient deficiencies, water issues, or disease outbreaks at an early stage. Quick detection enables timely intervention, leading to improved crop yields and reduced losses.

- iv. **Irrigation Management:** It is the organized process of planning, executing, and monitoring water use to meet the needs of crops in agriculture. This approach focuses on using water efficiently and sustainably to maximize crop growth, yield, and quality. It involves various practices, technologies, and strategies to ensure that crops receive the right amount of water at the right time, considering factors like soil type, climate conditions, and the specific needs of the crops.

Drones equipped with thermal or multispectral sensors can help assess water stress in plants and identify areas that need irrigation. This information allows farmers to optimize water usage and implement targeted irrigation strategies, reducing water waste and enhancing crop health.

- v. **Field Mapping and Planning:** It is the process of creating detailed maps of agricultural fields to support effective management and decision-making. This involves using tools like GPS, drones, and geographic information systems (GIS) to collect and analyse data about field characteristics, such as soil type, terrain, crop distribution, and moisture levels.

The planning aspect uses this mapped data to develop tailored strategies for crop management, irrigation, fertilization, and pest control, based on the specific conditions in each part of the field. By employing effective field mapping and planning, farmers can optimize resource use, improve productivity, and adopt precision agriculture practices for more sustainable and efficient farming. Drones can quickly and accurately generate three-dimensional (3D) maps of agricultural fields. These maps aid in land surveying, soil sampling, and crop planning. Farmers can identify variations in soil composition, terrain, or drainage patterns, leading to more informed land management decisions.

- vi. **Yield Estimation:** It is the process of predicting how much agricultural produce will be harvested from a specific area, usually expressed as weight or volume per unit of land (e.g., tons per hectare). This involves looking at

various factors such as historical yield data, crop growth conditions, weather patterns, soil health, and management practices.

Farmers use several techniques for yield estimation, including remote sensing, field sampling, and statistical modelling. Accurate yield estimation is crucial for effective farm planning, resource allocation, financial forecasting, and market analysis, enabling farmers and agricultural stakeholders to make informed decisions that boost productivity and profitability. Drones can play a significant role in yield estimation by collecting data on crop health, vegetation indices, and plant density. This information helps farmers plan better, optimize storage capacity, and make informed marketing decisions regarding harvesting

- vii. **Horticulture:** It is the branch of agriculture that focuses on the cultivation, management, and production of plants, including fruits, vegetables, flowers, and ornamental plants. It involves the science and practice of growing these plants for food, medicinal purposes, landscaping, and aesthetic value. In practical terms, drones bring significant advantages to horticulture.



**Figure 1.6: Monitoring of crops in horticulture using drone**

Equipped with advanced imaging technologies like multispectral and thermal cameras, drones allow farmers to monitor crop health, detect pest infestations, and assess irrigation needs with precision. This data-driven method enables targeted actions, minimizing the need for excessive pesticide use and water, supporting sustainable farming practices. Beyond monitoring, drones are used for tasks like planting seeds and spraying crops, efficiently covering large areas and reaching difficult terrain, saving both time and labour. Additionally, the data collected by drones helps predict crop

yields and prevent diseases, enabling farmers to make better-informed decisions. **(Figure 1.6).**

- viii. **Livestock Management:** Livestock management refers to the process of overseeing and controlling the care, breeding, feeding, and overall well-being of domesticated animals raised for food, fiber, labor, or other purposes. It involves practices that ensure the health, productivity, and sustainability of livestock, such as cattle, sheep, poultry, and goats. Key aspects of livestock management include proper feeding, disease prevention, breeding programs, housing and shelter, and waste management.

The goal is to optimize animal welfare and productivity while maintaining environmental sustainability and economic viability in farming operations. Effective livestock management plays a crucial role in producing high-quality animal products like meat, milk, and eggs. Drones are becoming increasingly valuable in livestock management due to their versatility. They are used for various tasks, such as sanitizing farm areas and animal sheds by spraying disinfectants. Drones also play a role in conducting behavioral and phonemic studies of livestock. Additionally, they are utilized for delivering semen, vaccines, medications, and fertile eggs, making it easier to reach remote areas.

Drones are particularly useful for counting animal and poultry populations, especially in nomadic and pastoralist communities, and for tracking livestock movements and migrations. They also help map feed and fodder areas and monitor the population dynamics of cattle within their home ranges.

- ix. **Fisheries:** Fisheries involve the capture, farming, and selling of fish and other aquatic life, providing food and livelihoods for millions. Drones are increasingly being used in this industry to improve management and sustainability. For example, countries like the Republic of Palau, Belize, Jamaica, and Costa Rica are using drones to fight illegal fishing. Drones can patrol large areas of water, spotting illegal fishing boats and activities, helping authorities enforce fishing regulations. Additionally, drones are being used in aquaculture to feed fish in remote or hard-to-access areas, such as water valleys, where human access is limited. This technology improves efficiency and helps maintain healthy fish populations.
- x. **Forestry:** It is the science, art, and practice of managing forests, tree plantations, and related natural resources to meet environmental, economic, social, and ecological objectives. In forestry, drones play a valuable role in creating detailed information systems for forest conservation. By capturing aerial images, drones can produce high-resolution ortho-maps, which are used to analyze, plan, and manage data within a Geographic Information System (GIS). This technology helps forest

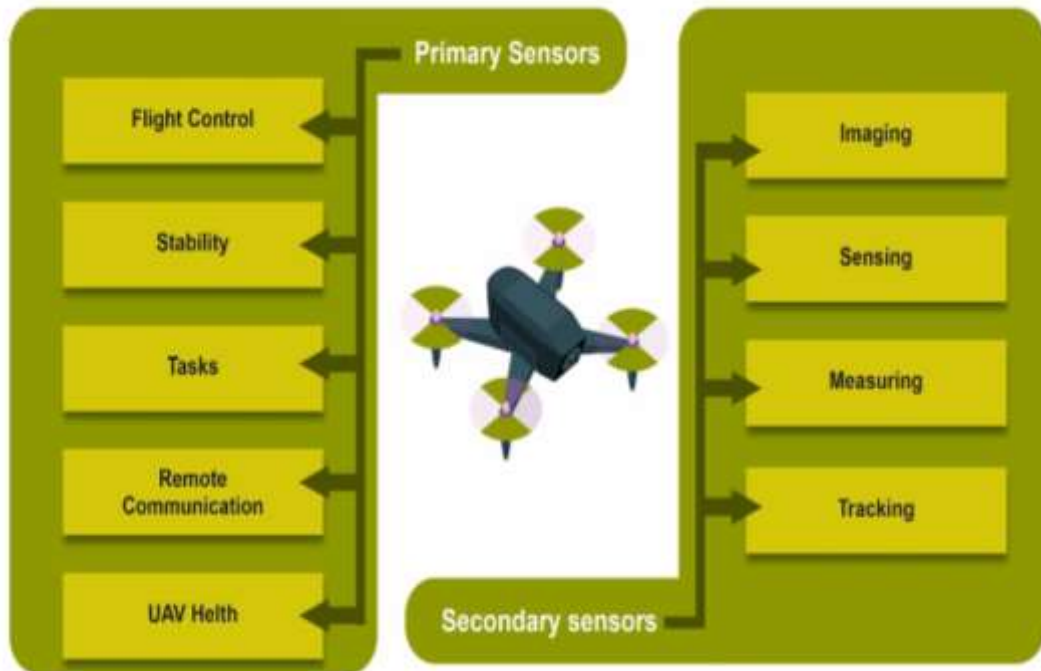
managers with tasks like operational planning and monitoring illegal activities or encroachments. Drones are also used to gather important data, such as carbon capture levels, assess tree canopy health, monitor conservation efforts, track native species, and survey biodiversity. They provide a cost-effective and efficient way to evaluate forest ecosystems and manage resources sustainably.

### **Sensors Integrated with Drones: Primary and Secondary Sensors**

Drones have various sensors, which it uses to gather data and perform specific tasks accurately. These sensors enable drones to navigate, gather information and interact with their environment. In the perspective of drones, primary and secondary sensors refer to the various types of sensors that are utilized to collect data and information during flight. These sensors play an important role in enabling the drone to perform its intended tasks effectively, whether it is aerial photography, surveillance, mapping, environmental monitoring, or any other application. Now, let us understand the primary and secondary sensors with their classifications (**Figure 1.7**):

- i. **Primary Sensors:** These are the main sensors that are crucial for the basic operation and navigation of the drone. They provide data that directly contributes to flight control and stability. These sensors are further categorized as:
  - a) **Global Positioning System (GPS):** It is a satellite-based navigation technology that provides drones with precise location, altitude, and velocity data. GPS sensors on drones enable accurate positioning, allowing them to determine their exact coordinates during flight. This information is essential for navigation, flight planning, and maintaining stability during operations. Drones rely on GPS for tasks like plotting flight paths, maintaining hover stability, performing autonomous missions, and returning to their starting point (return-to-home feature). Accurate GPS data is also crucial for precision tasks such as aerial mapping, surveying, and monitoring agricultural fields.
  - b) **Inertial Measurement Unit (IMU):** It is a key sensor system in drones that tracks movement and orientation by using accelerometers and gyroscopes. It measures the drone's acceleration and rotation rates, such as pitch, roll, and yaw, helping maintain stability and precise control during flight. The IMU continuously monitors changes in the drone's motion and sends data to the flight controller, which makes real-time adjustments to ensure smooth and stable flight. This system is crucial for altitude estimation, keeping the drone balanced in various conditions, and ensuring accurate performance in activities like aerial mapping, photography, surveying, and

precision farming.



**Figure 1.7: Applications of primary and secondary sensors**

- c) **Barometer:** A Barometer in drones is a key sensor used to measure air pressure, which helps calculate the drone's altitude during flight. As the drone ascends or descends, the atmospheric pressure changes, and the barometer detects these variations to estimate how high the drone is flying above the ground. This data is critical for maintaining stable altitude, particularly in tasks like aerial photography or surveying, where precise height control is needed for accurate results. By comparing the air pressure at the drone's location with standard sea-level pressure, the barometer allows the drone to keep a consistent altitude during flight. This is especially useful in precision applications like agriculture or mapping, ensuring the drone stays at the correct height for optimal performance. The barometer works in conjunction with GPS and the IMU for smooth, balanced flight control.

ii. **Secondary Sensors:** Secondary Sensors in drones are additional sensors that complement the primary navigation and control systems (like GPS, IMU, and barometers) to enhance performance and provide more detailed data (**Figure 1.8**). These sensors gather specific information to assist with tasks such as obstacle detection, environmental monitoring, and payload operation. These can be classified further as:

- a) **Camera/Gimbal Systems:** Camera and gimbal systems are essential for capturing high-quality images and videos from a

drone. The camera can vary from basic models for simple visual observation to advanced high-resolution cameras used for professional aerial photography and videography. Gimbal systems stabilize the camera during flight, ensuring smooth and steady footage, which is crucial for applications such as real estate marketing, cinematography, and surveying.

- b) **LiDAR (Light Detection and Ranging):** LiDAR sensors use laser beams to measure distances to objects and create detailed, accurate 3D maps of the terrain and surrounding structures. These sensors are particularly useful in applications like land surveying, environmental monitoring, and forestry management, where precise topographical data is necessary for planning and analysis.
- c) **Thermal Imaging Sensors:** Thermal imaging sensors detect heat emitted from objects, creating images that reveal temperature variations. Drones equipped with these sensors are used in search and rescue operations to locate missing persons, in surveillance to identify heat signatures, and in infrastructure inspections to find heat leaks in buildings or electrical components.
- d) **Multispectral/Hyperspectral Sensors:** Multispectral and hyperspectral sensors capture light across multiple wavelengths, allowing for detailed analysis of plant health and environmental conditions. In agriculture, these sensors can assess crop health, monitor irrigation needs, and detect diseases or pests, helping farmers optimize their crop management practices.
- e) **Radar:** Radar sensors on drones help detect obstacles and facilitate collision avoidance by emitting radio waves and measuring the reflections from surrounding objects. This technology is valuable for navigating in poor visibility conditions, making it ideal for search and rescue missions, delivery services, and inspections in challenging environments.
- f) **Gas and Chemical Sensors:** Drones equipped with gas and chemical sensors can detect the presence of specific gases or pollutants in the atmosphere. These sensors are used in environmental monitoring to assess air quality, detect leaks in industrial sites, or monitor hazardous materials, enhancing safety and compliance with regulations.
- g) **Sonar Sensors:** It is a device that use sound waves to detect and locate objects underwater or in challenging environments. Sonar sensors, commonly used in underwater applications, can also be

adapted for drones flying over water bodies. They measure water depth and can map underwater topography, making them useful for marine research, fishing, and assessing aquatic environments.



**Figure 1.8: Secondary sensors used in drones**

The choice of primary and secondary sensors depends on the drone's anticipated use, the level of data required, and the budget available for sensor integration. Different combinations of sensors enable drones to accomplish a widespread range of tasks and gather diverse types of data.

**Table 1.1** shows the applications of various sensors integrated with drones for proper functioning and attainment of objectives for which we are using a drone.

**Table 1.1: Applications of various sensors integrated with drones**

S. No.	Type of Sensor	Applications and Uses
<b>Primary Sensors</b>		
1.	GPS	The global positioning system (GPS) sensors are receivers with antennas that use a satellite-based navigation system with a network of 24 satellites in orbit around the earth to provide position, velocity, and timing information. In drones also, these are responsible for providing accurate location and position of drone.
2.	IMU	An IMU (Inertial Measurement Unit) is a device that measures and reports acceleration, orientation, angular rates, and other gravitational forces.
3.	Barometer	Barometers are sensors that measure



		atmospheric pressure. This air pressure information is used to determine drone's altitude.
<b>Secondary Sensors</b>		
1.	Digital Camera	A drone digital camera works by capturing images or videos using a camera mounted on a drone. It measures surface properties in visible spectrum such as growth, weeds, greenness, etc. in the field of agriculture.
2.	Multispectral Camera	It is a type of camera that has an ability to capture different spectra or images beyond the range visible to the human eye. In agricultural drones, these are used to identify pest and diseases infestation, water and nutrient stress etc.
3.	Thermal Camera	The thermographic camera, also called thermal camera, refers to a device, which, from the infrared radiation of the objects themselves, measures their temperature and provides a thermal image of them without the need to have contact with them. In agricultural context, these are used to identify heat stress, water stress and biological stress.
4.	LiDAR	LiDAR, which stands for Light Detection and Ranging, is a technology used for precise data collection in the form of 3D models. In agricultural drones, it captures light for digital elevation models, plant/tree height, volume, and canopy density.
5.	Hyperspectral Camera	Hyperspectral Imaging is a new analytical technique based on spectroscopy. It collects hundreds of images at different wavelengths for the same spatial area. In agriculture, these are used to identify pest and diseases infestation, water and nutrient stress etc.
6.	Radar	Radar systems detect objects by emitting radio waves in short pulses. If this signal hits an object, it bounces back to the radar antenna. The radar then amplifies the reflected signal to find out how big the object is, and how fast it is moving. In drones, these are used for the detection of obstacle and to avoid collision.

7.	Sonar	An echo sounder or SONAR (Sound, Navigation, and Ranging) system that sends out sound pulses from just below the water surface to the ocean floor, and measures the time it takes for the pulse to return, determining the depth of the water. In drones, these are used to be adapted for drones flying over bodies of water to measure water depth or underwater topography.
8.	Gas and Chemical Sensors	Gas and chemical sensors are used to detect specific gas and chemicals present in the air.

### Advantages of Agriculture Drones

Drones in agriculture can accomplish a broad variety of tasks including crop mapping, irrigation, soil analysis, pest management, etc., making it the most suitable component. There are numerous advantages of utilising drones in agriculture, including:

- (i) **Efficient Crop Monitoring:** Efficient crop monitoring is the organized observation and analysis of agricultural crops using advanced technology to gather critical data for better decision-making while minimizing resource consumption. Drones equipped with high-resolution cameras and multispectral sensors can fly over fields to capture detailed images of crops. This allows farmers to monitor crop health, identify stress or disease areas, and estimate yields without extensive ground surveys. (Figure 1.9 and 1.10).



Figure 1.9: Drone for aerial imaging



**Figure 1.10: Use of drone for crop health monitoring**

- (ii) **Crop Management:** It refers to the strategies and practices employed to enhance the growth and health of crops based on collected data. By analysing the data collected from drones, farmers can make informed decisions about when and where to apply fertilizers, adjust irrigation schedules, and take measures to improve overall crop health. This leads to more efficient use of resources and better crop outcomes.
- (iii) **Improved Yield:** Improved yield involves maximizing the amount and quality of crops harvested from a specific area of land. Drones can identify areas within fields that are underperforming due to factors like nutrient deficiencies or pest infestations. With this information, farmers can target specific sections for interventions, such as applying additional irrigation or pest control measures, ultimately increasing crop yield and quality.
- (iv) **Cost Savings:** Cost savings in agriculture refers to reductions in operational expenses associated with farming activities. Drones can efficiently survey hard-to-reach areas of farmland, such as steep slopes or wet fields, without the need for expensive machinery or labour. This not only cuts costs associated with manual labour but also minimizes wear and tear on equipment.
- (v) **Time Efficiency:** Time efficiency in agriculture is the ability to complete farming tasks quickly and effectively, optimizing labour and resource use. Drones can cover large areas of farmland in a fraction of the time it would take traditional methods, allowing farmers to rapidly detect problems such as irrigation issues, pest infestations, or nutrient deficiencies, enabling prompt corrective actions.
- (vi) **Improved Safety:** Improved safety refers to reduced risk of injury to farmers and farm workers during agricultural operations. By using

drones to survey fields and monitor crops from the air, farmers can minimize the need for manual inspections in potentially hazardous areas, reducing the risk of accidents or injuries associated with farming operations.

- (vii) Environmental Sustainability:** Environmental sustainability in agriculture involves practices that minimize environmental impact and promote the long-term health of ecosystems. Drones help farmers optimize the use of resources like water and fertilizers, ensuring that these inputs are applied precisely where needed. This reduces waste, minimizes runoff, and promotes more sustainable farming practices that protect the environment.

Overall, the use of drones in agriculture has enormous potential to improve efficiency, reduce costs, and increase crop yields, while also promoting sustainable and responsible farming practices.

### Limitations of Drones in Agriculture

Drones are one of the most innovative methods of how to carry in-field monitoring. At the same time, there are certain limitations of agriculture drones, including:

- (i) Weather Conditions:** Weather conditions refer to atmospheric factors, such as wind speed, rainfall, and temperature, that can affect the performance and safety of drone operations. Drones are unable to operate in severe weather conditions like high winds or heavy rain. For instance, if a storm is approaching, farmers may have to delay drone flights for crop monitoring, reducing their ability to gather timely data, which is crucial for effective decision-making.
- (ii) Cost:** Cost refers to the financial investment required to purchase, operate, and maintain drones and their associated technologies. Agricultural drones can be a significant investment, often costing thousands of dollars. Additionally, specialized sensors and ongoing maintenance can further increase expenses. For example, a farmer might find the initial purchase of a drone worthwhile, but the ongoing costs of upgrades and repairs could strain their budget.
- (iii) Legal and Regulatory Issues:** Legal and regulatory issues encompass the laws and guidelines governing the use of drones in specific regions, which can include licensing requirements, airspace restrictions, and privacy concerns. Farmers must navigate a complex landscape of regulations when using drones. For example, they may need to apply for permits to operate drones in their area, and failure to comply with these regulations could result in fines or legal action, complicating their ability to utilize drones effectively.
- (iv) Data Processing:** data processing involves the steps necessary to analyse and interpret the information collected by drones to make it actionable.

While drones can collect vast amounts of data, farmers may lack the technical skills or software needed to analyse this information effectively. For instance, a small-scale farmer may be able to capture images of their crops but struggle to translate that data into actionable insights, such as identifying nutrient deficiencies or pest infestations.

**(v) Limited Battery Life:** Limited battery life refers to the operational time a drone can function before needing to be recharged or have its batteries replaced. Most agricultural drones have a flight time of only 15 to 20 minutes, which can limit their ability to cover large fields in a single flight. For example, a farmer trying to monitor a 50-acre field may need to land the drone multiple times to recharge, making the monitoring process more time-consuming and less efficient.

**(vi) Limited Payload Capacity:** Limited payload capacity refers to the maximum weight a drone can carry, which constrains the type and number of sensors or equipment it can transport. Drones can only carry a limited amount of weight, which may prevent farmers from equipping their drones with multiple sensors simultaneously. For instance, if a farmer wants to use a camera for aerial imagery and a LiDAR sensor for topographic mapping, they may have to choose one due to the drone's weight limits, which can reduce the comprehensiveness of data collected.

Overall, while the use of drones in agriculture has the potential to revolutionize farming practices, there are still limitations and challenges that need to be addressed to make them accessible and practical for farmers.

### DID YOU KNOW?

- Drones have been used to deliver medical supplies, including vaccines and emergency medications, during the COVID-19 outbreak.
- Drones are utilised for the inspection of critical infrastructure such as power lines, bridges, and pipelines. They can access hard-to-reach areas, reducing the need for manual inspections and improving overall safety.
- In some experimental projects, drones have been used for pizza delivery. The idea is to transport hot, delicious pizzas directly to customers, bypassing traffic and speeding up the delivery process.
- The World Animal Foundation reports that more than 20,000 elephants are poached annually, a problem that is having a significant impact on animal populations. Different programs, such as Air Shepherd, are being used to combat poaching with drones.

### Activities

**Activity 1:** Engage in a hands-on learning experience focused on identifying and exploring the diverse applications of drones across various fields. In this interactive

game, you will collaborate in small groups to match specific drone types with their corresponding features and applications.

To facilitate this activity, you will need a display board for affixing identified drones alongside their applications, images of drones with scenarios depicting their uses, descriptions outlining the structural aspects of the drones, and key features for each type of drone. The procedure involves forming small groups with a mix of participants, where each group will select a type of drone. Your challenge will be to match your assigned drones with the descriptions and applications provided at your table. Additionally, each group must present the key features of their assigned drone, specifically in relation to its application. Finally, you will affix your findings to the display board at the front of the class, creating a visual reference for everyone. Feel free to utilize available information sources to assist you in identifying the drones, their features, and their applications

**Activity 2:** Engage in a DIY (Do It Yourself) activity to deepen your understanding of drone technology, components, and their functions. You will need drone kits containing basic components such as frames, motors, propellers, and flight controllers, along with tools for assembly like screwdrivers and pliers. Additionally, printouts of instructional manuals for drone assembly and a well-organized workspace with adequate lighting will be essential. Visual aids or diagrams illustrating drone components can also be helpful. The procedure begins by forming two groups of equal size within the class. Each group will receive a drone kit, complete with all necessary components and the instructional manual. As you start the assembly process, ensure that safety measures are observed. After assembling your drones, present them to the class, discussing any challenges faced and the solutions you implemented during the process. Finally, carefully disassemble your drones, following proper procedures, while emphasizing the importance of understanding the assembly in reverse to gain a comprehensive grasp of the technology.

## Check Your Progress

### A. Multiple Choice Questions

1. What is one of the primary uses of drones in agriculture?
  - a) Soil Sampling
  - b) Pest Control
  - c) Crop Health Assessment
  - d) Weather Monitoring
2. How do drones evaluate water stress in plants?
  - a) By measuring soil temperature
  - b) By analysing weather patterns
  - c) By evaluating water stress in plants and identifying areas needing irrigation
  - d) By assessing crop yield

3. In which area can drones assist farmers aside from crop health?
  - a) Pest Management
  - b) Livestock Management
  - c) Soil Fertility
  - d) Market Analysis
4. What type of sensor is commonly used in drones for detailed land assessment?
  - a) Thermal Sensors
  - b) GPS
  - c) LiDAR Sensors
  - d) Infrared Cameras
5. How can drones contribute to reducing pesticide and water use in agriculture?
  - a) By applying fertilizers
  - b) By monitoring weather conditions
  - c) By using advanced imaging to reduce pesticide and water use
  - d) By assessing soil health
6. Which sensor is often used in drones to measure atmospheric pressure?
  - a) Gyroscope
  - b) Accelerometer
  - c) Barometer
  - d) Magnetometer
7. How do drones help detect water and nutrient stress in crops?
  - a) By measuring soil temperature
  - b) By detecting water and nutrient stress
  - c) By applying fertilizers
  - d) By monitoring weather patterns
8. What is a limitation associated with drone technology in agriculture?
  - a) High operational costs
  - b) Limited battery life affecting operational range
  - c) Lack of data processing capabilities
  - d) Poor image quality
9. What type of sensor is often used in precision agriculture for mapping and analysis?
  - a) Ultrasonic Sensor
  - b) LiDAR
  - c) GPS
  - d) Thermal Sensor
10. What capability do drones have that allows them to detect crop stress?
  - a) Thermal imaging
  - b) Optical imaging
  - c) Detecting crop stress beyond the visible spectrum
  - d) GPS mapping

<b>Module 2</b>	<b>Operating Procedures for Use of Drone in Agriculture</b>
<b>Module Overview</b>	
<p>This module is designed to equip you with a detailed understanding of the operational procedures and considerations for using drones in agriculture. The first session, parameters affecting selection of drone, covers the various factors that influence the choice of drones for agricultural tasks. These include drone size, payload capacity, battery life, sensor compatibility, and the specific requirements of different crop types. you will learn how to select the most suitable drone based on these parameters to achieve optimal results.</p> <p>The second session on crop nutrient applications, focuses on how drones can be used to efficiently apply nutrients to crops. The session covers different types of crop nutrient solutions, aerial spraying techniques, and precision agriculture strategies that ensure even and effective distribution of nutrients. This knowledge will help you to improve crop health and yield while minimizing resource wastage.</p> <p>In the third session on prerequisites for using drones, you will explore the essential legal, safety, and technical requirements for operating drones in agriculture. This includes understanding regulatory guidelines, obtaining necessary certifications, and preparing for drone flight operations. Emphasis will be placed on safety protocols, maintenance routines, and pre-flight checks to ensure safe and compliant drone operations in the field.</p>	
<b>Learning Outcomes</b>	
<p>After completing this module, you will be able to:</p> <ul style="list-style-type: none"> <li>• Identify the key parameters that influence drone selection for various agricultural tasks.</li> <li>• Describe the importance of flight range, payload capacity, and battery life in choosing a drone.</li> <li>• Demonstrate the process of using drones for spraying pesticides, fertilizer and other crop nutrients.</li> <li>• Identify the essential prerequisites required before operating a drone.</li> <li>• Identify the safety measures to be followed during drone operation.</li> <li>• Develop a checklist for safe drone flight.</li> </ul>	



## Module Structure

Session 1: Parameters Affecting Selection of Drone

Session 2: Crop Nutrient Applications

Session 3: Prerequisites for Using Drones

Session 4: Precautions during Drone Operation

### Session 1: Parameters Affecting Selection of Drone

In this session, you will explore the parameters that influence the selection of drones for various applications. Understanding these parameters is crucial for choosing the right drone to meet specific operational needs, whether in agriculture, cinematography, surveying, or search and rescue operations. You will examine key factors such as payload capacity, flight time, range, camera quality, and ease of use, as well as regulatory considerations and environmental conditions. By the end of this session, you will have a clear understanding of how to assess and prioritize these parameters, enabling you to make informed decisions when selecting drones for different purposes.

The utilization of drones in agriculture has become more prominent in recent times. Several states are actively evaluating this emerging technology for Indian farming. Using drones to apply pesticides holds significant potential for wider adoption. Drones can achieve precise targeting in agricultural cultivation (**Figure 2.1**). They are poised to enhance the efficiency of crop protection chemical applications. Drones reduce the need for manual labour and curtail application time. They also minimize water and chemical usage while mitigating environmental



**Figure 2.1: Application of pesticides using a drone**

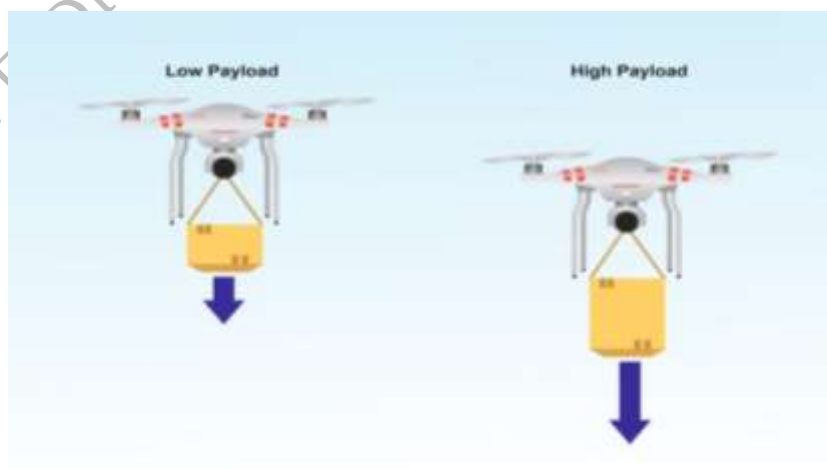
drift. Furthermore, this technology helps in diminishing human exposure to hazardous chemicals. Traditional agricultural practices involve manual or tractor-

mounted spraying of pesticides, resulting in substantial wastage of pesticides and water, along with environmental contamination. Conversely, drone-based spraying necessitates lesser quantities of water and pesticides, which is possible due to the improved application methods and bio-efficiency. In this module, you will know about the parameters that affect drone selection, the prerequisites that need to be considered while using drone, the safety measures that must be adhere while operating drone and using drone to asses/map and apply crop nutrients. Selection of the right drone for pesticide and fertilizer spraying is crucial to ensure successful and efficient utilization of fertilizer and pesticides.

**Payload:** A payload refers to the additional cargo or equipment that a drone, is designed to carry for a specific purpose. In the case of drones, the payload typically consists of devices like cameras for photography or videography, LiDAR systems for mapping, sprayers for agricultural tasks, thermal sensors for inspections or surveillance, or even medical supplies for delivery purposes. The payload is an important consideration because it directly affects the drone's performance, such as its flight time, speed, and stability, by adding extra weight and potentially altering its aerodynamics. The capacity of a drone to carry a payload depends on factors like its size, power, and design. The following are several key factors that needs to be considered during the drone selection process.

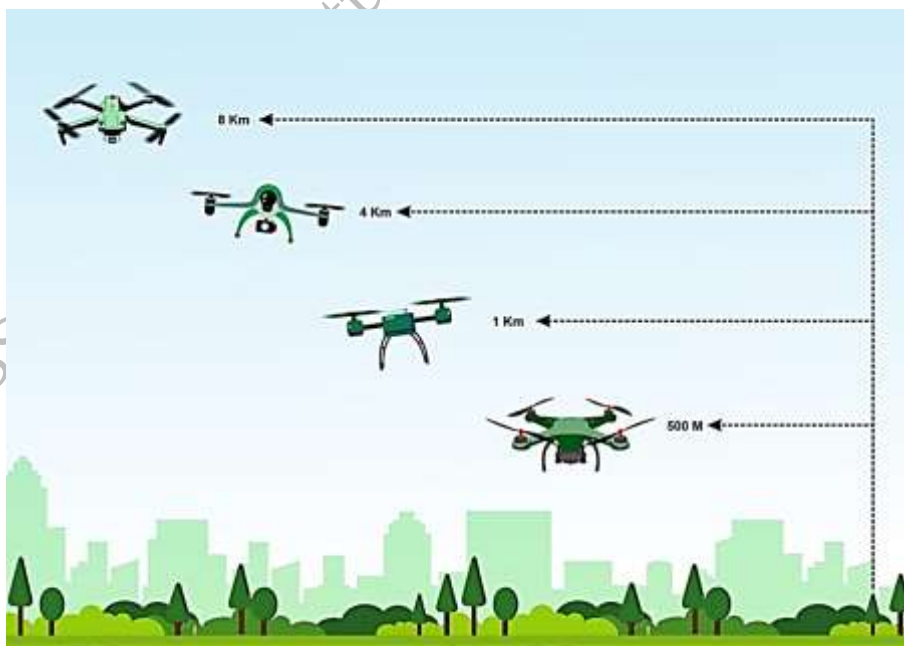
- i. **Payload Capacity:** The payload refers to the weight and capacity that a drone can carry in addition to its weight. This includes any equipment, sensors, cameras, or cargo intended for transport or use during flight. In agricultural applications, for example, the payload might consist of fertilizers, pesticides, or imaging devices used for monitoring crop health.

The payload is a critical factor in determining a drone's functionality, performance, and suitability for specific tasks. The payload capacity of agriculture drones is a crucial factor that determines the volume of liquid they can carry for spraying. It determines the amount of pesticides or fertilizers the drone can carry (**Figure 2.2**).



**Figure 2.2: Drone payload system**

- ii. **Flight Time:** Flight time refers to the duration a drone can remain airborne on a single battery charge or fuel load before it needs to land for recharging or refuelling. It is a critical factor that influences the operational range and efficiency of drone missions. In agriculture, the flight time of a drone can significantly impact how effectively farmers can monitor large fields. For instance, if a drone has a flight time of only 20 minutes, it may only cover a limited area before needing to land and recharge, which can slow down the data collection process. This limitation can affect the timeliness of identifying crop health issues or managing resources effectively. Farmers may need to plan their flights strategically, ensuring they have multiple batteries available or choosing the best times for monitoring to maximize the drone's operational capabilities.
- iii. **Range:** It refers to the maximum distance a drone can fly away from the operator or its control station while maintaining a reliable connection for control and data transmission. It is a crucial specification for determining how far a drone can operate effectively without losing communication. In agricultural applications, the range of a drone is vital for monitoring large fields, especially in remote areas. For instance, if a drone has a range of 5 kilometres, it can cover extensive farmland without needing to return frequently. This capability allows farmers to gather data over vast distances, optimizing crop monitoring, irrigation management, and pesticide application. However, if the drone's range is limited, farmers may need to use multiple drones or make several trips to monitor their fields, increasing time and labour costs. Understanding a drone's range helps farmers plan their operations efficiently and ensures effective coverage of their agricultural land. **(Figure 2.3).**



**Figure 2.3: Drone flight ranges**

- iv. **Flight Control System:** In agriculture, the flight control system significantly impacts how effectively a drone can perform its tasks. For example, a drone equipped with advanced GPS capabilities can precisely map and survey large fields, ensuring accurate data collection for crop monitoring. Stabilization systems help the drone maintain a steady altitude and position, even in windy conditions, which is crucial for capturing high-quality images and data. Autopilot features allow farmers to pre-program flight paths, enabling the drone to operate autonomously and efficiently cover large areas without constant manual control. A user-friendly and sophisticated flight control system enhances the usability of the drone, making it accessible for farmers with varying levels of technical expertise and ensuring reliable performance in various agricultural applications.
- v. **Sensor Quality:** Sensor quality refers to the performance characteristics and resolution of the cameras and other sensors attached to a drone. This includes aspects such as image resolution, sensitivity, and the ability to capture data across different wavelengths (for example, thermal or multispectral).

In agricultural applications, high-quality sensors are essential for accurately monitoring crop health, assessing soil conditions, and conducting detailed surveys. For instance, a drone equipped with a high-resolution camera can capture detailed aerial images that allow farmers to identify issues like pest infestations, nutrient deficiencies, or water stress in crops. Similarly, thermal sensors can detect variations in temperature across a field, helping farmers pinpoint areas that may require irrigation or other interventions. Multispectral sensors can capture data in different spectral bands, enabling precise analysis of plant health and vigour. Overall, the quality of these sensors directly affects the reliability and usefulness of the data collected, enabling farmers to make informed decisions that enhance productivity and sustainability.

- vi. **Remote Control or Autonomous:** Drones that require manual operation provide the operator with real-time control over the flight path and tasks. This is useful for specific tasks that need direct human intervention, such as inspecting a particular area of a field or adjusting the flight path in response to changing conditions. However, it can be labour-intensive and may not be practical for covering large areas.

Drones that operate autonomously can follow pre-programmed routes using GPS waypoints or advanced AI navigation systems. This allows for systematic coverage of extensive agricultural lands without continuous operator input. For example, a farmer can program the drone to survey a large field, capturing high-resolution images or multispectral data

efficiently. This reduces the time and labour required for monitoring crops, while also minimizing human error. Autonomous drones are particularly advantageous for repetitive tasks, allowing farmers to focus on analysing the data collected rather than managing the flight itself.

- vii. **Weather Resistance:** Weather resistance refers to a drone's ability to operate effectively in adverse weather conditions, such as rain, snow, wind, or extreme temperatures, without compromising its performance or safety. In agricultural applications, the ability of drones to withstand challenging weather is crucial for maximizing their utility and operational efficiency.
- viii. **Regulations and Compliance:** Regulations and compliance refer to the legal framework and guidelines that govern the operation of drones, including where they can be flown, how they should be operated, and the necessary permits or licenses required for their use. In the agricultural sector, understanding and adhering to drone regulations is crucial for safe and lawful operations.
- ix. **Portability/Size:** Portability/size refers to the physical dimensions and weight of a drone, which affect its ease of transport and ability to operate in various environments.

In agriculture, the size and portability of drones play a significant role in their application and effectiveness:

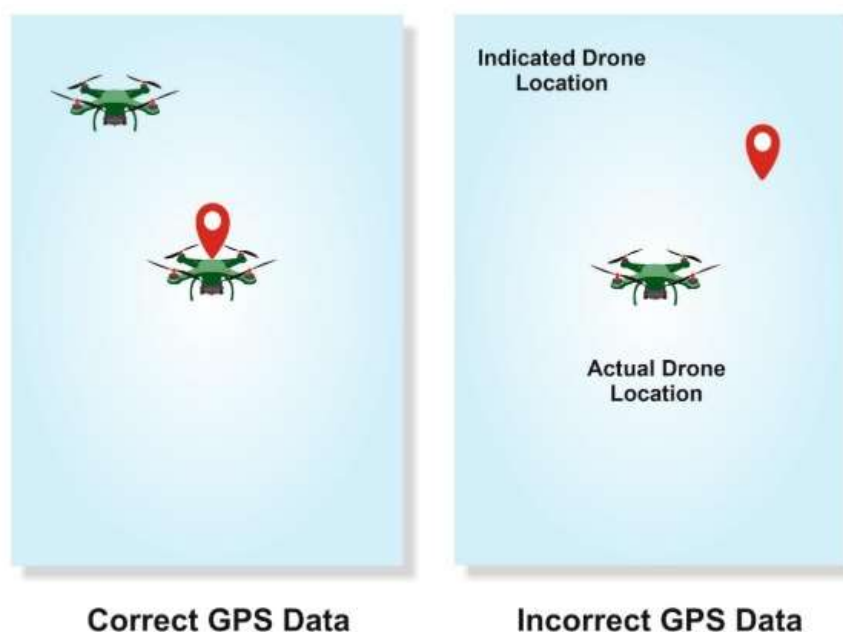
- i. **Maintenance and Repair:** Maintenance and repair refer to the processes involved in keeping a drone operational, including routine checks, repairs, and the availability of replacement parts. In agriculture, regular maintenance ensures drones perform reliably. Farmers need easy access to spare parts and knowledgeable technicians to handle repairs, especially for more complex models. Proper maintenance helps prevent downtime during critical farming seasons, ensuring that crop monitoring and management tasks are carried out efficiently.
- ii. **Budget:** Budget refers to the financial resources available for purchasing a drone, which can significantly affect the choices and capabilities of the equipment. Farmers should consider their budget when selecting a drone, as prices vary widely based on features, capabilities, and quality. Establishing a budget helps narrow down options, ensuring that the chosen drone meets the necessary requirements for agricultural tasks without overspending.
- iii. **Data Transmission:** Data transmission refers to the system that facilitates the transfer of information from the drone to the operator or cloud storage, crucial for real-time applications. Reliable data transmission is vital for live video streaming and remote sensing in

agriculture. High-quality radio links ensure that data, such as images or sensor readings, are transmitted in real time, enabling farmers to make timely decisions based on the most current information.

- iv. **Battery Swapping/Charging:** Battery swapping/charging refers to the methods used to replace or recharge a drone's power source between flights. Quick battery swapping systems minimize downtime, allowing farmers to maximize productivity during busy seasons. Drones that require longer charging times might delay operations, making it crucial to choose models that allow for fast battery changes.
- v. **Noise Level:** Noise level refers to the amount of sound produced by a drone during operation. In urban or densely populated agricultural areas, low-noise drones are preferred to minimize disturbance to nearby residents or wildlife. Quiet operation is particularly beneficial during sensitive tasks like crop inspections or pest monitoring.
- vi. **Software and Analytics Integration:** Software and analytics integration refers to the compatibility of drones with software tools for processing, analysing, and visualizing collected data. Drones that integrate easily with data analysis software can enhance the value of collected data. Farmers can make informed decisions based on detailed analytics regarding crop health, soil conditions, and resource usage, optimizing their agricultural practices.
- vii. **Security Features:** Security features encompass measures taken to protect a drone from unauthorized access and data breaches. Drones used in agriculture often handle sensitive data, such as farm layouts and resource management. Strong security features, including encrypted communication and anti-hacking measures, help safeguard this information from potential threats.
- viii. **Training and Skill Level:** Training and skill level refer to the necessary knowledge and expertise required to operate a drone effectively and safely. Farmers may need to undergo training to understand the operational aspects of drones, including navigation, data collection, and maintenance. Ensuring operators are well-trained helps maximize the benefits of using drones in agriculture while ensuring compliance with regulations.
- ix. **Battery Type:** Battery type refers to the specific technology used for a drone's power source, influencing flight duration and overall performance. Different battery types, like LiPo (Lithium Polymer) and Li-ion (Lithium Ion), have unique energy densities, impacting how long a drone can fly. Choosing the right battery type affects operational efficiency in agricultural tasks, particularly during critical periods like planting and

harvesting.

- x. **Obstacle Avoidance and Collision Sensors:** Obstacle avoidance and collision sensors are technologies that help drones detect and avoid obstacles during flight. Advanced drones equipped with collision sensors enhance safety during operation, especially in complex agricultural environments. These sensors help prevent crashes, allowing for more confident flying over fields with trees, buildings, or other structures.
- xi. **Global Positioning System (GPS) Accuracy:** GPS accuracy refers to the precision with which a drone's location is determined using satellite signals. Accurate GPS is crucial for navigation and autonomous operations in agriculture. Reliable GPS technology ensures precise positioning during tasks like spraying or monitoring, reducing overlaps and ensuring complete coverage of the area. **(Figure 2.4).**



**Figure 2.4: Application of GPS for locating a drone**

- xii. **Cost:** Cost refers to the total financial outlay required to purchase and operate a drone, including initial purchase, maintenance, and operational expenses. Cost is a critical factor in selecting a drone for agricultural use. Farmers must ensure that the drone fits within their budget while meeting essential requirements for payload capacity, range, and sensor quality. Considering durability and long-term operational costs helps in making a more informed investment. Cost is an important factor in any investment decision. Choose a drone that fits within your budget. Ensure it meets the necessary requirements for payload capacity and range. Consider the quality of the camera or sensor as well as GPS accuracy. Durability should also be considered.

- xiii. **Autopilot:** Autopilot features allow drones to fly automatically along predefined routes without constant manual control. Autopilot systems enable drones to handle complex flight paths and manage altitude and speed during agricultural tasks, such as crop monitoring or spraying. These features reduce the operator's workload and increase efficiency, allowing for more precise and effective operations in the field.
- xiv. **Waypoint Features:** Waypoint features enable users to program specific GPS coordinates that a drone follows during its flight. This functionality allows operators to create precise flight paths for various tasks, such as surveying, mapping, or monitoring. The drone autonomously navigates to each waypoint, ensuring efficient and repeatable flight patterns. In agricultural applications, waypoint features are particularly beneficial for tasks like crop spraying and monitoring. By setting predetermined waypoints, farmers can optimize spraying operations, ensuring that chemicals are applied accurately and evenly across the field. This capability reduces the likelihood of overlaps or missed areas, improving resource efficiency and minimizing waste.

Ultimately, the choice of drone should be based on a thorough understanding of certain specific requirements and how well a particular drone's parameters align with those needs.

### DID YOU KNOW?

- High-end drones can capture photos with resolutions exceeding 20 megapixels and shoot videos in 4K or even 6K resolution, providing stunning aerial imagery.
- Advanced drones often come with autonomous flight features, allowing them to fly predefined routes, follow subjects, or return to a designated home point automatically.
- Consumer drones may reach speeds of around 30 mph, racing drones designed for competition can hit speeds exceeding 100 mph, providing an adrenaline rush for drone enthusiasts.

### Precautions and Pre-requisites for Drone Based Pesticide Application

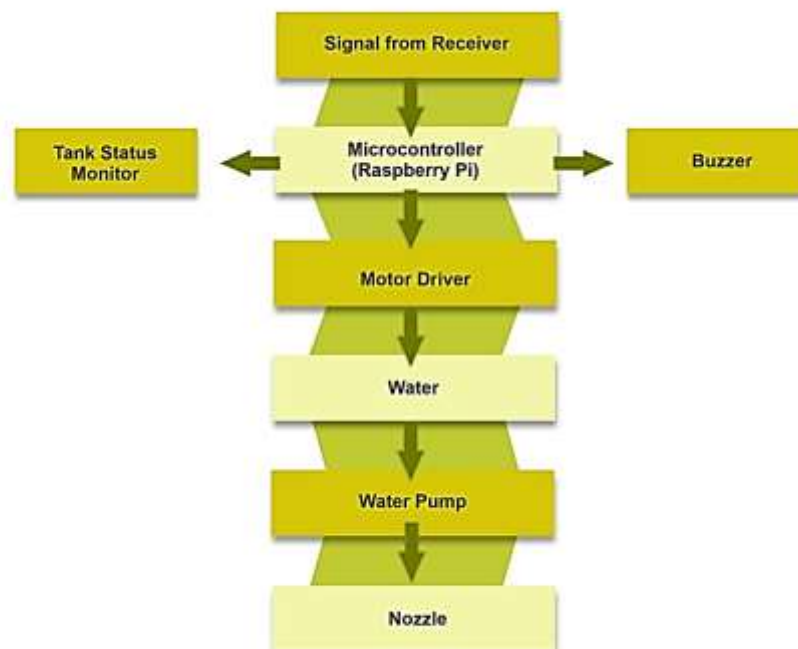
Before, during, and after operating drone for pesticide application, it is crucial to follow these guidelines to ensure safety and compliance. Drone Spraying system is explained in **figure 2.5**. The following are some guidelines for the pre-application phase of drone-based pesticide application:

- i. **Avoid Restricted Areas:** Do not fly your drone in restricted zones (marked in red and yellow), such as near airports or sensitive electronic facilities.



You can operate freely in green zones without needing prior approval.

- ii. **Meet Digital Sky Standards:** Make sure your drone complies with Digital Sky regulations, including having the 'No Permission-No Take-off' feature installed in its hardware and firmware.
- iii. **Obtain a Unique Identification Number (UIN):** If your flight is in controlled airspace, get a UIN from the Directorate General of Civil Aviation (DGCA) and attach it to your drone.
- iv. **Secure an Unmanned Aircraft Operator Permit (UAOP):** If you are conducting commercial pesticide application, acquire a UAOP from the DGCA and keep it easily accessible during your operations.
- v. **Check Drone Condition:** Before flying, inspect your drone to ensure it is in good physical condition and free of damage for safe operation.
- vi. **Be Aware of Interference:** Stay alert for potential interference from mobile devices or other obstacles that could disrupt the drone's signal during operation.
- vii. **Maintain Visual Line of Sight (VLOS):** Always keep your drone within your line of sight while flying to ensure safe and effective control.



**Figure 2.5: Drone spraying system**

**Operational Guidelines for Drone-Based Pesticides Application:**

To ensure safe and effective pesticide application using drones, operators must adhere to specific guidelines. The following are some guidelines for Drone-based Pesticides Application:

- i. **Operator Proficiency:** Ensure that all operators are trained in drone operation and safe pesticide usage.
- ii. **Alcohol Consumption:** Refrain from consuming alcohol within 8 hours before the operation.
- iii. **Spray System Calibration:** Calibrate the drone's spray system to ensure accurate application of labelled pesticide rates.
- iv. **Pre-Flight Inspection:** Thoroughly inspect the drone for any system leaks before each operation.
- v. **Designated Areas:** Establish suitable areas for take-off, landing, and tank mixing activities.
- vi. **Treatment Area Marking:** Clearly mark the intended treatment area, its boundaries, and identify obstacles (e.g., walls, trees) for safety.
- vii. **Buffer Zone:** Establish a minimal buffer zone, as specified by DGCA/CIBRC, between the treatment area and non-target crops.
- viii. **Water Source Verification:** Confirm that there are no water sources within 100 meters of the target area to prevent pesticide contamination.
- ix. **Authority Notification:** Notify relevant authorities, such as the Executive Officer of Gram Panchayat, Panchayat Samiti, and the local Agriculture Officer, at least 24 hours before operation.
- x. **Area Security:** Restrict entry of unrelated individuals and animals during the operation period under the supervision of the territory in-charge.
- xi. **Flight Logs Maintenance:** Maintain accurate flight logs and promptly report any incidents or accidents to the concerned authorities, including DGCA and local law enforcement.
- xii. **Permission for Crowded Areas:** Obtain explicit permission before flying the drone over gatherings of people or public events.
- xiii. **Restricted Zones:** Avoid flying the drone over government or military

installations and any restricted zones without proper authorization.

- xiv. **Private Property:** Secure permission before flying the drone over private property.
- xv. **Controlled Airspace:** In controlled airspace near airports, file a flight plan or secure AAI/ADC permission at least 24 hours prior to operation.
- xvi. **Hazardous Materials:** Avoid transporting or releasing hazardous materials using the drone.
- xvii. **Flight from Moving Vehicles:** Refrain from flying the drone from moving vehicles, ships, or aircraft.
- xviii. **Regulatory Compliance:** Operate the drone in accordance with the guidelines outlined in the Unmanned Aircraft System (UAS) Rules, 2021.

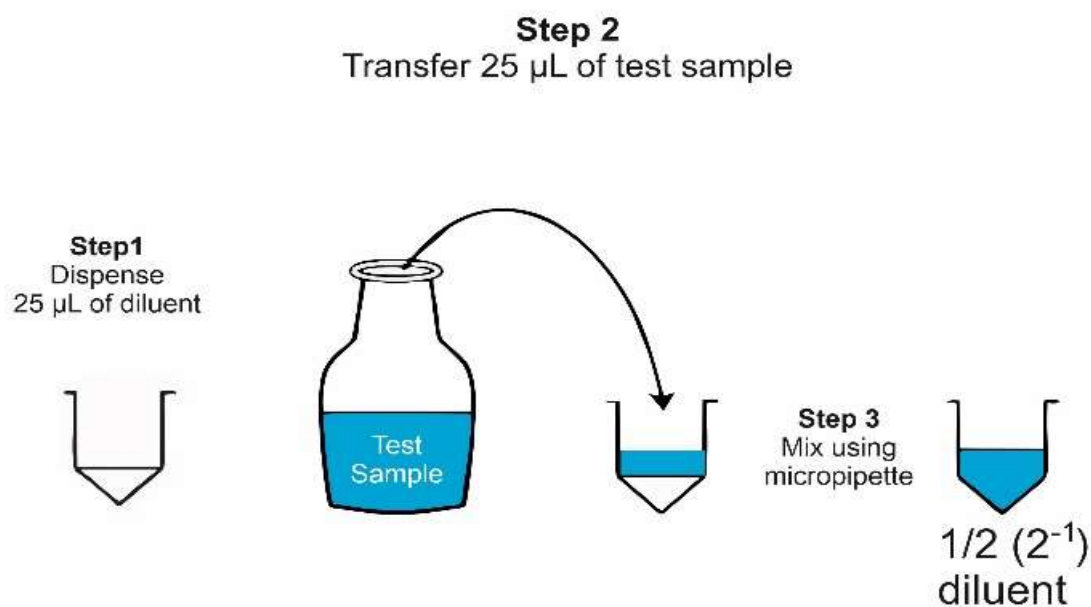


**Figure 2.6: Safety instruction labels**

The following are the practical guidelines for drone-based pesticide application, focusing on optimizing the operation and ensuring safety and environmental protection:

- i. **Label Review:** Before starting, carefully review the pesticide labels to understand the safety instructions and warning signs. This ensures compliance and safety during application. **(Figure 2.6).**
- ii. **Personal Protective Equipment (PPE):** Always wear appropriate PPE, such as gloves, masks, goggles, and protective clothing, to safeguard against chemical exposure.
- iii. **No Food or Drink:** Refrain from eating, drinking, or smoking while conducting spraying activities to prevent contamination and ensure personal safety.

- iv. Logical Flight Route: Plan a logical flight route that minimizes excessive turns. This not only enhances efficiency but also reduces the risk of overlaps and gaps in coverage.
- v. Downwind Positioning: Ensure the operation team positions themselves consistently at the downwind edge of the field, with the direction of sunlight (backlight) to avoid exposure to pesticide drift.
- vi. Preliminary Spray: Conduct a preliminary spray using pure water for at least 5 minutes before applying pesticides. This helps ensure that the spray system is functioning correctly and prevents the contamination of the pesticide mix.
- vii. Two-Step Dilution Process: Follow a two-step dilution process for effectively dissolving the pesticide solution, ensuring accurate mixing and optimal performance during application. **Figure 2.7** represents the two-step dilution process.



**Figure 2.7: Two-step dilution process for pesticide**

- viii. Warning labels: These are the labels that provide crucial safety and regulatory information to ensure responsible operation. They typically include guidance on flight safety, such as avoiding people, obstacles, and flying in no-fly zones (**Figure 2.8**).



**Figure 2.8: Warning labels**

- ix. **Optimized Pressure Levels:** Use appropriate pressure levels to achieve an optimized droplet spectrum, targeting droplets greater than  $100\mu\text{m}$  for effective coverage and reduced drift.
- x. **Weather Conditions:** Monitor and consider the following weather conditions before spraying:
  - a) **Wind Speed:** Ensure wind speed is within acceptable limits to prevent drift.
  - b) **Temperature:** Choose a temperature range that minimizes evaporation and maximizes effectiveness.
  - c) **Humidity:** Aim for adequate humidity levels to enhance pesticide absorption.
  - d) **Flying Height:** Maintain an appropriate flying height above the target crop to ensure effective pesticide coverage while minimizing potential drift.
  - e) **Water Volume:** Ensure the correct volume of water is used for dilution and application, adhering to product specifications for optimal results.

- f) **Flying Speed:** Maintain a suitable flying speed to achieve consistent and uniform spray coverage across the treatment area.
- xii. **Avoid Contaminating Crops:** Prevent the drone from traversing through crops that have been exposed to drifting spray to avoid contamination of non-target plants.
- xiii. **Bee Foraging Awareness:** Avoid spraying during periods of active bee foraging, especially throughout the day. Prevent spray drift towards flowering nectar crops to protect pollinators.
- xiv. **Non-Target Organism Impact:** Consider the impact of pesticides on non-target organisms such as fish, birds, and silkworms. Always adhere to the product label instructions and implement measures to mitigate risks associated with pesticide use.
- xv. **Anti-Drift Nozzles:** Utilize anti-drift nozzles to minimize the dispersion of spray particles, protecting human health and the environment from unintended exposure.

Applying pesticides and fertilizers in crops using drones requires careful planning and consideration of several factors to ensure effective and targeted treatments.

### **Key Aspects to be considered During Pesticides Application**

Now, let us understand about the key aspects to consider during the application process:

- i. **Crop Type:** Identify the specific crop being treated, as each has distinct growth patterns and vulnerabilities to pests and diseases. Choose pesticides and fertilizers that are specifically formulated for that crop to ensure effective treatment.
- ii. **Crop Stage:** Assess the developmental stage of the crop (e.g., seedling, vegetative, flowering) before applying any treatment. Timing the application correctly is critical to meet the crop's nutrient and protection needs during that phase.
- iii. **Soil Conditions:** Evaluate the soil quality by conducting tests for nutrient levels and pH. This information will guide the selection and application of fertilizers, ensuring that nutrients are available to the crop when needed.
- iv. **Environmental Conditions:** Monitor the weather before application, focusing on temperature, humidity, and wind speed. Avoid applying pesticides or fertilizers during adverse weather conditions, especially

windy days, to prevent drift and enhance efficacy.

- v. **Drone Speed and Altitude:** Set the drone to fly at an optimal speed and altitude for application. Proper calibration is essential to ensure even coverage and the correct application rate of pesticides and fertilizers.
- vi. **Spray Nozzle and Droplet Size:** Choose the right spray nozzles and adjust droplet sizes based on the specific crop and environmental conditions. Larger droplets minimize drift, while smaller droplets enhance coverage for effective treatment.
- vii. **Application Rate:** Calibrate the drone to apply the correct amount of pesticides and fertilizers according to the recommended rates. This precision helps prevent wastage and mitigates potential environmental harm.
- viii. **Record Keeping:** Keep detailed logs of each application, including the type and amount of pesticide or fertilizer used, the area treated, and the weather conditions during application. This practice is vital for regulatory compliance and future reference.
- ix. **Environmental Impact:** Select eco-friendly pesticides and fertilizers that comply with local regulations. This helps reduce negative impacts on non-target organisms and contributes to sustainable farming practices.
- x. **Safety Precautions:** Prioritize safety during the application process. Drone operators must adhere to safety guidelines and wear appropriate Personal Protective Equipment (PPE) to minimize exposure to chemicals.

By considering these factors and implementing best practices, drone operators can achieve precise and efficient pesticide and fertilizer application, promoting crop health and maximizing yield while minimizing environmental impact. Regular monitoring and data analysis can further optimize the application process, fostering sustainable and responsible agricultural practices.

### **Key Aspects to be considered Post-application**

After the application of pesticides or fertilizers, it is crucial to follow these safety and maintenance guidelines to ensure both environmental protection and personal safety. The guidelines are as follows: -

- i. Timely evacuate and move to an area with fresh air.
- ii. It is essential to perform a triple rinse of any empty containers with water.
- iii. Efforts should be made to minimize waste generation.
- iv. Disposal of waste should be done in accordance with local regulations.
- v. Do not incinerate or bury hazardous waste.

- vi. Empty containers should not be left in the field; they must be disposed of following the Insecticides Rule 1971.
- vii. Install warning signs in the application area to remind people.
- viii. Take a shower and change into clean clothing.
- ix. Prevent leakage of plant protection products during transportation and storage.
- x. Keep these products inaccessible to unauthorized individuals, animals, and food. Immediately manage any spills.
- xi. Adhere to the maintenance schedule provided by the drone manufacturers.

### **Critical Parameters to be considered for Drone-Based Pesticides Application**

#### **Parameters Related to Drones:**

Exclusive permission for agricultural spraying using drones should be granted only to individuals or entities that have received certification or approval from the Directorate General of Civil Aviation (DGCA), as this certification ensures the reliability of the drones. Drones must be equipped to handle varying payloads, including tanks that deplete during use, and their nozzle systems should be designed to guarantee a continuous spray swath when flying at the minimum allowable height over uniformly dispersed crops like paddy or sugarcane.

The drone must also be fitted with a precise altitude sensor to consistently maintain the correct height above crops throughout the entire spraying mission. Additionally, evaluating the drone's GPS accuracy and map precision is essential for establishing a safety buffer when creating a geo-fence around the field or obstacles. The drone's spray system should incorporate adjustable flow control to ensure even distribution of the payload. Essential fail-safe mechanisms must be in place, such as an automatic Return-to-Home (RTH) feature when the tank is empty, and the drone should be able to resume its mission from the exact point where the RTH was initiated.

Furthermore, leak prevention is critical in the drone's spray system to ensure no leakage of pesticides or insecticides occurs during application, with thorough checks conducted before each flight to confirm this.

- i. **Pesticides/insecticides:** When using pesticides or insecticides in agricultural operations, it is critical to follow established regulations and guidelines to ensure safe and effective application. The use of pesticides and insecticides must strictly comply with the approvals provided by the Central Insecticides Board and Registration Committee (CIB & RC), and the application dose should remain within the range approved by these authorities. It is essential to establish compatibility between the pesticides or insecticides (whether liquid or solid) and the drone spray system before the mission, ensuring factors such as solubility, formulation, stability, and suitability for spraying through the drone's nozzle. When mixing multiple



pesticides or insecticides, adherence to the CIB & RC guidelines is mandatory. Additionally, the minimum dilution must meet the necessary criteria to ensure effective horizontal and vertical coverage of the substance being spread. If dilution is required, clean water should be used unless an alternative approved by CIB & RC is specified.

- ii. **Environment Limitations:** The use of drone-based spraying could be authorized under favourable weather conditions. This ensures optimal outcomes. Suitable wind speed, temperature, and relative humidity are important factors to consider, among others.
- iii. **Pilot Training:** To ensure the safe operation of agricultural drones, strict pilot training and certification guidelines must be followed. Permission to operate agricultural drones will only be granted to pilots who are certified by the Directorate General of Civil Aviation (DGCA). To obtain this certification, pilots must undergo mandatory training developed by the National Institute of Plant Health Management (NIPHM) in Hyderabad. This training will cover essential aspects of handling pesticides and insecticides. It will also address specific operational protocols for agricultural missions and guidelines for crop protection. Furthermore, the training will include comprehensive modules on the safe and effective operation of pesticide and insecticide spray drones. This ensures that pilots are well-equipped to carry out their responsibilities safely and efficiently.

#### **Drift Management Critical Operational Parameters**

Drift Management Critical Operational Parameters refer to the key factors that must be controlled to prevent pesticide or chemical spray from drifting away from the targeted area during aerial applications, such as drone-based spraying in agriculture. Drift can lead to unintended exposure of nearby crops, water bodies, or areas, which can be harmful. To manage this effectively, certain operational parameters are critical:

- i. **Spraying Height:** Adjusting the height at which the drone operates ensures that the chemicals are applied as close as possible to the target, reducing the chances of drift due to wind or air currents.
- ii. **Drone Speed:** Controlling the speed of the drone helps to maintain accuracy in the application, preventing overspray or under-application, which can cause drift.
- iii. **Nozzle and Droplet Size:** Selecting the appropriate nozzle and droplet size is crucial to ensure that the spray is fine enough to cover the target area but not so fine that it can easily be carried away by the wind.

- iv. **Geo-fencing and Buffer Zones:** Establishing a virtual boundary around the target area using geo-fencing creates a buffer zone that prevents the drone from spraying beyond the intended zone, reducing the risk of drift.
- v. **Timing of Sprays:** Scheduling spraying operations with respect to weather conditions, such as avoiding spraying before or after rainfall, helps to ensure that the chemicals are not washed away or spread to unintended areas.

Given the prevalence of small land holdings, the risk of spray drift onto nearby crops requires careful planning to mitigate this concern. Beyond considering wind conditions, several critical operational measures must be implemented. These include adjusting the drone's spraying height, controlling the drone's speed, and selecting appropriate nozzle droplet sizes to ensure precision. Establishing a demarcated buffer zone using geo-fencing is also essential to prevent unintended spread. Additionally, scheduling sprays with an appropriate time gap before or after rainfall is crucial to ensure effectiveness. Adherence to further guidelines provided by the Central Insecticides Board and Registration Committee (CIB & RC) over time is also necessary to ensure safe and effective spraying practices.

### **Safeguarding the Non-Targets**

The protection of non-target areas is essential, and this can be achieved by adhering to specific operational protocols. First, buffer zones must be implemented in line with the guidelines endorsed by the Central Insecticides Board and Registration Committee (CIB & RC) to prevent pesticide or insecticide drift, thereby safeguarding adjacent farms or distinct crops. Operators must also follow precautions, such as maintaining the minimum distance from the drone as specified by the CIB & RC and avoiding flying the drone in the windward direction whenever possible.

To prevent exposure, human and animal movement within the farm during and immediately after spraying must be restricted. Additionally, drone-based pesticide operations should comply with both CIB & RC and Directorate General of Civil Aviation (DGCA) guidelines, ensuring safe distances from water bodies, residential areas, fodder crops, public facilities, dairy farms, poultry areas, and other sensitive zones.

By adhering to these measures, the impact on non-target areas can be minimized, fostering safer and more responsible agricultural practices.

### **Registration requirements of pesticides for drone application**

The requirements for registering pesticides for drone application may change over time. They will be evaluated based on safety, effectiveness, legal obligations, and guidelines established by the Central Insecticides Board and Registration Committee (CIB & RC). These guidelines are subject to periodic updates. It is

mandatory for drone users to use only pesticides approved by the Central Insecticides Board and Registration Committee.

To obtain registration for insecticides/pesticides for use with drones, applicants must adhere to the procedures outlined by the CIB & RC under the Insecticides Act of 1968. The application should be submitted to CIB & RC secretariat.

### **Spray Monitoring Form**

Spray monitoring data, completed by the operator or service provider, needs to be submitted within seven days of pesticide application via drone. This data should be sent through email using the designated address specified in the CIB & RC guidelines, or it can be submitted through an online portal designed for this purpose. The prescribed format for data submission is provided in annexure-1 (SOP for drone application and agriculture 2021)

### **DID YOU KNOW?**

- Drones can fly at low altitudes, directly above the crops, minimizing pesticide drift.
- Pesticide application using drones is often faster compared to traditional methods. Drones can cover large areas in a relatively short time, allowing for timely treatment of crops and minimizing the impact of pests on agricultural yields.
- Drones can navigate diverse terrains, including hilly or uneven landscapes, making them suitable for farms with varying topography.
- Drones enable quick response to pest outbreaks. Farmers can deploy drones promptly to assess the situation and apply pesticides as needed, preventing the rapid spread of pests and minimizing crop damage.

### **Activities**

**Activity 1:** In this activity, you will work in groups to learn about pesticides and fertilizers used in agriculture. Activity will begin with a discussion on the importance of these products and how they help improve crop growth and yields. You can also use search engines on your computer or phone to research more information.

After the discussion, your group will receive a set of different pesticides and fertilizers, along with information sheets that explain their uses, benefits, and potential risks. Your task is to carefully review the products and their corresponding information.

Once you have understood the details, each group will discuss how these pesticides and fertilizers are used. You will also talk about the advantages and

any possible risks. After the discussion, you will present your findings to the class. Highlight key points using sticky notes or other visual aids.

Finally, note down your key takeaways and insights about the proper use of pesticides and fertilizers in agriculture. Share any new perspectives you have gained.

**Activity 2:** In this activity, you will work in small groups to create posters illustrating the proper steps for pesticide and fertilizer application in agriculture, emphasizing responsible chemical use.

Procedure:

- Use mobile devices or computers to gather information on correct dosage and application techniques.
- Form small groups, and use the provided poster board, art supplies, and images to design an engaging, informative poster.
- Present your poster to the class, explaining the key steps for accurate application.
- Explore other groups' posters during a gallery walk to learn from their designs.

## Check Your Progress

### A. Multiple Choice Questions

1. What is a crucial factor in determining the operational capabilities of a drone?
  - a) Weight of the drone
  - b) Flight time
  - c) Type of battery
  - d) Colour of the drone
2. How does the payload capacity affect a drone's operations?
  - a) It determines the drone's speed
  - b) It dictates how much liquid (e.g., pesticide) the drone can carry
  - c) It affects battery life
  - d) It influences the drone's range
3. Which aspect is important for the effectiveness of a drone's navigation system?
  - a) Battery life
  - b) GPS accuracy
  - c) Colour of the drone
  - d) Design of the propellers

4. What is one guideline for drone operation near water sources?
  - a) Fly as low as possible
  - b) Avoid flying within 100 meters of water sources
  - c) Always fly over water
  - d) Use water-resistant drones only
  
5. What feature enhances a drone's operational efficiency?
  - a) Manual control
  - b) Autopilot functionality for efficient and repeatable operations
  - c) Larger propellers
  - d) Remote control distance
  
6. What is a significant feature that protects drones during various conditions?
  - a) Colour design
  - b) Weather resistance
  - c) Speed capabilities
  - d) Weight reduction
  
7. What is a necessary step before flying a drone over private property?
  - a) Notify local authorities
  - b) Obtain permission from property owners
  - c) Fly at a lower altitude
  - d) Use a larger drone
  
8. Why is it important to adhere to restricted zone regulations when operating a drone?
  - a) To reduce battery consumption
  - b) It ensures drones cannot operate in restricted zones without prior approval
  - c) To improve flight time
  - d) To enhance image quality
  
9. How does a drone's maintenance schedule affect its operation?
  - a) It increases flight speed
  - b) It minimizes downtime between operations
  - c) It reduces payload capacity
  - d) It enhances colour visibility
  
10. What is a key reason for ensuring proper control of the drone during operation?
  - a) To increase battery life
  - b) To avoid losing control of the drone and reduce the risk of accidents
  - c) To improve GPS accuracy
  - d) To enhance flight time

## Session 2: Crop Nutrient Application

In the previous session, you explored various factors that influence the choice of drones. In this session, you will learn the applications of drones for delivering nutrients to crops.

### Crop Nutrient Management

Crop Nutrient Management is the strategic practice of supplying crops with the essential nutrients they need for optimal growth, health, and productivity. This involves determining the right type, amount, and timing of nutrient applications to match the crop's requirements, soil conditions, and environmental factors. The goal of crop nutrient management is to maximize crop yield and quality while minimizing nutrient waste and environmental impact. Key nutrients, often referred to as macronutrients (such as nitrogen, phosphorus, and potassium) and micronutrients (like zinc, iron, and manganese), must be balanced to ensure the plant's development throughout its growth stages. Effective nutrient management practices also include soil testing, monitoring nutrient levels, and using methods like fertilization, organic amendments, or precision agriculture tools such as drones for efficient nutrient delivery.

Soil nutrient application, guided by the evaluation of soil nutrient levels, represents a precision agriculture technique that resides within the realm of future-oriented technology and is presently undergoing research and development. The committee, however, maintains the perspective that drones hold remarkable potential for the management of soil nutrients.

Integrating drones into the process of assessing and applying soil nutrients stands to revolutionize precision agriculture, offering benefits such as resource conservation, reduction of environmental risks, labour cost savings, and amplified yields in crops, land utility, and overall economic productivity. Agricultural drones serve the purpose of optimizing farming operations, maximising crop yield, overseeing crop growth through the evaluation and mapping of diverse nutrients, and also efficient spraying of soil and crop nutrients.

### Normalized Difference Vegetation Index

Normalized Difference Vegetation Index (NDVI) is a numerical metric used in the field of remote sensing and geospatial analysis to evaluate the density and health of vegetation within a specific geographic area. This index plays an essential role in applications related to agriculture, forestry, and environmental monitoring. NDVI is calculated by taking the difference between the reflectance of Near Infrared (NIR) and red-light bands in the electromagnetic spectrum.

The NDVI formula is as follows:

$$NDVI = \frac{(NIR - Red)}{(NIR + Red)}$$

Where, NIR represents the reflectance of near infrared light and Red represents the reflectance of red light.

The outcome of this calculation falls within the range of (-1) to (+1), with different values indicating various environmental conditions. Positive NDVI values (ranging from (0) to (+1)), typically signifies healthy vegetation, with higher values indicating denser and more robust plant cover. NDVI value of (0), suggests the presence of non-vegetated surfaces like bare soil or rocks. Negative NDVI values (ranging from (-1) to 0), generally correspond to non-vegetated surfaces such as water bodies, urban areas, or cloud cover.

NDVI proves to be a valuable tool for monitoring factors such as vegetation growth, crop health, the detection of drought stress, and the study of land use changes. Its importance is especially evident in remote sensing applications, where satellite or drone imagery is employed to examine extensive geographical regions and monitor changes in vegetation conditions over time.

### **Nutrient Assessment/Mapping**

Nutrient assessment and mapping are a critical process in precision agriculture that involves evaluating soil nutrient levels and distributing this information spatially across a field to optimize crop health, enhance yields, and promote sustainable farming practices.

Soil nutrient mapping using drones enables real-time, site-specific nutrient management, which is crucial for optimizing crop health. Unlike traditional soil sampling methods that provide nutrient data from only select points, drones allow for comprehensive coverage of fields, capturing spatial and temporal variations in soil nutrients quickly. This drone-based soil nutrient analysis is efficient and energy-saving, enabling swift and precise application of nutrients where they are needed most. This not only improves yields but also reduces fertilizer use and minimizes soil pollution.

Drones can capture high-resolution images of fields using multispectral and hyperspectral technology, which are quickly sent to cloud-based software for generating detailed prescription maps. These nutrient prescription maps can then be integrated into farming machinery, allowing for accurate and targeted application of fertilizers across the field, ultimately enhancing crop growth and productivity.

### **DID YOU KNOW?**

- Nitrogen is a key nutrient for plant growth, and some crops, like corn, have a particularly high appetite for it. Corn is often referred to as a "nitrogen hog" due to its substantial nitrogen needs during the growing season.
- Iron, zinc, copper, and manganese are some of the micronutrients that plays an essential role in plant metabolism that can be used on field using drones.
- Soil pH influences nutrient availability. If the pH is too high or too low, some nutrients might not be readily available to plants. Farmers use lime to adjust pH levels and keep the nutrient balanced.

### **Spraying of Soil/Crop Nutrients**

It refers to the application of fertilizers, micronutrients, and other soil amendments using aerial drones to enhance agricultural productivity. This method utilizes drones equipped with advanced spraying systems to deliver nutrients directly to the target areas of crops and soil. The spraying can include both solid (e.g., granules, powders) and liquid forms (e.g., water-soluble fertilizers, growth regulators) to ensure the crops receive the necessary nutrients in a timely and efficient manner.

When using drones for soil and crop nutrient applications, several essential factors need to be considered to ensure optimal effectiveness. First, the type and concentration of the nutrients to be sprayed or broadcast are critical, as they influence the overall application strategy. The efficiency of the drone largely depends on the quality of its spraying systems and sensors, which must be capable of delivering nutrients accurately. Drones offer versatility in the types of nutrients they can apply, handling both solid forms like powders, crystals, and granules, as well as liquid forms, including water-soluble nutrients and growth regulators, catering to both organic and inorganic needs.

Furthermore, drones significantly enhance efficiency and coverage, allowing farmers to cover at least ten times more area per day compared to traditional knapsack sprayers, which saves valuable time. Water conservation is another key advantage, with drone applications potentially reducing water usage by 80-90% compared to conventional methods, depending on the spraying system used. Additionally, tailored nozzle options are available to match the specific requirements of the nutrient form and concentration, ensuring precise and efficient application, ultimately leading to improved crop health and productivity.



**Drone, sensors, data processing software and soil nutrient spraying system**

Drones offer a promising solution to ease the labour demands of agricultural tasks, particularly in fertilizer application, while simultaneously expanding daily crop coverage. This will provide a significant ease of farming, enabling them to allocate saved time to other essential activities, while promptly addressing biological challenges.

Three drone configurations with sensors are:

- (a) Drones equipped with multispectral cameras,
- (b) Drones integrated with fertilizer spraying systems for granular/liquid substances, and
- (c) Drones combining multispectral cameras with fertilizer spraying systems for granular/liquid applications.

Three distinct protocols for soil nutrient delivery are possible:

- i. Recommended Dose of Fertilizer (RDF) Protocol:** This protocol aligns with crop growth stages and soil nutrient requirements, allowing immediate deployment for both liquid and granular nutrients, encompassing Macro, Micro, and Nano-Micro fertilizers. RDF-based applications respond directly to recommendations.
- ii. Two-Step Operation Protocol:** In the initial step, field soil imaging evaluates nutrient status, processing data to create GPS-tagged nutrient requirement maps. These maps, driven by soil indices, inform the dispensing drone about precise nutrient quantities for various crops and stages. The software computes nutrient amounts accordingly, supporting variable rate application.
- iii. Real-Time Operation Protocol:** This advanced approach requires real-time imaging and nutrient application. It necessitates effective live processing on the drone. Achieving seamless imaging, processing, and delivery simultaneously is essential. This process requires extensive research and development due to technological complexities.

**Feasibility of sustainable adoption of drone**

Affordable drones are now widely available, offering the ability to capture ground data along with corresponding geographic coordinates, enabling users to gain comprehensive and easily accessible insights into ground conditions. These drones can be programmed to execute predefined flight plans, ensuring precise data collection and input delivery. One of their key advantages is the ability to swiftly image large fields, covering extensive land in a single flight, which provides drones with valuable synoptic assessment capabilities.

In India, the drone industry is rapidly expanding across various sectors, particularly in agriculture, making the integration of drone-based technologies, such as soil nutrient applications, feasible on a sustainable basis. Drone technology can also be effectively used for spraying bio liquid fertilizers onto different crops, although careful formulation and experimentation are required for chemical liquid fertilizers. The transition to uniform foliar application of nutrients or urea can begin even before extensive Research and Development (R&D) into variable nutrient mapping is completed. Real-time nutrient mapping using spectral metrics can help predict nutrient deficiencies, enabling precise foliar application of nutrients.

Under standard conditions, a drone with a 10 kg payload capacity can cover approximately 30 acres per day, operating for around six hours with the support of five battery sets. The operational cost for such drone-based applications may range between ₹350-450 per acre, depending on the crop type and agro-climatic conditions, for flight operations lasting between 6 to 20 minutes.

### **Standard Operating Procedures (SOPs) for use of Drone Assessment/ Mapping of Soil Nutrients and Application of Nutrients Crops**

#### **Procedures for use and application of crop nutrients**

- i. Adhere to Fertilizer Control Order (FCO) guidelines when employing crop nutrients in agricultural practices.
- ii. Only adequately trained individuals should be responsible for the application of crop nutrients.

#### **Agricultural application practices to be followed:**

- i. Follow the recommendations from authorized agencies or institutions regarding the type and quantity of crop nutrients to utilize.
- ii. Before applying, verify the appropriate dosage and compatibility of the nutrients to be used. Additionally, adhere to good agricultural practices that are outlined separately, such as fertilizing when the soil is moist.
- iii. Avoid applying crop nutrients if heavy rainfall is expected.
- iv. Regularly calibrate the system used for applying crop nutrients, whether it involves distribution, spraying, or broadcasting. This ensures accurate application and loading rates.
- v. When mixing crop nutrients, do so in a clean environment with covered equipment, minimizing the risk of spills coming into contact with rainwater

or storm water runoff.

- vi. Exercise caution to prevent excessive use of crop and soil nutrients and avoid combining them with pesticides, as this could result in phytotoxicity. (Phytotoxicity refers to the harmful effects that certain substances, such as chemicals or pesticides, can have on plants, leading to damage, impaired growth, or reduced yields). Refer to pesticide application guidelines in such cases.

### **Using drones for solid (granular/powder) crop nutrient application:**

When using drones for the application of solid crop nutrients, such as granular or powdered fertilizers, it is essential to follow specific operational guidelines to ensure effective distribution. The drone should maintain an altitude of 1.0 to 3.0 meters above the crop canopy, adjusting this height based on the type of crop and its growth stage. The forward speed of the drone should be kept within 3 to 8 meters per second to optimize nutrient delivery. Utilizing appropriate dispensers, such as rotating disc types or pneumatic dispensers, is crucial for evenly distributing the granular nutrients. Each flight should limit the payload of granular or powdered nutrients to a maximum of 10 kg, allowing for efficient application as the drone moves. Ideally, the rotational speed of the dispensing disc should be set between 800 to 1000 rpm, or operators should adhere to the manufacturer's guidelines to ensure optimal performance. Following these parameters enhances nutrient application efficiency and promotes healthy crop growth.

The procedures for applying liquid crop nutrients using drones are essential for effective agricultural practices. Drones can be employed to apply a variety of agricultural formulations, including liquid bio-fertilizers, organic substances such as *jivamrit* and vermiwash, bio-decomposers, nano-fertilizers, soluble micronutrients, and bio-stimulants. These applications should comply with the recommendations from approved agencies or institutions. It is advisable to maintain a drone altitude of 1.0 to 2.0 meters above the crop canopy, depending on the specific crops and their growth stages. During each flight, the liquid payload should not exceed 10 litres, and crop nutrients can be dispensed while flying at speeds ranging from 3.0 to 6.0 meters per second. For optimal results, positioning the spraying nozzle beneath the drone's motors helps minimize spray droplet drift. Care must also be taken to ensure that spraying is confined within the designated target area to maximize efficiency and minimize unintended application.

## **Activities**

**Activity 1:** During a visit to a local agricultural field, you will observe various methods of crop nutrient application, including spraying micronutrients, applying NPK fertilizers (nitrogen, phosphorus, potassium), and incorporating manure, compost, and cover crops. You will learn how NPK fertilizers, essential for plant

growth, are used across crops like cereals, vegetables, and fruits, and understand the role of organic matter in enhancing soil health. To deepen your understanding, research nutrient application techniques using mobile devices or computers. After the visit, document your observations in a diary and participate in a class discussion to share insights on nutrient management in agriculture.

**Activity 2:** In this activity, you will be introduced to the application of drones for nutrient management in agriculture. The materials needed for this activity include drone models or images for demonstration, a whiteboard or flip chart, markers and coloured pens, and printed images or diagrams illustrating drone nutrient application.

The activity will begin with a discussion providing a brief overview of traditional methods of nutrient application in agriculture. Next, you will demonstrate how drones, using models or images, can be utilized for nutrient application, highlighting how drones equipped with spray systems can precisely deliver nutrients to crops, thereby minimizing waste and ensuring even coverage. You can use search engines on your computer or mobile device to gather relevant information about drone usage in nutrient application.

After the demonstration, you will form small groups and be assigned hypothetical farming scenarios. Each group will then plan a nutrient application strategy using a drone, considering factors such as crop type, field size, and specific nutrient needs. Your plan should be displayed on the whiteboard or flip chart, and finally, each group will present their nutrient application plan to the class, explaining their rationale and decision-making process.

## Check Your Progress

### A. Multiple Choice Questions

1. What is one of the primary benefits of using drones in agricultural operations?
  - a) Increased labour costs
  - b) Increased resource conservation
  - c) Reduced crop yield
  - d) Lower soil quality
2. What index is commonly used to assess vegetation health with drones?
  - a) Plant Growth Index
  - b) Normalized Difference Vegetation Index
  - c) Soil Quality Index
  - d) Crop Density Index

3. Which nutrient is commonly monitored for optimal crop growth using drones?
  - a) Potassium
  - b) Nitrogen
  - c) Phosphorus
  - d) Calcium
4. What are the key advantages of using drones for agricultural applications?
  - a) Increased labour costs
  - b) Reduced productivity
  - c) Time efficiency and energy savings
  - d) Increased pesticide use
5. Which protocol ensures the optimal amount of fertilizer application in drone operations?
  - a) General Fertilizer Protocol
  - b) Recommended Dose of Fertilizer (RDF) Protocol
  - c) Maximum Nutrient Application Protocol
  - d) Fertilizer Reduction Protocol
6. What feature allows drones to enhance precision agriculture?
  - a) Pre-programmed flight paths
  - b) Manual control by the operator
  - c) Real-time imaging and nutrient application
  - d) GPS-guided soil testing
7. What is the typical flying height range of drones used for crop spraying?
  - a) 5.0 to 7.0 meters
  - b) 1.0 to 3.0 meters
  - c) 10.0 to 15.0 meters
  - d) 8.0 to 12.0 meters
8. In what forms can fertilizers be applied using drones?
  - a) Only in solid form
  - b) Only in liquid form
  - c) Both solid and liquid forms
  - d) Only in gas form
9. What is an important step before applying nutrients using drones?
  - a) Calibrate the drone's flight path
  - b) Verify the compatibility of nutrients
  - c) Measure crop height
  - d) Analyse the weather conditions

10. How much water can drones save during agricultural applications compared to traditional methods?

- a) 50-60%
- b) 30-40%
- c) Drones save 80-90% of water during applications
- d) 10-20%

### Session 3: Prerequisites for Using Drones

In the previous session, you learned about crop nutrient applications. In this session, you will learn about prerequisites for using drones. This session will cover the necessary requirements before deploying drones in agriculture, including site assessment, legal permissions, safety measures, and the preparation of drones and equipment to ensure effective and safe operations.

Imagine yourself making a tasty cake for your friend's birthday. Now, to make cake, you must have certain requirements, namely ingredients, whisk, a bowl etc. After knowing the entire requirement, you will be able to prepare the cake step-by-step. Therefore, as to prepare the cake, we should know the requirements, just as we need to know the prerequisites for using drone. As the usage of drones involves knowledge, practice, and advancement in functioning, one must also adhere to the rules and regulations for the operation and maintenance of drones. The following prerequisites need to be followed before, during, and post-operation for reducing drift and air pollution:

#### Key Preparations Before Drone Operation

The following are the prerequisites to be followed before the application of drones

- i. For both the service provider and operator, possessing the necessary flying permissions and licenses from the Directorate General of Civil Aviation (DGCA) is imperative. Moreover, the operator must hold an ICAR (Indian Council of Agricultural Research ICAR) Government-approved training centre certificate, attesting to their proficiency in operating, repairing, maintaining, and safely utilizing soil and crop nutrients. It is crucial that the operator is physically fit, mentally sound, and composed during operations.
- ii. An optimal operator team ideally consists of three to four members, encompassing a pilot, co-pilot, and one or two technicians responsible for formulation preparation, mixing, and addressing technical glitches. However, the team's size depends on the operational scale. Thorough training, certified by recognized centres, is obligatory for all team members.

Adequate office space with essential amenities should be available the operator team.

- iii. Monitoring weather conditions such as cloud cover, light intensity, temperature, wind speed, and direction is vital. Weather forecasts should guide flight decisions, avoiding drone operation in cloudy or rainy circumstances, including periods preceding and following rainfall and against the wind.
- iv. Crop and field conditions, as well as nearby obstacles, require continuous assessment. Selecting the home point for the drone should consider crop and field factors, while the flight path should accommodate the field shape and turning requirements. Ensuring a safe distance of at least 10 meters from the take-off point is essential. The operational team should be positioned downwind and in the backlight direction.
- v. Flying near high-tension electrical towers should be avoided to prevent signal interference. A buffer zone between drone treatment and non-target crops is necessary. Flying the drone 100 meters away from residential areas, water bodies, feed crops, dairy and poultry, and public utilities are recommended during soil and crop nutrient application.
- vi. Avoid applying soil and crop nutrients when bees are actively foraging on flowering nectar crops. When using substances that are toxic to non-target organisms, it is essential to follow the product label instructions closely and take extra precautions to reduce risks.
- vii. Thorough calibration of the drone and spraying unit before flight is essential. The spraying unit requires checks for pump pressure, nozzle wear, uniform spraying, and tank and line leakage. Maintaining the right pressure ensures optimal droplet size (100-150  $\mu\text{m}$ ). Soil and crop nutrient labels should be verified before tank filling at recommended concentrations. The operator must use Personal Protective Equipment (PPE) throughout **(Figure 2.9)**.



**Figure 2.9: Drone operator wearing PPE Kit in the field**

- viii. Clean water is crucial for preparing soil and crop nutrient solutions. Containers used for mixing must never be repurposed for domestic use, even after thorough washing.
- ix. The service provider should carry spare parts like propellers, batteries (at least four sets), motors, and nozzles to the operational site.

**During Application:** Here are the prerequisites to be followed during application drones

- i. Ensure continuous monitoring of drone behaviour throughout its operation to prevent any potential accidents. Additionally, it is important to monitor the spraying system to prevent any obstructions during its operation.
- ii. When flying the drone for spraying purposes, maintain a flight altitude of 1.0 to 3.0 meters above the crop canopy being targeted. The drone's speed should not exceed meters per second during the spraying process.
- iii. Promptly replace discharged drone batteries with fully charged ones.
- iv. Always adhere to the recommended guidelines and avoid using excessive doses or higher concentrations of crop nutrients.
- v. To guarantee safety, prohibit any human or animal movement within the operational field while the drone spraying is in progress.

**Post Application:** Here are the prerequisites to be followed post application drones

- i. Following the completion of the spraying task, the team and operator should vacate the area for fresh air, devoid of any soil or crop residue. Avoid entering the treated field right after spraying unless you are wearing proper protective clothing. For a minimum of 2 hours, warning signs must be placed around the sprayed zone to prevent potential risks to humans.
- ii. Remaining spray solutions ought to be disposed of in a secure location, such as barren and isolated areas. Empty containers should undergo a triple rinse. Disposal of waste must adhere to local regulations, avoiding burning or burying of hazardous materials. Empty crop nutrient containers must not be reused for other applications.
- iii. During transportation or storage of Plant Protection Products (PPPs), ensure the location is inaccessible to children, animals, and unauthorized individuals.
- iv. Post-spraying, wash hands, face, and change clothes immediately, preferably with soap. If any signs of chemical exposure occur, seek medical



attention. After every 20 hours of drone flight, check for wear, loose screws, and damage to propellers and frames.

### DID YOU KNOW ?

- Some drones use real-time kinematic (RTK) GPS technology, ensuring centimetre-level accuracy during flight. This high precision enables drones to follow predefined paths with exactitude, ensuring that inputs like pesticides or fertilizers are applied precisely where they are needed.
- Drones capture thermal images that reveal temperature variations in the crop canopy. This information aids in assessing plant stress levels and evaluating the effectiveness of the applied treatments.
- Drones equipped with specific sensors can detect pest infestations early on, allowing farmers to implement targeted control measures and reduce reliance on broad-spectrum pesticides.

### Activities

**Activity 1:** What are the prerequisites for using a drone? Make a presentation on various prerequisites to ensure safe, legal, and effective drone operations. Let us take an example of regulatory compliance in drone operation. The presentation may include the following:

- Introduction to regulatory compliances
- Importance of compliance
- Key regulatory bodies
- Registration and licencing
- Operational guidelines
- Communication protocols

You can take help of search engine or mobile application to learn about the prerequisites for using a drone.

**Activity 2:** Highlight the prerequisites of drone operation in terms of pre, during and post application. Write down in points, the prerequisites to consider safe and effective drone operation. Let us take an example of pre-application prerequisites to regulatory knowledge:

- **Pilot Certification:** Obtaining the necessary certifications and licenses and complying with any training requirements set by aviation authorities is crucial drone operation.
- **Equipment Readiness:** Ensure that the drone is in good working condition. Regularly check and maintain batteries, propellers, and other components.
- **Weather Monitoring:** Regularly monitor weather conditions before each flight to ensure safe operations.

- **Data Security and Privacy:** Develop protocols for secure storage, processing, and sharing of collected data.
- **Emergency Response Plan:** Develop and communicate emergency response procedures for unforeseen events.

You can take help of the ICT tools like mobile, computer, etc., to learn about the prerequisites for drone operation.

## Check Your Progress

### A. Multiple Choice Questions

1. What is required to operate a drone legally for agricultural purposes?
  - a) Weather report
  - b) Necessary flying permissions and licenses from DGCA
  - c) Calibration of drone sensors
  - d) Approval from local government
2. How many batteries are typically recommended for a drone to complete a full day of operation?
  - a) One
  - b) Two
  - c) Three to four
  - d) Five or more
3. When should pesticide applications be avoided to protect pollinators like bees?
  - a) During early morning hours
  - b) During late evening
  - c) Applying during active bee foraging
  - d) During night time
4. Which factors should be monitored to ensure the proper functioning of the drone during pesticide application?
  - a) Battery life and propeller speed
  - b) Flight altitude and wind speed
  - c) Pump pressure and nozzle wear
  - d) Crop height and growth stage
5. What is the ideal flying height for drones when spraying crops?
  - a) 0.5 to 1.0 meters
  - b) 1.0 to 3.0 meters
  - c) 3.0 to 5.0 meters
  - d) 5.0 to 7.0 meters

6. How long does it typically take to recharge a drone battery?

- a) 30 minutes
- b) 1 hour
- c) 2 hours
- d) 4 hours

**B. Fill in the Blanks**

- 1. The Indian Council of Agricultural Research is abbreviated as \_\_\_\_\_.
- 2. Precision agriculture can be implemented from the comfort of your \_\_\_\_\_.
- 3. Drones should not fly closer than \_\_\_\_\_ meters to populated areas.
- 4. Remote sensing by drones can help monitor \_\_\_\_\_ levels in crops.
- 5. The main components driving the propellers of a drone are its \_\_\_\_\_.
- 6. A typical drone can spray up to \_\_\_\_\_ liters of liquid per flight.

## Session 4: Precautions During Drone Operation

In this session, you will learn about key safety measures to take while operating a drone, including maintaining a safe distance from people and obstacles. You will explore best practices for assessing weather conditions before and during drone flights, as well as guidelines for safe take-off, landing, and in-flight operations. Additionally, this session will cover how to handle emergency situations effectively to minimize risks during drone operation.

Boarding on a journey into the skies with a drone is nothing short of an exciting adventure, where technology meets the limitless area above. However, the requirement of flying a drone goes hand in hand with the responsibility of ensuring a safe and compliant aerial experience. Just like any pilot, whether soaring on wings or propellers, adhering to precautions is the compass that guides a drone's journey. In this realm of innovation and exploration, understanding the importance of safety measures becomes the introduction to unlocking the full potential of flight. Let us understand the precautions to be taken during drone operation in detail.

### Pre-flight inspection

During drone operation, conducting a pre-flight inspection is crucial to ensuring safe and successful flights, as several issues can arise during this process that need prompt attention to prevent accidents and equipment failures. One significant concern is battery and engine maintenance; drone batteries must be charged correctly, and any signs of degradation or damage should be addressed, as faulty engines can lead to unstable flight behaviour or unexpected shutdowns. Additionally, cleaning and protecting the drone's sensors, camera, and motors from dust, dirt, and debris is vital for maintaining performance and image

quality.

Keeping firmware and software updated is also essential to avoid compatibility issues and security vulnerabilities. Calibration errors, such as those involving the compass, gyroscope, and IMU, can impact stability and accuracy, making regular calibrations necessary for optimal flight control. Safe storage and transportation are important to prevent physical damage; improper handling can lead to dislodged or broken parts. Furthermore, inadequate GPS signals or interference can disrupt the drone's ability to maintain position, while radio interference from other devices may result in loss of control. Sensor malfunctions can compromise stability and obstacle avoidance, leading to inaccurate data readings.

Propeller problems, such as damage or improper attachment, can cause imbalanced thrust, resulting in unstable flight. Finally, adverse weather conditions, including rain, strong winds, and low visibility, can significantly impact drone operations and present safety risks, underscoring the importance of thorough pre-flight inspections.

To mitigate these problems, drone operators should follow a thorough pre-flight checklist and conduct regular maintenance and updates. Additionally, ongoing training and awareness of potential issues will help operators identify and address problems promptly, ensuring safe and efficient drone operations.

### **Post-flight Inspection**

Post-flight inspection is a crucial step in drone operation, ensuring that the equipment is in good condition and that data collection missions are successful. However, several problems can be encountered during this phase:

- i. **Physical Damage:** Drones can experience physical damage during flights, such as collisions with obstacles, hard landings, or bird strikes. Post-flight inspections must identify any structural damage to the frame, propellers, or other components. This is essential for both safety and continued operational efficiency.
- ii. **Battery Health:** Drone batteries degrade over time, affecting flight duration and overall performance. A problem faced during post-flight inspection is assessing the battery's health, including checking for swollen cells, voltage irregularities, or capacity loss. Addressing battery issues is vital for flight safety and mission success.
- iii. **Sensor Malfunctions:** Drones rely on various sensors like GPS, LiDAR, or cameras for navigation and data collection. Problems with these sensors, such as calibration or damage, can lead to inaccurate data or even accidents. A thorough inspection should check for sensor functionality and accuracy.

- iv. **Software and Firmware Issues:** Drones are controlled by software and firmware. After a flight, issues may arise related to software glitches, firmware updates, or compatibility problems. These issues can affect the drone's stability, performance, or data processing capabilities.
- v. **Data Retrieval:** Collecting and storing data during the flight is a critical aspect of drone operations. Sometimes, data retrieval can be challenging due to technical issues like corrupted files, storage limitations, or transfer errors. A post-flight inspection should ensure that all required data is successfully retrieved and intact.
- vi. **Environmental Factors:** Weather conditions, such as rain, strong winds, or extreme temperatures, can influence drone operations and lead to problems during flight. Post-flight inspections should consider the effects of these environmental factors on the drone's performance and components.
- vii. **Regulatory Compliance:** Drone operations often require adherence to specific regulations and flight restrictions. Operators may face issues if they inadvertently violated airspace rules or operated in restricted zones during the flight. Identifying and addressing these compliance issues is essential to avoid legal repercussions.
- viii. **Human Error:** Sometimes, problems during drone operations can be attributed to human error, such as incorrect flight planning, inadequate training, or mistakes in operating procedures. A post-flight inspection should include a review of the operator's actions to identify areas for improvement.
- ix. **Maintenance Needs:** Routine maintenance tasks, like cleaning, tightening fasteners, or replacing worn-out parts, are essential for prolonging the lifespan of drones. Post-flight inspections often reveal maintenance needs that should be addressed to ensure the drone's reliability for future missions.
- x. **Documentation and Reporting:** Proper documentation of flight details, issues encountered, and maintenance actions taken is crucial for accountability and continuous improvement. Failing to document problems during post-flight inspections can lead to difficulties in diagnosing recurring technical issues or improving operational procedures.

### DID YOU KNOW?

- In several regions, drones must stay below a certain altitude, typically, 400 feet (122 meters), to ensure they do not hamper manned aircraft.
- The wind speed, rain, and temperature can significantly affect drone performance.
- Pilots need to be mindful of magnetic fields, avoiding areas with potential disturbances to maintain precise navigation.
- Respecting privacy, obtaining necessary permissions, and being mindful of data security are digital etiquettes essential for responsible drone operations.

### Activities

**Activity 1:** Fault-finding and rectification in drones involve troubleshooting issues that may arise during operation. Let us explore some common problems. For flight performance issues, the symptoms may include instability during flight or difficulty in maintaining altitude. Possible causes can be improper calibration or damage to components.

The rectification involves recalibrating the drone and inspecting the hardware for any damage. For motor or propeller issues, symptoms include unusual noise or reduced thrust.

Possible causes may be damaged propellers or malfunctioning motors. The rectification involves inspecting and replacing damaged propellers or motors. Battery problems may present as short flight times or sudden power loss.

The possible causes can be a degraded battery or poor charging practices. Rectification involves ensuring proper charging, using a reliable charger, and replacing the battery if necessary. Lastly, for camera and gimbal problems, symptoms may include shaky footage or inability to adjust the camera angle.

Possible causes include loose connections or misalignment of the gimbal. Rectification requires checking and securing connections, as well as recalibrating the gimbal to restore proper function.

**Activity 2:** Write in brief about the procedure for troubleshooting technical issues and equipment failure. Let us take an example of first step in the procedure for troubleshooting technical issues and equipment failure.

The first step is defining the issue and checking physical components. Clearly identify and document the issue. Understand when it started, any recent changes, or specific conditions under which the problem occurs. Also, inspect the drone for visible damage, loose connections, or disconnected components. Ensure propellers, motors, and other hardware are in good condition. You can take help of search engine on your mobile or computer to learn about the various aspects of troubleshooting technical issues and equipment failure.

### Check Your Progress

#### A. Multiple Choice Questions

1. What is the primary goal of training participants on drone repair and maintenance?
  - a) To improve drone speed
  - b) To increase drone payload capacity
  - c) To teach participants how to repair and maintain drones while emphasizing documentation
  - d) To reduce the drone's operational time
2. Why is it important to address unexpected problems during drone operation?
  - a) To improve battery life
  - b) To reduce flying time
  - c) To address unexpected problems and ensure smooth drone performance
  - d) To enhance drone visuals
3. How does proactive drone maintenance benefit operators?
  - a) By reducing the need for training
  - b) By decreasing operational time
  - c) By allowing them to address issues and prevent disruptions during operation
  - d) By increasing the weight of the drone

#### B. Fill in the Blanks

1. Proper \_\_\_\_\_ is essential to ensure the longevity and performance of drones.
2. Drones use \_\_\_\_\_ to collect data and monitor crop health.
3. Following standard \_\_\_\_\_ protocols helps prevent accidents during drone operations.
4. Monitoring drone \_\_\_\_\_ can help operators detect any abnormal performance.
5. Safe drone \_\_\_\_\_ are crucial for precision agriculture.

6. Drones need to navigate around \_\_\_\_\_ to prevent collisions during flight.
7. \_\_\_\_\_ batteries should be avoided to prevent power failure during drone operation.
8. Pilots should always monitor the drone's \_\_\_\_\_ status to ensure a safe landing.
9. Calibration of sensors improves the drone's \_\_\_\_\_ in data collection.
10. Proper documentation ensures \_\_\_\_\_ in drone maintenance and operation processes.

<b>Module 3</b>	<b>Rules and Regulations for Drone Operation</b>
<b>Module Overview</b>	
<p>This module is focused on providing participants with essential knowledge of maintaining drone functionality, handling emergencies, and adhering to legal regulations.</p> <p>In the first session on basic maintenance of drone, you will be introduced to routine maintenance procedures to ensure drone longevity and performance. Topics covered include cleaning, battery care, sensor calibration, and the replacement of parts. Proper maintenance techniques will be emphasized to prevent mechanical failures during operations.</p> <p>The second session on handling procedure in case of emergencies, prepares to respond to potential issues that may arise during drone flights. This includes troubleshooting common technical problems, dealing with malfunctions, managing unexpected weather conditions, and safely recovering a drone after a failure. Practical scenarios and simulations will be used to teach participants how to act swiftly and correctly in emergencies to prevent damage or injury.</p> <p>The third session on regulations of directorate general of civil aviation and safety guidelines, you will learn about the legal framework governing drone operations in agriculture. This session will cover the regulatory requirements set forth by the Directorate General of Civil Aviation (DGCA), including permissions, no-fly zones, and altitude restrictions. Emphasis will also be placed on understanding safety protocols, certification requirements, and the importance of complying with legal guidelines to ensure safe and lawful drone use.</p>	



## Learning Outcomes

After completing this module, you will be able to:

- Demonstrate the steps for basic drone maintenance, including battery care, motor checks, and sensor calibration.
- Identify the key components of a drone that require regular maintenance.
- Develop a plan for responding to technical malfunctions, mid-flight failures, or environmental hazards.
- Explain how to prevent emergencies through pre-flight checks.
- Explain the key regulations and compliance requirements outlined by the DGCA for drone operations.

## Module Structure

Session 1: Basic Maintenance of Drone

Session 2: Handling Procedure in Case of Emergencies

Session 3: Regulations of Directorate General of Civil Aviation and Safety Guidelines

### Session 1: Basic Maintenance of Drone

In this session, you will learn about basic maintenance of drone. This session will cover essential maintenance procedures to ensure optimal performance of your drone, including regular inspection of components, cleaning and lubrication, battery care, and firmware updates. By following these maintenance practices, you can enhance the longevity and reliability of your drone, reduce the risk of malfunctions, and ensure safe and efficient operation.

In farming operations, maintaining drones is vital to ensure their longevity and reliability in supporting agricultural tasks. Proper drone care and maintenance involve regular inspections to check for wear and tear on components such as propellers, motors, and batteries. Keeping the drone clean, free from dust and debris, and protecting it from extreme weather conditions helps prevent damage and deterioration.

Battery maintenance is especially vital, as batteries are essential for flight. It is essential to charge, store, and handle batteries according to the manufacturer's instructions to extend their lifespan. Additionally, software updates should be applied promptly to ensure the drone's firmware remains up-to-date and optimized for performance.

Regular maintenance not only maximizes the drone's operational efficiency but also minimizes the risk of unexpected failures during critical farming tasks. In this module, you will know the steps involved in drone maintenance, procedures that need to be followed during emergencies and rules, regulations and safety guidelines by authorised by Directorate General of Civil Aviation over the commercial usage of drones (**Figure 3.1**).



**Figure 3.1: Maintenance of a drone**

Maintaining the drone properly is essential to ensure its optimal performance, longevity, and safe operation. Regular maintenance routines encompass different aspects of the drone, including its equipment, batteries/engines, payloads, and sensors. The following are the basic maintenance steps that are undertaken for the better maintenance of drones:

- i. **Equipment Maintenance:** It is the regular practices and procedures implemented to ensure that drones remain in optimal working condition and can operate safely and effectively. This maintenance is crucial, especially in agricultural applications where drones are used for tasks like crop spraying, monitoring, and nutrient application. Key components of equipment maintenance for drones encompass several critical practices to ensure safe and efficient operations. Regular visual inspections of the drone's body, arms, propellers, and landing gear are essential for identifying visible signs of damage, such as cracks, dents, or wear, helping to prevent potential failures during flight. Connection checks must also be performed to ensure that all screws, nuts, and bolts are securely fastened, as loose components can lead to malfunctions or accidents.

Keeping the drone's exterior clean from dirt, dust, and debris is vital for maintaining performance and ensuring the proper functioning of sensors and cameras. Additionally, conducting functional testing of critical components, such as motors, batteries, and LED lights, is important to confirm their operational status, with LED lights being crucial for orientation and compliance with aviation regulations. Regular software

updates should be implemented to keep the drone's firmware and software current, thereby ensuring optimal performance and access to the latest features and safety protocols.

- ii. **Battery Maintenance:** It involves monitoring battery health, following proper charging practices, and storing batteries according to manufacturer guidelines to extend their lifespan. Lastly, regular calibration of the drone's sensors and flight controls is necessary for accurate navigation and operation. By adhering to these maintenance practices, drone operators can significantly enhance the safety and reliability of their equipment. It is crucial for ensuring the reliability and safety of drone operations. Regular battery checks are essential; inspect the drone's batteries for any signs of physical damage, such as bulging or punctures, and replace any damaged batteries immediately to avoid safety hazards during flight. Proper charging practices should be followed to prolong battery life, which includes avoiding overcharging or allowing the battery to fully discharge.

It is advisable to charge the battery right after each flight to ensure it's ready for the next operation. Additionally, storing batteries in a controlled environment with moderate temperatures helps maintain their health; if the drone will not be used for an extended period, utilizing the storage mode can prevent battery degradation. For drones equipped with combustion engines, it is important to adhere to the manufacturer's maintenance guidelines, which may involve checking for leaks, cleaning air filters, and applying lubrication to ensure smooth and efficient engine operation. By implementing these maintenance practices, the performance, lifespan, and safety of the drone can be significantly enhanced, leading to more reliable operations in the field.

- iii. **Payloads Maintenance:** Payloads Maintenance for Drones is critical to ensuring optimal performance and accurate data collection. Regularly clean the lenses, sensors, and cameras of any attached payloads to remove dust and debris, as these can significantly impact data accuracy and image quality. It's essential to check that payloads, such as cameras or sensors, are securely attached to the drone before each flight to prevent any detachment during operation. Additionally, calibrate payloads, including gimbals and sensors, according to the manufacturer's instructions to ensure they maintain their accuracy during data collection. By adhering to these maintenance practices, you can enhance the reliability of your drone's payloads and ensure the quality of the information gathered during flights.
- iv. **Sensors Maintenance:** Sensors Maintenance for Drones is essential for ensuring safe and efficient flight operations. Start by calibrating the drone's compass whenever flying in new locations or following the manufacturer's recommendations. This calibration is crucial for maintaining accurate flight control. Additionally, perform Inertial Measurement Unit (IMU) calibration as instructed to guarantee stable flight and precise sensor readings.

Regularly clean optical and ultrasonic sensors, which are vital for obstacle avoidance, to ensure they function effectively. By implementing these maintenance practices, drone operators can enhance flight safety and improve the overall performance of their drone's sensors.

Maintenance schedules may vary based on factors like flight frequency, operating environment, and drone model. It is important to refer to the drone's manual and manufacturer's guidelines for specific maintenance instructions. Keeping a record of maintenance activities help track the drone's performance and detect potential issues early. The consistent maintenance practices contribute to safe, reliable, and efficient drone operations.

### DID YOU KNOW?

- Regularly calibrating and properly storing drone batteries can significantly extend their life.
- Inspecting for any wear, cleaning, and addressing issues immediately after landing is like a pilot's routine maintenance checklist.
- Keeping sensors clean and free from dirt or debris is essential for accurate data and reliable obstacle avoidance.

### Activities

**Activity 1:** Practice emergency procedures for handling breakdowns during drone operations, ensuring one can respond effectively to unexpected technical failures.

**Materials Needed:**

- Model drones or drone simulation software.
- Emergency procedure guide (printed or digital).
- Safety gear (optional).

**Procedure:**

- Start by briefly discussing the importance of emergency procedures during drone operations.
- Refer a guide detailing emergency procedure for common breakdown scenarios.
- Discuss key steps, such as safe landing protocols, shutting down the drone, and contacting appropriate authorities.
- Create breakdown scenarios (e.g., loss of GPS signal, motor failure) using model drones or simulation software.
- Form small groups and assign each group a specific breakdown scenario.
- In your groups, participants should simulate the assigned breakdown scenario using the model drones or simulation software.

- Refer to the emergency procedures outlined in the guide.

Afterwards, discuss what worked well, challenges faced, and any insights gained during the hands-on practice. Share your experiences and learnings with the entire group and make a report on the same.

**Activity 2:** Prepare a presentation on maintenance tips for *Kisan* drone pilots. The presentation should be informative, outlining maintenance best practices tailored for *Kisan* (farmer) drone pilots. The topics may include routine checks, breakdown, schedule, and preventive maintenance, battery management, etc. As an example, the introduction slide may include the following:

- Brief overview of the role of drones in modern agriculture.
- Importance of drone maintenance for sustained performance.

As explained above, you may take the same in further way and prepare a presentation to learn about the maintenance tips for *Kisan* drone pilots. Feel free to utilize online resources for additional insights and information during the preparation of the presentation.

## Check Your Progress

### A. Multiple Choice Questions

1. What is the main objective of training participants in drone maintenance?
  - a) To increase flight time
  - b) To enhance drone speed
  - c) To teach participants how to identify and fix drone issues
  - d) To reduce battery consumption
2. Why is it important for participants to be trained in handling technical failures during drone operations?
  - a) To increase flight altitude
  - b) To optimize drone weight capacity
  - c) To equip participants to handle unexpected technical failures safely and efficiently
  - d) To decrease the cost of drone operations

### B. Fill in the Blanks

1. Regular maintenance of drone \_\_\_\_\_ is essential for ensuring safe and efficient operations.
2. A thorough \_\_\_\_\_ should be performed before each drone flight to check for physical damage.
3. Avoid \_\_\_\_\_ of drone batteries to prevent damage and extend battery life.
4. Drones are equipped to carry different types of \_\_\_\_\_ depending on the mission.

5. A well-calibrated \_\_\_\_\_ ensures the drone flies in the correct direction without deviation.
6. Before takeoff, it is important to check for any fuel or fluid \_\_\_\_\_ in drones that use liquid systems.
7. Operators should be trained on how to \_\_\_\_\_ drones in different weather conditions.
8. Each drone \_\_\_\_\_ has unique features and capabilities that must be understood for proper operation.

## Session 2: Handling Procedure in case of Emergencies

In the previous session, you learned about basic maintenance of drone. In this session, you will learn about handling procedure in case of emergencies. It will cover the steps to take when encountering emergency situations during drone operation, including dealing with unexpected weather changes, avoiding collisions, managing battery failures, and executing emergency landings. By understanding these procedures, you will be better prepared to respond effectively and ensure safety during unexpected events. In case of emergency, every second is crucial. Being prepared and knowing how to respond in emergencies is crucial for safe and responsible drone operation. The first thing one should do is to stay calm, understand the nature of emergency whether it is a loss of control, adverse weather, or any other issue. Now, let us understand the handling procedures in case of emergency in detail.

### Drone Emergency and Handling Procedure

In the event of a drone emergency, prioritizing the safety of people and property is crucial. The first step is to remain calm and composed, enabling rational decision-making during the crisis. Next, assess the situation by identifying the nature of the emergency, whether it be a sudden malfunction, unexpected behaviour, or a potential collision risk, and act accordingly. If the drone is malfunctioning or losing control, attempt to execute an emergency landing in a safe area, away from individuals and property. If the drone is equipped with a Return-to-Home (RTH) function, activate it to facilitate an automatic landing at the initial take-off point. In cases where further unexpected movements could occur, disconnect the power source to the drone to prevent accidents. Additionally, if the drone inadvertently enters restricted airspace, it's important to notify relevant authorities to report the emergency. After the situation is resolved, thoroughly inspect the drone for any damage and perform necessary repairs or maintenance to ensure safe operation for future flights. By following these guidelines, drone operators can effectively manage emergencies and minimize risks.

### Emergency Procedures during Loss of Link

In the event of a loss of link between the remote controller and the drone, it is essential to follow specific steps to manage the situation effectively (**Figure 3.2**). First, maintain visual contact with the drone, if possible, to track its location and trajectory.



**Figure 3.2: Emergency procedure during loss of link**

Next, attempt to re-establish the link by moving closer to the drone and checking the remote controller's connection status. If the drone is equipped with a Return-to-Home (RTH) feature, activate it to initiate an automatic return to the initial take-off point. If you can, switch to manual flight mode and attempt to regain control of the drone. Additionally, be prepared for the possibility of autonomous landing, as the drone may initiate this procedure if its battery is low. Staying aware of the drone's behaviour during this process is crucial to ensure a safe outcome. By adhering to these steps, operators can effectively respond to a loss of link scenario and mitigate potential risks.

### Consequences of Loss of Power

A loss of power during drone flight can lead to several severe consequences that pose significant risks. Firstly, a sudden loss of power can result in an uncontrolled descent, dramatically increasing the likelihood of a crash. Such crashes may not only damage the drone itself but can also lead to property damage if the drone collides with structures or objects on the ground. Additionally, there is a substantial risk of injury if the drone falls on people or animals in the vicinity. Beyond human and property safety, the environmental impact of a drone crash can also be considerable, particularly if the drone is carrying hazardous materials, which may lead to contamination or other ecological harm. Therefore, ensuring reliable power sources and monitoring

battery health is crucial for safe drone operation.

### **Emergency Procedures during Fly Away, Loss of GPS, and Collision**

In situations such as flyaway incidents, loss of GPS signal, or collisions, it is essential to follow specific steps to mitigate risks and regain control. Initially, if the drone remains responsive, the operator should attempt to regain control using the remote controller. If the drone is equipped with a Return-to-Home (RTH) feature, activating this function can facilitate an automatic return to the initial take-off point. Throughout the incident, it's crucial to monitor the drone's flight path and location to avoid potential collisions or hazards. If the drone exhibits unpredictable or uncontrollable behaviour, clearing the area is paramount to protect people and property from harm. Once the situation has been resolved, documenting the incident, including any damages or injuries, is advisable for future reference or insurance purposes. These steps help ensure safety and accountability in the event of an emergency.

It is crucial for drone operators to undergo proper training and familiarize themselves with their specific drone model's emergency procedures. Regular equipment maintenance and adhering to safety guidelines minimize the chances of emergencies and ensure safe and responsible drone operations.

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### **DID YOU KNOW?**

- The Return to Home (RTH) feature on drones can be a lifesaver. It provides an autonomous route back to the take-off point, helping avoid obstacles and ensuring a safe return even when control is compromised.
- During emergencies, drone batteries may experience a sudden voltage drop. Pilots need to monitor battery levels closely to prevent unexpected power failures and ensure a controlled landing.
- Many drones have built-in stabilization features that kick in automatically during critical situations, helping prevent erratic movements and ensuring a smoother recovery.

### **Activities**

**Activity 1:** This activity focuses on emergency procedures for handling the loss of communication link between a drone and a remote controller through simulated scenarios. Materials needed include model drones or simulation software, remote controllers, safety cones or markers for a designated flight area, and an emergency procedure guide (printed or digital).

Begin by designating a flight area using safety cones or markers. Create simulated scenarios to simulate the loss of communication link, varying the distance and



environmental conditions. Form small groups, each assigned a drone and a remote controller, and rotate the groups through different scenarios to practice the emergency procedures.

After each scenario, gather for a debriefing session to discuss challenges faced, successful responses, and areas for improvement. Review the key steps of the emergency procedures for a loss of communication link and summarize the lessons learned, emphasizing the importance of regular practice.

**Activity 2:** This activity focuses on understanding the consequences of power loss in drone operation, emphasizing the significance of power management and emergency planning. Materials needed include mini drones (one per group), a small obstacle course made of chairs, cones, or other items, printed scenarios (such as sudden power loss during flight), a stopwatch or timer, and a whiteboard with markers.

To begin, form small groups of 3-4 members each. Discuss the potential consequences of power loss during drone operation, including loss of control, safety risks, and impacts on mission success. Brainstorm and share ideas on how power loss could affect drone activities. Each group will receive a printed scenario related to power loss, such as a sudden loss of battery or electrical failure, and discuss how they would handle the situation, considering potential challenges and solutions (using search engines on computers or mobile applications if needed). After the hands-on activity, gather to discuss and write down your experiences, the challenges faced during power loss, and the effectiveness of the contingency plans developed.

## Check Your Progress

### A. Multiple Choice Questions

1. What is the first thing to do in case of a drone emergency?
  - a) Disconnect the power
  - b) Notify authorities
  - c) Remain calm
  - d) Execute emergency landing
2. If the drone has a "Return-to-Home" (RTH) feature during an emergency, what should you do?
  - a) Try manual control
  - b) Activate the RTH feature
  - c) Disconnect the power
  - d) Move closer to the drone

3. In case of a loss of link between the drone and the remote controller, which of the following steps should be taken first?
  - a) Activate RTH feature
  - b) Attempt reconnection
  - c) Execute emergency landing
  - d) Disconnect power
4. What is a possible consequence of a sudden loss of power during drone flight?
  - a) Flyaway
  - b) Loss of GPS
  - c) Crash risk
  - d) Drone stabilizes itself
5. After a drone emergency, what should be done before the next flight?
  - a) Contact authorities
  - b) Inspect and repair the drone
  - c) Charge the batteries
  - d) Update the drone's software
6. What is the primary purpose of practicing handling procedures for drones in the field?
  - a) To learn how to repair drones
  - b) To improve drone racing skills
  - c) To gain proficiency in safely operating drones
  - d) To study the history of drone technology
7. Why is practicing emergency procedures for loss of link crucial in drone operation?
  - a) To enhance artistic drone designs
  - b) To increase battery life
  - c) To swiftly and effectively manage communication loss between drone and controller
  - d) To explore drone manufacturing processes
8. What is the key benefit of simulating consequences of power loss during drone operation?
  - a) To predict future drone trends
  - b) To enhance drone battery life
  - c) To understand the importance of power management and contingency planning
  - d) To improve drone navigation skills

9. If connection between drone and remote controller is lost, the first step would be:
- Attempt to reconnect by pressing the switch
  - Wait for the drone to return automatically to home point
  - Immediately land the drone at safe place
  - Activate return to home
10. In event of motor or propeller failure the most appropriate action would be
- Increase throttle on operating motors
  - Reduce throttle on operating motors
  - Immediately land the drone at safe place
  - Keep flying drone using manual mode

### Session 3: Regulations of Directorate General of Civil Aviation and Safety Guidelines

In the previous session, you dealt with handling procedure in case of emergencies. In this session, you will learn about regulations of the Directorate General of Civil Aviation (DGCA) and safety guidelines. This session will cover the key regulations set forth by the DGCA regarding drone operations, including registration requirements, operational limitations, and safety protocols. You will also learn about the importance of adhering to these regulations to ensure safe and compliant drone usage, as well as the potential consequences of non-compliance. Understanding these guidelines is crucial for responsible drone operation and maintaining airspace safety.

Rules and regulations for drone operation are vital to ensure the safe and responsible usage of drones in various environments, including agriculture. These guidelines adhere to a maximum altitude limit, maintaining visual line of sight with the drone, and avoiding manned aircraft and controlled airspace. Most regulations also necessitate drone registration, especially for drones above a certain weight threshold, and mandate the operator's compliance with local, state, and federal aviation laws.

Privacy concerns are addressed by restrictions on flying over private properties or sensitive areas without prior consent. Operating drones in a reckless or unsafe manner, such as flying near crowds or near emergency response efforts, is typically prohibited. Adhering to these rules and regulations not only ensures safety but also promotes the responsible usage of drone technology in agriculture and other sectors.

#### Directorate General of Civil Aviation Safety Regulations

Operating drones in accordance with the regulations set by the Directorate General of Civil Aviation (DGCA) requires strict adherence to safety guidelines.

By following these rules, ensure that drone operations are safe, lawful and responsible.

**DGCA Safety Regulations:** It is vital to abide by the safety regulations outlined by DGCA, prioritizing the safety of both aviation activities and the public. These regulations cover various aspects of drone operations, including flight restrictions, operational limitations, and adherence to airspace regulations.

### **Airport Traffic Control (ATC) Operations**

Air Traffic Control (ATC) implements procedures to ensure the safe coexistence of Drone operations with manned aircraft within the airspace. ATC's approach involves various steps aimed at managing and coordinating drone flights while upholding safety standards. The following is a breakdown of the procedures ATC employs for drone operations. Smooth communication between drone operators and air traffic controllers is pivotal.

Key elements of effective drone operations in relation to air traffic control (ATC) include communication, flight plans, and monitoring. First, drone operators must establish communication with ATC to relay essential details about their intended flights, facilitating situational awareness and helping to prevent potential conflicts with manned aircraft. Providing flight plans and itineraries is crucial, as operators must inform ATC about the drone's intended flight path, location, and altitude. This information aids in maintaining appropriate separation between drones and manned aircraft, thereby mitigating collision risks. Additionally, ATC plays a vital role in monitoring and surveillance, guiding drone operators to avoid restricted airspace, such as military zones. Equipped with surveillance systems to track both manned and unmanned aircraft, ATC can communicate with drone operators via radio frequencies or other wireless means, ensuring safety and compliance in the shared airspace. ATC protocols may vary region to region and country to country, thus drone operators need to familiarize themselves with local rules and regulations for flying in a specific area.

### **Drone Registration**

There is a procedure to comply with DGCA's guidelines for drone registration. This involves registering your existing drones, transferring ownership when necessary and deregistering drones that are no longer in use. It is important to complete all required paperwork and documentation to ensure accurate records of drones. Drone Operation involves the controlled use of drone for various applications, including surveillance, agriculture, delivery, and mapping, requiring adherence to safety protocols and regulatory guidelines to ensure efficient and responsible flight practices. Understanding airspace regulations is vital for ensuring safe drone operations. Airspace maps designate authorized and restricted zones for drone flights, and it is essential for operators to familiarize themselves with these areas to avoid prohibited regions. Utilizing interactive maps can help visualize where drone flights are permitted, aiding in effective

flight planning. When necessary, operators must obtain prior permission from the Directorate General of Civil Aviation (DGCA) to operate in specific zones, ensuring compliance with airspace regulations (**Figure 3.3**).

A mandatory pre-flight verification process allows operators to confirm adherence to zonal restrictions. Additionally, recognizing that zoning restrictions can change due to various factors is crucial for preventing unintentional violations. Operators should stay informed about temporary red zones designated for special events or emergencies and avoid these areas when planning flights. Finally, making effective use of available data on airspace regulations and restrictions will support informed decision-making for safe drone operations.



**Figure 3.3: Permission protocol of drone zone**

### Remote Pilot Certificate

Acquiring a remote pilot certificate involves adhering to the established procedures set by the Directorate General of Civil Aviation (DGCA). This process typically requires candidates to undergo comprehensive training, pass examinations, and meet specific criteria. To begin, individuals must enrol in a DGCA-approved remote pilot training organization, which provides essential instruction to equip them with the necessary knowledge and skills for responsible drone operation. It is also crucial to be aware of the certificate's validity period; operators should renew or update their certificates as needed to maintain compliance with regulations. Additionally, understanding any applicable exemptions based on factors such as the drone's weight and the nature of the operation can further facilitate lawful and safe drone operations.

### Insurance for the Drone

Adhere to the stipulations of the Motor Vehicles Act, 1988, which mandates that drone operators carry liability insurance coverage. This insurance safeguards against potential damages or accidents arising from drone operations. By diligently adhering to DGCA's safety regulations and guidelines for drone registration, operation, pilot licensing, training, and insurance, one can contribute to a drone ecosystem that is both safer and more responsible, respecting aviation rules and the well-being of the public.

### DID YOU KNOW?

- India has several Area Control Centres (ACCs) and Approach Control Centres (APPs) strategically located across the country. These centres manage the airspace and provide services to aircraft during different phases of flight.
- DGCA plays a crucial role in maintaining the safety and security of civil aviation operations in India. It conducts inspections, audits, and investigations to ensure that airline, airports, and other stakeholders adhere to safety standards.
- ATC personnel are trained to handle emergencies effectively. They play a crucial role in coordinating responses during incidents like medical emergencies, diversions, or any unforeseen circumstances in aviation.

### Activities

**Activity 1:** This activity aims to raise awareness of safety rules during drone operation in an engaging and memorable way. Materials needed include printed cards with different drone safety rules (such as keeping a safe distance, flying in open areas, and avoiding obstacles), small cones or markers, and a stopwatch or timer.

Begin by forming small groups of 4-5 members each and setting up a relay course using small cones or markers arranged in a zigzag pattern across the classroom or outdoor space. Each group starts at one end of the course with a printed safety rule card. The first team member reads the safety rule aloud and runs to the first cone, placing the card there. The next team member picks up the card, reads the rule, and runs to the next cone, placing the card there.

This process continues until all safety rules have been placed along the course. After completing the relay, gather for a discussion where each group shares the safety rules they placed and explains the importance of each rule. Finally, prepare a poster illustrating the key drone safety rules learned during the activity and

display it in front of the classroom to reinforce the importance of safety in drone operations.

**Activity 2:** The Directorate General of Civil Aviation (DGCA) regulates the process of obtaining a Remote Pilot License (RPL) for drone operations in India. To initiate a group discussion, focus on the important aspects of acquiring a remote pilot certificate, including prerequisites, training requirements, written exams, practical assessments, and the significance of complying with regulations.

The general prerequisites for obtaining a Remote Pilot Certificate in India include being at least 18 years old and having passed at least the 10th standard (class 10) or its equivalent from a recognized board. Additionally, the applicant must obtain security clearance from the Ministry of Home Affairs (MHA) and security vetting from the Ministry of Civil Aviation (MOCA).

Training must be conducted through a DGCA-approved Flying Training Organization (FTO), and the applicant needs to be medically fit, often requiring a medical fitness certificate from a registered medical practitioner. Furthermore, the operator must have third-party insurance for the drone.

After completing the training, the applicant must pass a DGCA-conducted exam covering various aspects of drone regulations, safety, and operations. Finally, the applicant must submit the required documents, including the application form, training certificates, security clearance, and other relevant materials, to the DGCA.

### Check Your Progress

#### A. Multiple Choice Questions

1. What should be the first response during a drone emergency?
  - a) Call for help
  - b) Remain calm
  - c) Disconnect power
  - d) Attempt to land immediately
2. In the event of a loss of link between the remote controller and the drone, what should you do first?
  - a) Attempt reconnection
  - b) Activate RTH
  - c) Disconnect power
  - d) Notify authorities
3. What is the primary purpose of the Return-to-Home (RTH) feature?
  - a) To capture more images
  - b) To automatically return the drone to the take-off point
  - c) To assist in landing in water
  - d) To enhance battery life

4. What should you do if the drone is behaving unpredictably?
  - a) Try to regain control
  - b) Monitor its trajectory
  - c) Clear the area
  - d) All of the above
  
5. What is one consequence of losing power during a drone flight?
  - a) Improved performance
  - b) Enhanced control
  - c) Crash risk
  - d) Increased flight time

**B. Fill in the Blanks**

1. The first thing to do during a drone emergency is to stay \_\_\_\_\_.
2. If the drone is malfunctioning, attempt to execute an \_\_\_\_\_ landing.
3. In case of a loss of link, maintain \_\_\_\_\_ contact with the drone.
4. If available, activate the \_\_\_\_\_ feature to initiate an automatic return.
5. A loss of power can lead to a sudden uncontrolled \_\_\_\_\_.
6. After resolving an emergency, it is important to document the \_\_\_\_\_ for future reference.
7. Regular equipment maintenance helps minimize the chances of \_\_\_\_\_ during operations.



**Module 4****Entrepreneurship Opportunities in Drone Technology****Module Overview**

This module aims to provide with a foundational understanding of the entrepreneurial potential within the growing field of drone technology. The first session on business and entrepreneurship opportunities in drone technology, explores the various business avenues that drones can unlock across different sectors, particularly agriculture, surveying, delivery services, and environmental monitoring. You will learn about the current market trends, emerging opportunities, and the steps required to establish a drone-based business. The session will also cover case studies of successful drone businesses, offering insights into how entrepreneurs have leveraged this technology to create innovative solutions.

The second session on introduction to the business plan, focuses on the key components required to develop a solid business plan. You will be introduced to market research, competitive analysis, financial planning, and marketing strategies tailored to drone-based ventures. By the end of the session, they will have a basic framework for creating a business plan that can serve as the foundation for launching or expanding a drone-related business.

**Learning Outcomes**

After completing this module, you will be able to:

- Identify emerging business opportunities in the drone technology industry.
- Identify various sectors where drones are creating new entrepreneurial ventures
- Evaluate the challenges and advantages of starting a drone technology-based enterprise.
- Develop skills in drafting a clear and structured business plan, including market analysis, business strategy, and financial projections.
- Describe the importance of a business plan in securing funding and guiding the business towards long-term success.

## Module Structure

Session 1: Business and Entrepreneurship Opportunities in Drone Technology

Session 2: Introduction to the Business Plan

### Session 1: Business and Entrepreneurship Opportunities in Drone Technology

In this session, you will learn about business and entrepreneurship opportunities in drone technology. This session will explore the various avenues for entrepreneurship within the drone industry, including applications in agriculture, delivery services, aerial photography, surveying and mapping, infrastructure inspection, and emergency services. You will also examine the market trends, potential challenges, and strategies for starting and growing a successful drone-related business. Additionally, the session will highlight the importance of innovation and staying informed about regulatory developments to seize opportunities in this rapidly evolving field.

Entrepreneurship is like being the captain of your own ship in the world of business. It is about executing creative idea, taking the initiative, and turning your dream idea into a reality. Entrepreneurs are like adventurous sailors who navigate through the unpredictable seas of the market, facing challenges and embracing opportunities. They bring something new to the market, whether it is a product, service, or a unique solution to a problem. It involves risk-taking, as entrepreneurs invest their time, money, and effort into their ventures, hoping for success.

Entrepreneurship opportunities in drone technology are growing as the capabilities and applications of unmanned aerial vehicles continue to expand. Entrepreneurs can seize various avenues in this rapidly evolving field. Drone manufacturing and customization offer opportunities to create specialized drones tailored to specific industries such as agriculture, cinematography, or surveying.

Drone services, including aerial photography, mapping, and inspections, are in high demand across sectors. Developing innovative software solutions for data analysis, flight planning, or drone management can also be lucrative. Entrepreneurs can explore drone education and training programs to meet the increasing demand for skilled drone pilots. Furthermore, emerging fields like drone delivery and urban air mobility present ground-breaking possibilities for forward-thinking entrepreneurs. As regulations evolve and technology advances, the drone industry remains ripe with entrepreneurial opportunities for those who can identify niche markets and pioneer new applications. In this module, you will know about the various business and entrepreneurship opportunities available through drone technology and you will learn the process of making a business plan. Business and entrepreneurship opportunities in drone technology have been rapidly growing due to the versatility and potential applications of drone's in

various industries (**Figure 4.1**). The following are some key job opportunities and business ideas in drone operations:

- i. **Drone Pilots:** Professional drone pilots are in demand for various tasks such as agricultural operations (spraying and imaging), aerial photography, videography, surveying, mapping, and inspections. They can work as freelancers or hired by companies for specific projects.
- ii. **Pilot Instructors:** As the drone industry expands, the need for qualified drone pilot instructor for training pilot increases. Entrepreneurs can establish drone training schools or academies to offer courses and certifications for aspiring drone pilots.
- iii. **Precision Agriculture Services:** Drones with advanced sensors and imaging technology can revolutionize agriculture. Entrepreneurs can develop precision agriculture solutions, providing farmers with important data for crop health monitoring and optimization of farming practices.
- iv. **Flight Planners:** Flight planning is important for safe and efficient drone operations. Entrepreneurs can provide flight-planning services to businesses and organizations involved in surveying, agriculture, infrastructure inspection, and other industries that require drone-based data collection.



**Figure 4.1: Business and entrepreneurship opportunities in drone technology**

- v. **Drone Software Engineers:** Customized drone software is essential for specific industry applications, such as precision agriculture, environmental monitoring, and infrastructure inspections. Entrepreneurs with expertise in drone software development can create specialized solutions for clients.
- vi. **Drone Data Specialists:** Drones generate huge amount of data during flights, including aerial imagery, LiDAR data, and thermal imaging. Entrepreneurs can offer data processing and analysis services to extract valuable insights for various industries, like agriculture, construction, and disaster response.
- vii. **Drone Repair and Maintenance Services:** With the growing number of drones in operation, there is a rising demand for repair and maintenance services. Entrepreneurs can establish drone repair centres to provide technical support and keep drones in optimal condition.
- a) **Drone Insurance Services:** As drone usage becomes more widespread, the need for drone insurance coverage is rising. Entrepreneurs can set up drone insurance agencies to cater the specific needs of drone operators and businesses.
- b) **Aerial Media Services:** Drone technology has revolutionized aerial photography and videography. Entrepreneurs can offer aerial media services for capturing stunning footage for real estate, tourism, events, and advertising purposes.
- c) **Drone Delivery Services:** With the advancement of drone technology and regulations, drone delivery services have emerged as a potential business opportunity. Entrepreneurs can explore last-mile delivery solutions using drones for various products, including food, medicine, and small parcels.
- d) **Environmental Monitoring:** Drones can be deployed for environmental monitoring, like tracking wildlife, studying ecosystems, and assessing natural disasters. Entrepreneurs can offer specialized environmental monitoring services to research organizations and governmental agencies.
- e) **Inspection Services:** Drones are widely being used for inspections of infrastructure, buildings, and industrial facilities. Entrepreneurs can establish drone inspection services for companies in construction, energy, and engineering sectors.

### Self-employment opportunities in drone operation

Self-employment opportunities in drone operations have expanded significantly, as the drone industry continues to grow. Individuals with expertise in drone technology, piloting skills, and a keen understanding of various industries can explore these avenues to build successful self-employed careers. Let us understand about some self-employment opportunities in drone operations (**Figure 4.2**):



**Figure 4.2: Self-employment opportunities in drone operation**

- i. **Precision Agriculture:** It assist farmers by offering drone-based services for crop health monitoring, nutrient management, and yield prediction. Drones equipped with multispectral cameras and sensors can provide valuable details into crop conditions.
- ii. **Environmental Monitoring:** Environmental monitoring involves the systematic collection and analysis of data regarding environmental conditions, such as air and water quality, soil health, and biodiversity, to assess the impact of human activities, comply with regulations, and inform decision-making for sustainable management and conservation efforts. To conduct environmental monitoring using drones, one should collaborate with environmental agencies and research organizations to track changes in ecosystems, wildlife habitats, and natural disasters.
- iii. **Aerial Photography and Videography:** This sector offer professional aerial photography and videography services for events, real estate, tourism, advertising, and more. Drones can capture stunning aerial shots that traditional photography might not achieve.

- iv. **Mapping and Surveying:** The drone industry provide mapping and surveying services to industries such as construction, agriculture, land development, and urban planning. Drones that have advanced sensors can gather data, speedily and accurately, for creating maps and 3D models.
- v. **Inspections and Monitoring:** The drone's field specialize in conducting inspections of infrastructure, pipelines, power lines, buildings, and other hard-to-reach areas. Drones can offer a cost-effective and safe alternative to traditional manual inspections.
- vi. **Search and Rescue Operations:** It establish a drone-based search and rescue service to assist emergency responders in locating missing persons or providing aerial support in disaster-stricken areas.
- vii. **Filmmaking and Cinematography:** It is responsible for combining people's passion for film with drone technology by offering cinematic aerial shots for films, documentaries, commercials, and music videos.
- viii. **Roof Inspections:** It focuses on providing roof inspections for homeowners and insurance companies. Drones can identify roofing issues without the need for manual inspections, making the process more efficient.
- ix. **Event Coverage:** The sector offers drone services for covering outdoor events such as weddings, concerts, sports events, and festivals. Aerial shots add a unique perspective to event coverage.
- x. **Wildlife Conservation:** It collaborate with conservation organizations to monitor and protect wildlife populations using drone technology. Drones can help track animal movements and habitat changes.
- xi. **Infrastructure Monitoring:** The sector monitors the structural health of bridges, dams, and other critical infrastructure using drones equipped with sensors and cameras.
- xii. **Drone Training and Consultation:** It provides training and consultation services to individuals and businesses looking to enter the drone industry.
- xiii. **Real Estate Marketing:** It assist real estate agents by providing aerial views of properties for sale. Aerial imagery enhances property listings and gives potential buyers a comprehensive view.
- xiv. **Delivery Services:** With advancements in drone technology and regulations, explore the possibility of offering small parcel delivery services using drones.

Each of these self-employment opportunities requires a solid understanding of drone technology, regulatory compliance, and industry-specific knowledge. Building a strong portfolio, marketing of services, and maintaining professionalism will be key to establishing a successful self-employed career in the drone operations field.

### Qualities of an Entrepreneur

Entrepreneurs possess a diverse range of qualities that play a pivotal role in their ability to initiate, manage, and expand a business successfully. These attributes shape their mind-set, actions, and approach towards challenges and opportunities (**Figure 4.3**). The following are some key qualities that define an effective entrepreneur:

- i. **Visionary:** Entrepreneurs possess a clear and compelling vision of their business's future. They can foresee opportunities, identify market gaps, and conceptualize the trajectory of their venture.



**Figure 4.3: Qualities of an entrepreneur**

- ii. **Passion:** A deep passion for their business idea fuels entrepreneurs' determination. This fervour propels them to overcome obstacles and persist even when faced with adversity.
- iii. **Resilience:** Entrepreneurs confront setbacks and failures, but their resilience empowers them to rebound and learn from these experiences.

- They perceive failures as valuable learning moments rather than roadblocks.
- iv. **Risk-Taker:** Entrepreneurs are willing to take calculated risks to achieve their objectives. They recognize that growth and innovation often require stepping beyond their comfort zones.
  - v. **Adaptability:** The business landscape is dynamic, and successful entrepreneurs demonstrate adaptability. They swiftly respond to changes, pivot strategies, and seize emerging opportunities.
  - vi. **Problem-Solving Skills:** Entrepreneurs excel as problem solvers. They approach challenges with creativity, devising ingenious solutions and transforming hurdles into stepping-stones.
  - vii. **Decision-Making:** An entrepreneur's ability to make informed decisions amidst uncertainty is paramount. They confidently navigate complex choices that influence their business's direction.
  - viii. **Leadership:** Entrepreneurs lead by example, inspiring their teams with their work ethic and vision. They establish a company culture grounded in values and foster a sense of purpose.
  - ix. **Effective Communication:** Communication is vital for conveying their vision to stakeholders, negotiating deals, and cultivating relationships with customers, collaborators, and investors.
  - x. **Networking:** Entrepreneurs understand the power of networking. They cultivate relationships that offer avenues for collaboration, mentorship, and growth opportunities.
  - xi. **Time Management:** Successful entrepreneurs skilfully manage their time, prioritizing tasks that contribute to their venture's advancement while staying focused on overarching goals.
  - xii. **Creativity:** Entrepreneurs exhibit creative thinking, generating innovative ideas that distinguish their business from competitors and captivate their target audience.
  - xiii. **Resourcefulness:** Often starting with limited resources, entrepreneurs display resourcefulness by making the most of available assets and uncovering alternative solutions.
  - xiv. **Lifelong Learning:** Entrepreneurs possess an appetite for knowledge, continually seeking insights from experiences, mentors, and educational avenues to enhance their expertise.



- xv. **Customer-Centric Mind-set:** Entrepreneurs recognize the significance of meeting customer needs. They value feedback, drive improvements, and cultivate enduring relationships with their clientele.
- xvi. **Financial Insight:** A profound grasp of financial management, budgeting, and revenue generation ensures entrepreneurs secure their business's financial stability and growth.

These qualities collectively empower entrepreneurs to navigate the intricate landscape of business, seize opportunities, and guide their enterprise towards prosperity. Although no entrepreneur embodies all these traits equally, their willingness to cultivate and nurture these attributes significantly bolsters their capacity to build a thriving and impactful business.

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### DID YOU KNOW?

- Small and medium-sized enterprises (SMEs) are an important part in the global economy. They account for a substantial portion of job creation and contribute significantly to GDP in many countries.
- Young entrepreneurs are actively pursuing their business ideas. Many start-ups are founded by individuals in their 20s and 30s, showcasing the energy and innovation that young minds bring to the business world.
- Start-up ecosystems and innovation hubs are thriving in various cities worldwide. Places like Silicon Valley, London, Berlin, and Bangalore have become synonymous with fostering entrepreneurial talent and innovation.

### Activities

**Activity 1:** This activity focuses on the preparation of a poster highlighting business and entrepreneurship opportunities related to drones. Materials needed include large poster paper or chart paper, coloured markers, pens, and other art supplies, as well as printed information on drone-related business opportunities (optional).

Begin by discussing the rising use of drones across various industries and how this trend has opened up new business and entrepreneurship opportunities. Introduce the concept of entrepreneurship, emphasizing its benefits, such as innovation, independence, and potential financial rewards. Write down your ideas on the board or a flip chart, then form small groups of 3-4 members each.

Each group will conduct brief research using electronic devices to focus on a specific aspect of drone applications, such as aerial photography, agriculture,

surveillance, or delivery services. After gathering information, create visual charts that highlight the identified business opportunities using drawings, diagrams, and keywords to represent your ideas, emphasizing the benefits of entrepreneurship.

Each group will then present their chart to the class, explaining the drone-related business opportunities they identified while showcasing the advantages of entrepreneurship. Finally, arrange a gallery walk where students can view and discuss each group's chart, and summarize the key points learned from the activity in your diary or portfolio.

**Activity 2:** Develop a presentation that showcases the journeys and achievements of entrepreneurs within the drone industry. The presentation should include key sections such as an introduction, which sets the stage for the discussion; an evolution of the drone industry, detailing the significant advancements over time; and the Importance of Entrepreneurs, highlighting their role in driving innovation and growth.

Additionally, feature a success story that encompasses the background, journey, key achievements, and milestones of a notable entrepreneur in the drone sector. Invite entrepreneurs to share their experiences and engage in a discussion about the opportunities available in the drone industry that aspiring entrepreneurs can explore. Provide tips for success based on the insights gained, and conclude with a look at Future Trends in the industry. Utilize information and case studies obtained through ICT tools to enhance your understanding of entrepreneurship in the drone sector, ensuring a comprehensive and engaging presentation.

## Check Your Progress

### A. Multiple Choice Questions

1. Identify the most promising entrepreneurship opportunity in drone technology among the following?
  - a) Writing fiction novels about future drone applications.
  - b) Flying drones for recreational purposes.
  - c) Starting a drone delivery service for local businesses.
  - d) Viewing drone captured data on social media platforms.
2. Which of the following business ventures can take advantage from the application of drone technology?
  - a) Opening a traditional brick-and-mortar bookstore.
  - b) Launching an artisanal bakery.
  - c) Running a vintage car restoration shop.
  - d) Establishing a drone photography and videography service.

3. How can entrepreneurs leverage the drone technology in agriculture?
  - a) By selling traditional farming equipment.
  - b) Organizing cooking classes using drone footage.
  - c) Providing aerial crop monitoring and precision spraying services.
  - d) Offering guided nature tours using drones video recording.
4. How can drones significantly contribute to wildlife conservation efforts in forests?
  - a) By facilitating photography and videography of people visiting forests.
  - b) By tracking animal movements within the forest and habitat changes taking place.
  - c) By monitoring weather patterns for predicting climate change.
  - d) By delivering packages to remote areas in the forest.
5. What role can entrepreneurs should not play in the drone industry for safe and efficient drone operations?
  - a) Drone Delivery Specialists
  - b) Drone Repair Technicians
  - c) Drone Data Analysts
  - d) Drone Racing Organizers
6. What is a crucial personal quality for an entrepreneur?
  - a) Exclusively relying on others for decision-making.
  - b) Avoiding risks at all costs.
  - c) Adaptability and willingness to embrace change.
  - d) Preferring a fixed routine over flexibility.
7. Why is resilience an important trait for entrepreneurs?
  - a) It allows entrepreneurs to avoid challenges altogether.
  - b) It helps entrepreneurs ignore customer feedback.
  - c) It enables entrepreneurs to persevere through setbacks and failures.
  - d) It leads entrepreneurs to take unnecessary risks.
8. How does effective communication benefit entrepreneurs?
  - a) It wastes valuable time.
  - b) It leads to misunderstandings and conflicts.
  - c) It aids in building relationships, conveying ideas, and securing opportunities.
  - d) It hinders creativity and innovation.

## Session 2: Introduction to the Business Plan

A business plan is a formal document that outlines a business's objectives, strategies, and the necessary actions to achieve its goals. It serves several purposes, including providing strategic direction by defining the business's vision, mission, and the products or services offered to meet market needs. The plan includes a comprehensive market analysis, detailing the industry, target market, and competition, which helps identify opportunities and threats (**Figure 4.4**).

Additionally, it outlines operational processes, organizational structure, and the resources required, such as personnel, equipment, and technology. Financial projections, including anticipated income statements, cash flow statements, and balance sheets, are essential components that outline funding needs and expected revenue. Furthermore, the business plan discusses potential risks and challenges, along with strategies to mitigate them. For those seeking investment or loans, it also details the amount of funding needed and its intended use. Overall, a well-structured business plan serves as a roadmap for the business's future and effectively communicates its viability to potential investors, stakeholders, and partners. Creating a comprehensive business plan is a critical step in the successful launch of a drone service business. This business plan should encompass various aspects of your venture, from the initial concept to financial projections.

Let us understand an outline that can help structure the drone service business plan:



**Figure 4.4: Introduction to a business plan**

- i. **Executive Summary:** An executive summary is a brief overview of a larger document, providing key stakeholders with a quick understanding of the main points, findings, and recommendations. Found at the beginning of business plans or reports, it highlights the document's purpose, key objectives, methodologies, and conclusions. The goal is to engage the reader and summarize essential information for informed decision-making, encouraging further reading of the full content.  
Within the executive summary, the goal is to present a concise yet all-encompassing snapshot of the drone service business. Now, you will understand the critical components of the plan, offering a quick, informative glimpse into the business concept, target market, services, and strategic approaches. It is an introductory gateway, providing a clear and concise understanding of the essence of the drone service business, priming them for the in-depth details presented throughout the rest of the business plan.
- ii. **Business Concept:** A business concept is a clear description of an idea for a business, outlining its purpose, target market, and the unique value it offers to customers. This will provide a detailed exploration of the core ideas behind the drone service business. In this, one can articulate the mission and vision for the venture. This includes outlining the purpose and long-term aspirations that drive the desired operations. Additionally, one can define the core values and specific business objectives. These principles underpin the company's culture and guide its strategic decisions. It is essential to ensure that these fundamental principles align with the overall mission and vision of the drone service business. This approach serves as the foundation for the values and aspirations that will shape the business throughout its journey.
- iii. **Target Market:** The target market is a specific group of consumers identified as the intended audience for a product or service, based on shared characteristics such as demographics, preferences, and behaviours. The concept of the target market identifies the specific characteristics of the ideal customer base. In this, one can paint a detailed portrait of the audience, one aim to serve with the drone services. This involves not only describing the demographics and geographic locations of the target customers but also delving into their behaviours and preferences. By providing a comprehensive understanding of who the customers are and what motivates their choices, equipping the business with valuable insights that will guide the marketing strategies and service offerings, ultimately ensuring a more tailored and effective approach to meeting their needs.
- iv. **Market Research:** Market research is the process of gathering, analysing, and interpreting data about a market, including information about the target audience, competitors, and industry trends, to inform

business decisions. In the market research section, a comprehensive examination of the drone service industry, offering insights into prevalent trends and the competitive landscape is provided. This involves a detailed analysis of the current market dynamics, emerging trends, and a thorough evaluation of the competitors and their positioning. Additionally, conducting a SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis, one can identify and highlight the strengths and weaknesses inherent to the own drone service business, along with the opportunities and potential threats within the market. This strategic assessment is a crucial step in understanding the business's competitive edge and challenges, paving the way for informed decisions and effective strategies.

- v. **Service Portfolio:** A service portfolio is a collection of all the services offered by a business, detailing their features, benefits, and value propositions to potential customers. In this, a comprehensive outline of the diverse drone services the business intends to offer, which may encompass a range of applications such as aerial photography, mapping, inspections, and more are identified. In addition to listing these services, it is essential to elucidate the unique features and benefits they bring to potential clients. This provides a clear understanding of the value the services bring to the table and helps in differentiating the offerings in the competitive market. By emphasizing the specific advantages and applications of the services, one can create a compelling case for potential customers, highlighting how the drone solutions can meet their needs effectively.
- vi. **Sales Strategy:** A sales strategy is a plan that outlines how a business will sell its products or services to achieve specific revenue goals and attract target customers. It is responsible for laying out a comprehensive plan for both sales and marketing. This involves detailing the strategies one intend to employ to attract customers, generate leads, and ultimately grow the client base. Additionally, it describes how one can aim to manage customer relationships effectively, ensuring satisfaction and fostering loyalty. This section serves as a roadmap for the entire sales and marketing process, providing insights into the methods and tactics used to connect with potential clients, convert leads into customers, and maintain strong, enduring relationships with them.
- vii. **Pricing Structure:** The pricing structure refers to the framework that outlines how a business sets the prices for its products or services, considering factors like costs, market demand, competition, and perceived value. It establishes the pricing model for the drone services business offers. This entails articulating the methodology by which one can determine the rates for the services, whether it is based on factors like service packages, project complexity, or other variables. Simultaneously, it is vital to carry out a comprehensive analysis of the

pricing landscape within the industry to ensure that the rates are competitive and in line with market norms. This dual strategy approach to pricing not only helps you set rates that are attractive to your customers but also demonstrates the commitment to offering competitive and fair pricing within the drone service sector.

- viii. **Regulatory Compliance Procedures:** It is the processes and guidelines a business follows to ensure its operations adhere to relevant laws, regulations, and standards in its industry. It is responsible to provide a comprehensive overview of the specific regulations and requirements that the drone service business must strictly adhere. This includes a detailed explanation of the legal framework, permits, licenses, and any industry-specific guidelines necessary to operate drones safely and within the boundaries of the law. Moreover, one can outline the safety protocols that the business has in place to ensure the well-being of both the team and the public. This emphasis on regulatory compliance and safety not only safeguards the operations but also builds trust with clients by demonstrating the commitment to responsible and lawful drone service practices.
- ix. **Licensing:** Licensing refers to the legal authorization granted by a regulatory authority that permits individuals or organizations to engage in specific activities or operate within a particular industry, ensuring compliance with established standards and regulations. It provides a clear and detailed account of the licenses and permits essential for the smooth operation of drone service business. This includes specifying the exact types of licenses and permits required for the business. This ensures compliance with all legal and regulatory requirements. Providing transparency regarding the necessary documentation demonstrates a commitment to operating within the law. It also helps establish trust with clients who seek assurance of the business's legitimacy. Additionally, this commitment highlights adherence to industry regulations.
- x. **Insurance Procedure:** Insurance procedures refer to the processes and steps involved in obtaining insurance coverage, including assessing risks, selecting appropriate policies, completing necessary documentation, paying premiums, and filing claims to protect against potential losses or liabilities related to business operations. It procures with a comprehensive overview of the insurance coverage that will be in effect to safeguard the drone operations. This encompasses a detailed account of the types of insurance policies the business will carry, with a particular focus on liability coverage. By outlining these insurance policies, one not only demonstrate the commitment to risk management but also offer peace of mind to the clients and partners, assuring them that the drone services are conducted with a strong safety net in place, minimizing potential liabilities and mitigating risks.

- xi. **Equipment and Technology:** It provide a comprehensive inventory of the drone models, cameras, and other technological tools that will be integral to the drone service operations. This detailed list is vital for highlighting the capabilities and resources at the disposal. Additionally, it addresses the plans for equipment maintenance, highlighting the commitment to ensuring that the technology remains in optimal working condition. It is essential to touch upon potential upgrades, signifying the willingness to stay current with technological advancements in the ever-evolving drone industry. This also serves to assure clients that the drone services are backed-up by reliable and up-to-date equipment and technology.
- xii. **Operational Plan:** It is an inclusive framework of the inner workings of the drone service business. This entails detailing the business's workflow, including the processes and steps involved in delivering the services efficiently. This also address the management of the supply chain, highlighting the procurement and distribution processes crucial to the operations. If applicable, this may include a description of any physical locations and facility requirements. By presenting these elements, one offers a clear picture of how the business operates and how it manages the various logistical and operational aspects that contribute to the successful delivery of the drone services. This level of transparency and detail is essential for clients and partners. It helps them understand the structure of the business. It also provides insights into the efficiency of operations. This clarity fosters trust and confidence in the organization.
- xiii. **Physical and Human Resources:** Within this concept, the fundamental components that support the drone service business are summarized. This includes identifying the staffing requirements, encompassing roles such as pilots, technicians, and administrative personnel, who play pivotal roles in the business operations. One can also elaborate on the training requirements and qualifications essential for each role, ensuring that the team is equipped with the necessary expertise to perform their duties effectively. Additionally, this may specify equipment needs, such as specialized tools and facilities required to support the operations, ensuring that the business is well equipped to deliver high-quality drone services. Providing this comprehensive insight emphasizes the commitment to building a capable team. It also shows the dedication to maintaining the necessary resources for successful service delivery.
- xiv. **Online Presence:** It describes the strategy for establishing and nurturing a robust digital footprint for the drone service business. This encompasses a detailed plan for website development, addressing how the online platform will be designed to effectively represent the services and engage potential clients. Furthermore, it elaborates on the approach to social media engagement, explaining how one intend to utilize various platforms to connect with the target audience and promote the services. This concept also touches on the online marketing initiatives, showcasing



the commitment to using digital channels to reach and engage the audience effectively, thereby building a strong online presence that enhances the visibility and credibility in the industry.

- xv. **Revenue Model:** Within the revenue model section, one will be providing a comprehensive breakdown of the income sources that sustain the drone service business. This encompasses a clear explanation of the various revenue streams, such as project-based fees or annual maintenance contracts, through which the business generates income. Furthermore, this section will include sales forecasts and revenue projections, offering a glimpse into the anticipated financial performance of the business over time. By presenting these financial details, one not only provide transparency regarding how the business generates revenue but also offer insights into its future growth potential, instilling confidence in potential investors and partners.
- xvi. **Financial Aspects:** It presents a thorough overview of the financial foundation of the drone service business. This includes an itemized breakdown of start-up costs and an outline of the funding requirements necessary to initiate the operations. Additionally, one will offer a comprehensive view of financial projections, incorporating income statements, cash flow statements, and balance sheets. This data provides insight into the anticipated financial performance of the business over time. Furthermore, one will conduct a break-even analysis, outlining the point at which the revenue equals the costs, which is a crucial milestone for the business's profitability. These financial details offer a clear picture of the business's financial health and sustainability, crucial for investors and stakeholders evaluating the venture.

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### DID YOU KNOW?

- The concept of a business plan has ancient roots. In the 4th century B.C., Aristotle wrote about the importance of planning in his work "Politics," emphasizing the need for forethought in any undertaking.
- Some famous businesses, like Southwest Airlines and Starbucks, are said to have had their initial business plans sketched out on napkins. This highlights that the core ideas and strategies can be captured in simple, informal formats.
- Not just for-profit ventures benefit from business planning. Non-profit organizations also use business plans to outline their mission, goals, and strategies for achieving social or community impact.
- Google's initial business plan had a unique section titled "Don't Be Evil," emphasizing the company's commitment to ethical behaviour and social responsibility.

## Activities

**Activity 1:** A business plan is a comprehensive document that outlines the goals, strategies, and operational details of a business. It serves as a roadmap for entrepreneurs, providing a structured and systematic approach to starting, managing, and growing a business.

Develop a business plan for a service related to drone operation.

Let us take an example of a component of business plan named executive summary. The executive summary may include a concise overview of the business, its mission, and the key highlights of the plan.

Compile a report by crafting a comprehensive business plan specifically tailored for a drone-related service.

**Activity 2:** Learn the concept of a business plan as a roadmap for entrepreneurs and highlighting the importance in guiding a business's goals and strategies.

### Materials Needed:

- Whiteboard
- Markers

### Procedure:

- Form small groups and introduce the concept of an elevator pitch. (A short and compelling summary of a business idea that can be delivered in the time it takes an elevator ride).
- Each pair will have to develop a brief elevator pitch for a hypothetical business idea related to drone services (e.g., drone photography, surveying, delivery, etc.). Present your elevator pitch to the class.
- Use the whiteboard to note down key elements mentioned in each pitch.
- Lead a brief discussion on the common elements observed in the elevator pitches, emphasizing the importance of clarity, conciseness, and the ability to convey essential information in a short time.
- Conclude the activity by writing down the importance of being able to articulate a business idea clearly and concisely.

## Check Your Progress

### A. Multiple Choice Questions

1. What is the primary purpose of an executive summary in a business plan?
  - a) To provide a detailed analysis of competitors
  - b) To offer a concise overview of key elements and goals
  - c) To outline the financial projections of the business
  - d) To describe the core values of the company
2. What is the primary function of a vision statement in a business plan?
  - a) To describe the products or services offered
  - b) To summarize the financial projections
  - c) To outline long-term goals and aspirations
  - d) To identify the target market
3. In a business plan, what does the competitive landscape section typically include?
  - a) Financial projections
  - b) Analysis of market trends
  - c) Description of core values
  - d) Identification of competitors and their profiles
4. What is the distinction between business goals and objectives in a business plan?
  - a) Goals are specific and measurable, while objectives are broad aspirations.
  - b) Goals are the overarching aspirations, while objectives are specific and measurable actions.
  - c) Goals and objectives are terms used interchangeably in a business plan.
  - d) Goals relate to long-term objectives, while objectives are short-term in nature.
5. What role do core values play in a business plan?
  - a) They define the financial projections of the business.
  - b) They guide day-to-day operations and decision-making.
  - c) They describe the competitive landscape of the industry.
  - d) They identify potential new entrants in the market.
6. Why is transparency about key assumptions important in a business plan?
  - a) To confuse readers with complex technical terms
  - b) To provide a summary of the business's achievements
  - c) To demonstrate the use of SWOT analysis
  - d) To shed light on factors underlying forecasts and strategies

**Answer Key****MODULE 1: DRONES IN AGRICULTURE****Session 1: Principles of Crop Production and Management**

## A. Multiple Choice Questions

1. (b)
2. (c)
3. (c)
4. (b)
5. (b)
6. (b)
7. (b)
8. (a)
9. (b)
10. (b)

**Session 2: Applications of Drones in Agriculture**

## A. Multiple Choice Questions

1. (c)
2. (c)
3. (b)
4. (c)
5. (c)
6. (c)
7. (a)
8. (b)
9. (b)
10. (b)

**MODULE 2: OPERATING PROCEDURES FOR USE OF DRONE IN AGRICULTURE****Session 1: Parameters Affecting Selection of Drone**

## A. Multiple Choice Questions

1. (a)
2. (b)
3. (b)
4. (b)
5. (b)
6. (c)
7. (b)
8. (b)

9. (b)

10. (b)

### **Session 2: Crop Nutrient Applications**

#### A. Multiple Choice Questions

1. (b)

2. (b)

3. (b)

4. (c)

5. (b)

6. (c)

7. (b)

8. (c)

9. (b)

10. (c)

### **Session 3: Prerequisites for Using Drones**

#### A. Multiple Choice Questions

1. (b)

2. (c)

3. (c)

4. (c)

5. (b)

6. (c)

#### B. Fill-in-the-Blank

1. ICAR

2. Home

3. 100

4. Nutrient

5. Motors

6. 20

### **Session 4: Precautions During Drone Operation**

#### A. Multiple Choice Questions

1. (c)

2. (c)

3. (c)

#### B. Fill in the Blanks

1. Maintenance

2. Sensors

3. Safety

4. Behaviour
5. Operations
6. Obstacles
7. Swollen
8. Flight
9. Accuracy
10. Accountability

### **MODULE 3: RULES AND REGULATIONS FOR DRONE OPERATION**

#### **Session 1: Basic Maintenance of Drone**

##### A. Multiple Choice Questions

1. (c)
2. (c)

##### B. Fill in the Blanks

1. Equipment
2. Visual inspection
3. Overcharging
4. Payloads
5. Compass
6. Leaks
7. Fly
8. Model

#### **Session 2: Handling Procedure in case of Emergencies**

##### A. Multiple Choice Questions

1. (c)
2. (b)
3. (b)
4. (c)
5. (b)
6. (c)
7. (c)
8. (c)
9. (a)
10. (c)

#### **Session 3: Regulations of Directorate General of Civil Aviation and Safety Guidelines**

##### A. Multiple Choice Questions

1. (b)
2. (a)
3. (b)

4. (d)

5. (c)

**B. Fill in the Blanks Answers**

1. Calm

2. Emergency

3. Visual

4. RTH

5. Descent

6. Incident

7. Emergencies

**MODULE 4: ENTREPRENEURSHIP OPPORTUNITIES IN DRONE TECHNOLOGY**

**Session 1: Business and Entrepreneurship Opportunities in Drone Technology**

**A. Multiple Choice Questions**

1. (c)

2. (d)

3. (c)

4. (b)

5. (d)

6. (c)

7. (c)

8. (c)

**Session 2: Introduction to the Business Plan**

**A. Multiple Choice Questions**

1. (b)

2. (c)

3. (d)

4. (b)

5. (b)

6. (d)

## Glossary

**Accelerometer:** A device that measures the rate of change in velocity (acceleration) of an object in one or more directions. It is commonly used in devices like drones, smartphones, and fitness trackers to detect motion, tilt, and vibration.

**Conservation Agriculture:** Practices aimed at sustainable crop production that includes reducing soil erosion, conserving water resources, reducing greenhouse gas emissions, promoting biodiversity, and preserving ecosystems.

**Crop Diversity:** The practice of growing different types of crops on the same land, which can reduce risks associated with pests and diseases and enhance productivity.

**Crop Rotation and Diversification:** The practice of growing different crops in a specific sequence on the same land to break pest and disease cycles, improve soil health, and optimize resource utilization. Crop diversification involves methods like intercropping or mixed cropping to reduce risks and enhance productivity.

**Crop Selection:** The process of choosing which crops to cultivate, taking into account factors such as climate, soil type, market demand, and local expertise to maximize yields and minimize risks.

**Environmental Stewardship:** Sustainable crop production practices that minimize soil erosion, conserve water resources, reduce greenhouse gas emissions, promote biodiversity, and preserve ecosystems, ensuring agricultural sustainability.

**Executive Summary:** It is responsible to present a concise yet all-encompassing summary of the drone service business. It is a brief overview that summarizes critical information from the document, such as the problem or opportunity being addressed, objectives, key findings, goals, and recommendations.

**Harvest and Post-Harvest Management:** The procedures for harvesting crops at the right stage of maturity and handling techniques to minimize post-harvest losses. Proper storage, processing, and transportation methods are used to maintain crop quality and market value.

**Integrated Pest Management (IPM):** An approach to managing pests and diseases that combines various strategies, including cultural, biological, and chemical methods, to minimize their impact while minimizing harm to the environment.

**Irrigation Management:** The efficient control and provision of water for crops based on their water requirements, soil moisture levels, and weather conditions to ensure optimal growth and yield.



**Local Conditions:** Considering the specific environmental, climatic, and soil characteristics of a particular region or location when making agricultural decisions and implementing best practices.

**Nutrient Management:** Balancing the application of essential nutrients, often through organic and inorganic fertilizers, according to soil nutrient levels and crop requirements to maintain soil fertility and prevent imbalances or deficiencies.

**Online Presence:** It describes the strategy for establishing and nurturing a robust digital footprint for the drone service business. This encompasses a detailed plan for website development, addressing how the online platform will be designed to effectively represent the services and engage potential clients.

**Optimize Resource Utilization:** Maximizing the efficient use of resources such as water, nutrients, and land to enhance crop yields and reduce waste.

**Ortho-map:** An ortho-map is a geometrically corrected aerial or satellite image that represents the Earth's surface accurately, with uniform scale and no distortion. It allows for precise measurements of distances and angles and is commonly used in mapping, land use planning, and environmental analysis.

**Pest and Disease Management:** The implementation of strategies, including Integrated Pest Management (IPM), to protect crops from pests and diseases while minimizing environmental harm through cultural practices, biological control, and judicious use of pesticides.

**Scientific Advancements and Technologies:** Incorporating the latest scientific knowledge and technological innovations into farming practices to continually improve crop production and management.

**Seed Selection and Quality:** The practice of selecting high-quality seeds with strong genetic traits and high germination rates, considering factors like purity, viability, and resistance to pests and diseases.

**Service Portfolio:** It is a comprehensive outline of the diverse drone services the business intends to offer, which may encompass a range of applications such as aerial photography, mapping, inspections, and more are identified.

**Soil Management:** The set of activities, including ploughing, harrowing, and land levelling, aimed at creating an ideal seedbed for crop growth.

**Sustainable Agriculture:** Agricultural practices that aim to meet current agricultural needs without compromising the ability of future generations to meet their own needs, considering environmental, economic, and social factors.

**Gyroscope:** A device that measures or maintains the orientation and angular velocity of an object. It is used in drones, smartphones, and navigation systems to provide stability and assist in determining the object's position in 3D space.

**Weed Control:** The techniques used to manage weed growth, such as timely weeding, mulching, and herbicide use, to reduce competition with crops and maximize yields.

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