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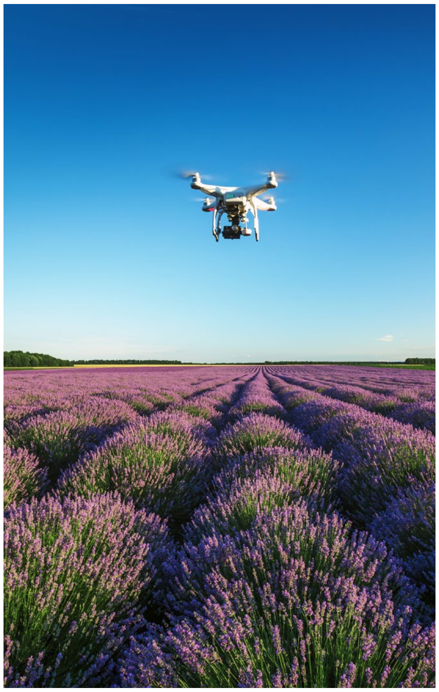

Unnamed aerial vehicles

What you need to know for use in production agriculture

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An emerging technology that has the potential to revolutionize the agriculture industry is creating excitement among production agriculture groups. This technology has the capability to measure crop health in near real-time, assess and map crop damage, help identify diseases and other crop health issues, and even apply low-volume treatments to remedy issues within a crop during the growing season. An **unmanned aerial vehicle (UAV)**, or **drone**, is a small aircraft that has evolved technologically to the point that almost anyone can safely operate it. Because of these advancements, UAVs have the potential to become an extremely useful tool for production agriculture. This fact sheet attempts to answer some frequently asked questions about the current usefulness of UAVs and how they can be implemented in production agriculture systems.

What are UAVs and how do they work?

There are multiple terms that all refer to what has traditionally been called a "remote-controlled airplane" or "remote-controlled helicopter," including **unmanned aerial vehicle (UAV)**, **unmanned aircraft system (UAS)**, and **drone**. All of these terms refer to the same general category of aircraft that is remotely operated from the ground. The agriculture industry is beginning to use these aircraft to fly over fields and utilize remote sensing technology for better in-season crop management by assessing crop health and generating timely actionable information. Currently, there are two distinct types of UAVs available: fixed-wing and multirotor. Each type of UAV has advantages and disadvantages to consider when implementing in a production agriculture system.

FIGURE 1. Two examples of fixed-wing UAVs. These aircraft are typically flown with autopilot systems and require mechanical launching in some cases (right). The fixed-wing types of UAVs require much more space for launching and landing than the multirotor UAVs. Photos courtesy of Simerjeet Virk at the University of Georgia.

Fixed-wing UAVs

The fixed-wing UAV looks like what most people would consider to be a typical airplane (figure 1). These machines have an electric motor that drives a propeller mounted in the vertical plane. The propeller is located either in the front or at the rear of the aircraft and usually in the center of the machine. Some fixed-wing UAVs have two motors and two propellers, one located on each wing, but usually these are larger models. These aircraft typically fly at speeds of approximately 20 to 40 miles per hour. Flight durations are generally limited to 40 minutes or less based on battery technology and capacity. These aircraft can assess 80 to 150 acres in a short amount of time by flying high and fast. The increased area assessed comes at the cost of reduced resolution, depending on the sensor being implemented. Fixed-wing UAVs are generally operated in autonomous mode, where a flight plan is preloaded onto the controller of the aircraft. These UAVs are typically launched manually or mechanically and require more area to successfully launch and land than the multirotor UAVs.

Multirotor UAVs

Rotor-type UAVs utilize propellers that are oriented in the horizontal plane, like a helicopter, and maneuver by rotating these propellers at different speeds (figure 2). These UAVs generally have four propellers but can have as many as eight, depending on the size of the aircraft. Top flight speeds tend to be lower than fixed-wing craft, but the margin is closing as models improve. A significant advantage gained by multirotor UAVs is the capability to hover in a fixed location. Rotor-type UAVs can fly low and slow, providing the opportunity for increased measurement resolution and even individual plant assessment if required. The area required for takeoff and landing is also significantly less than for fixed-wing UAVs. These aircraft can be flown in manual or autonomous mode and real-time video feedback is common.

FIGURE 2. These three multirotor-type UAVs are considered "small," and their use is governed by the FAA Part 107 rule as long as the total flying weight is less than 55 pounds.

What type of information can be gained from UAV data collection?

A wide selection of sensors is available to be mounted to a UAV for assessment of production agriculture fields. At the time of publication, there are three main types of sensors available for UAV data collection: visible/color sensors (figures 3 and 4a), multispectral sensors (vegetative index) (figure 4b), and thermal sensors (figure 4c). Visible/color sensors provide a color (RGB) image of the field being assessed. This perspective can provide information to a producer or crop consultant about the current health of a crop. Commonly used multispectral sensors collect images in green, red, red-edge, and NIR bands, which are used to create vegetative indices that measure specific properties of the crop canopy. The most common vegetative index sensor is the Normalized Difference Vegetative Index (NDVI), which provides information about the crop health, or greenness of the plant (chlorophyll content of the leaves). NDVI maps can be used to delineate management zones for site-specific nitrogen applications, irrigation requirements, or other chemical applications for pest or insect control. Thermal sensors utilize infrared light emittance to measure the temperature of the crop canopy. Canopy temperature is an indirect indication of plant stress induced by lack of water, fertilizer, or damage by pests. It is mostly used to assess crop damage or for irrigation scheduling.

Generally, data collected by any of these sensors consists of still images triggered by location within the field that can be merged, or stitched, to create a single large image of the field for interpretation. This image can be assessed in a Geographical Information System (GIS) software package to provide multiple data layers within a map for trend identification and assessment. A few currently available sensors provide real-time vegetative index image feedback as the field is flown. This could be utilized to identify problem areas and check them immediately instead of having to wait for data processing and analysis to be completed. However, these sensors are capable of only identifying differences, even ones not apparent to the human eye, within a field or crop. They do not provide information about the cause of those differences; it is necessary to visit areas that show differences to determine the cause of the problem.

FIGURE 3. Visible light UAV images can provide information about the growing crop and where correctable problems might be located.

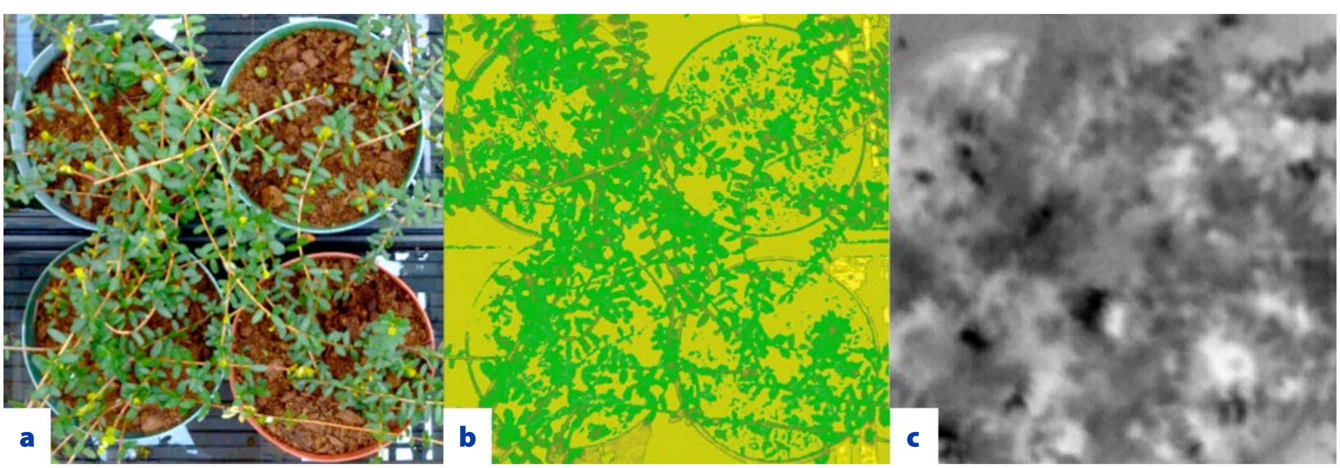
What rules, if any, do I need to follow when flying my UAV for agricultural purposes?

UAV rules and regulations are created and governed by the Federal Aviation Administration (FAA). Currently there are provisions for flying a UAV as a hobbyist, which apply if the UAV is personally owned, being flown for entertainment purposes only, and no financial benefit is gained from the UAV flight. Commercial flights, however, are flights conducted for business purposes and fall under different provisions. An example of the FAA's definition of a flight for business purposes would be a farmer flying to look at the top of the grain bin (which is part of the farm business) before climbing up to make a repair. Thus the FAA considers any flight involving a farm or crop to be a commercial flight. In late 2016, the FAA released rules regarding commercial small UAS (UAV) flights. These rules are referred to as Part 107. They apply to any UAV weighing less than 55 pounds (figure 2) and mostly follow the rules that were previously enforced on hobbyist pilots. Highlights of Part 107 include:

- Daytime operation only.
- Pilot must maintain visual line of sight with the UAV at all times. (First-Person View (FPV) goggles are not line of sight.)
- Maximum altitude of 400 feet.
- Maximum speed of 100 miles per hour.
- Pilot must see and avoid manned aircraft. Manned aircraft always have the right-of-way, and UAVs must yield in all cases.
- Pilot must have a remote pilot certificate from the FAA for commercial operations.
- Automated flight plans are allowed as long as the pilot can take control immediately to avoid danger.
- No operation over people not involved in the flight operation unless under a covered structure.

The biggest change with the Part 107 rules was the requirement of the remote pilot certification. To obtain this certification, you must go to a registered FAA testing facility and pass an aeronautical knowledge written exam, for which online study guides are available. The certification is valid for two years and affords the remote pilot the right to conduct and oversee commercial UAV flights. This certification is required for all agricultural flights in the United States. For more information about Part 107 and the process to become a certified remote pilot, visit the FAA's Unmanned Aircraft Systems website at https://www.faa.gov/uas/.

FIGURE 4. Using different light wavelengths and computer software, plant health can be measured and possible problems identified before they are visible to the human eye: (a) visible light image, (b) NDVI index from a spectral image, and (c) thermal image of cranberry plants.



How do I implement UAV-based data collection into my agriculture operation or business?

Starting small in both investment and physical size of the aircraft will allow you to learn the capabilities of a UAV, which comes with experience flying in differing situations and weather conditions. Alternatively, partnering with another producer or professional who already owns the necessary equipment may be a good way to get started. While the technological advancement of these aircraft has made them much easier to operate and maintain, they still have limitations. Physical limitations of the aircraft include maneuverability, acceleration and deceleration, and ability to fly in wind. A small aircraft will be more limited than a large aircraft, thus teaching the pilot more quickly what is safe and what is not. Also, replacement parts for small and highly common aircraft are much less expensive than those for larger aircraft. Once the pilot has experience and is comfortable with a small, less expensive aircraft, a larger investment in aircraft and sensors can be made. Currently, the initial investment cost for a multirotor with a visible/color camera with readily accessible replacement parts is between $1,000 and $1,500.

Data processing and analysis is another major hurdle to overcome when implementing UAVs and sensors in a production agriculture system. Individual images at specific locations within a field are useful, but spatial information can be developed by stitching georeferenced images together to make a single large image. Stitching software can be a stand-alone package residing on a personal computer, or it can be cloud based, where images must be uploaded to a server. Once the stitched images are created, Geographical Information System (GIS) software is required to generate maps of the data and delineate management zones within the fields. Both the stitching software and the GIS software have associated costs.

Consideration should be given to the fact that UAV-based agricultural measurement has two obstacles to overcome: 1) profit margins in the agriculture industry are usually very small, so return on investment is critical to a technology's usefulness; and 2) timing of the measurement is key to the value of the data to the farmer and/or crop consultant. Delays in data collection and analysis can occur due to poor weather conditions that restrict flight and limit time (images typically should be captured around solar noon under consistent lighting conditions). Also, slow internet connectivity to upload images for analysis or sharing and user experience with data analysis software can cause delays since data files are quite large, and the analysis software takes time to learn.

In conclusion, UAVs have great potential to provide significant amounts of valuable data to production agriculture. The data generated from remote sensing technology mounted to UAVs can be utilized to improve management decisions for farmers. Investment in this technology requires a willingness to maintain a remote pilot certification from the FAA and to meet timing requirements to maximize the value of the data generated from the UAV.

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