Unmanned Aerial Vehicles May Soon Play a Substantial Role in the Infrared Remote Sensing of Agricultural Fields Under Newly Proposed FAA Regulations

Aerial photography has been used in agriculture in the United States since the 1930s to help farmers evaluate their cropland. The U.S. Department of Agriculture has historically used aerial photography to determine percentage of farmland planted in specific crops. It is a cost-effective method of covering large plots of land. Panchromatic, or black & white photography, was first used and is still used to some extent. However, it is difficult to distinguish between certain types of vegetation in many cases and evaluation of plant health is somewhat limited. Infrared (IR) film, both panchromatic and color (most commonly used), was developed by the military to distinguish camouflage painted surfaces from real vegetation. This new technology soon found its way into the agriculture and natural resource community as a means of determining plant stress. Vegetation response to solar radiation is well known. A small amount of solar light is reflected by the outer leaf surface while a greater amount is absorbed into the inner mesophyll tissue for use in photosynthesis and reflected back by the cell walls as near-infrared light. This keeps healthy plants from overheating.

As a plant grows, the amount of chlorophyll in the leaf increases with the increase in leaf area. Chlorophyll absorbs red and blue light while reflecting green so plants generally appear green to the human eye (visual light). In a mature plant, the chlorophyll and corresponding green reflectance tends to stabilize while the reflectance of near-infrared (NIR) light increases proportionally to the increase of cell walls, intercellular spaces and total plant surface area. In a deteriorating plant, chlorophyll decreases along with the collapse of tissue cell walls and a resulting decrease in green and NIR reflectance accompanied by an increase in blue and red reflectance. Correlating these variations can help identify plant species, vitality, stage of maturity and moisture content. Plant stress is commonly detectable in the infrared before it can be seen visually, thus alerting the farmer in time to avoid permanent damage to the plant. Soil characteristics can also be determined to some extent by interpreting vegetation vitality patterns. Range and pastureland can be monitored for stress, often caused by overgrazing, by comparing healthy vegetation spectral signatures with those of the land to be monitored.

Researchers and farmers often use what is called the Normalized Difference Vegetation Index (NDVI) to evaluate the health of vegetation. The NDVI ratio is heavily influenced by chlorophyll production and is thus a numerical indicator for quantifying plant vitality. It is calculated by the following equation:

\[
\text{NDVI} = \frac{\text{NIR} - \text{Red}}{\text{NIR} + \text{Red}}
\]
This split image shows the left pane as a raw NIR/Red image left and a processed NDVI image right. Software looks at the NIR and red values for each pixel and uses the formula above to assign a color to each calculated value generating the false-color image at right. Various vegetation health levels are indicated by red, orange and yellow while green and blue indicate roads and infrastructure. The dark area top right is a lake. This image is from Public Lab (http://publiclab.org/wiki/near-infrared-camera).

Since visible light is absorbed for photosynthesis and near-infrared is generally reflected, live green plants appear bright in the near-infrared and somewhat dark in red light. The index values range from -1 to +1 with dense, healthy vegetation plotting from the middle to the upper end of the scale. This information can be used to adjust levels of irrigation and chemicals applied to fields in order to obtain optimum overall growth in what has become known as “precision agriculture”.

Long-wave infrared (8-14um) can also be used to monitor vegetation by measuring the emitted thermal radiation rather than the NIR. Stressed crops show a higher temperature than healthy ones because of a higher absorption of solar radiation due to collapsed cell walls and decreased leaf area. Stressed areas can then be visited for further evaluation of the problem. The image below was taken with the Infrared Cameras Inc. (ICI) 9640 infrared camera shown below.
Aerial photo surveys have traditionally been done by piloted aircraft and more recently by satellite. Today unmanned aerial vehicles (UAVs), sometimes referred to as drones, stand ready to take over much of this work. Small infrared and visual cameras carried aloft by these airplane and helicopter type vehicles can provide data to farmers, land managers, ecologists and wildland firefighters in a more timely and cost-effective manner than previous methods. Large drones can spray for insects and diseases as well as apply fertilizer and herbicide. The Federal Aviation Administration (FAA) claims to regulate UAVs and currently takes the stand that nearly all commercial operations, including agricultural use, are generally illegal. For now, limited operations on a case-by-case basis may be conducted in training, research & development and demonstration after receiving an Experimental Airworthiness Certificate in addition to having certified pilots and aircraft. Government agencies and public universities can apply for a Certificate of Authorization that allows them to use drones for limited operations such as military training exercises, law enforcement, border patrol and firefighting.

Many farmers have already begun using UAVs claiming that these aircraft are “models” which the FAA has traditionally not regulated, and they (the FAA) have no jurisdiction over these
aircraft, even those used for commercial purposes. A number of attorneys agree with them further stating that the 2012 Act is a directive to the FAA and does not apply to the general public. In 1991 the FAA set forth voluntary guidelines for model aircraft operations. These included flying below 400 feet, away from populated areas and not flown within 3 miles of an airport. Also, in the 2012 FAA Modernization and Reform Act, Congress defined model aircraft as unmanned aircraft flown “within the visual line of sight of the person operating the aircraft for hobby or recreational purposes.” However, an FAA Notice in 2007 stated “you may not fly an Unmanned Aerial Vehicle for commercial purposes by claiming that you’re operating according to the Model Aircraft guidelines.” Under these current guidelines, farmers can legally use drones to monitor gardens or fields that are grown only for personal, noncommercial use. However, new regulations are expected that could blow this industry wide open especially in the field of agriculture which is generally thought to be the UAV industry’s largest potential market. In fact, a recent ABC News report projected that 80% of commercial drone use will be for agricultural purposes once FAA rules are relaxed.

A number of companies are poised to cash in on the coming drone market. One UAV developer and manufacturer, DJI (www.dji.com), is a global leader in providing “flying platforms” for aerial photography. Their Phantom Series offers ready-to-fly quadcopters that are suitable for recreational as well as professional use. Prices start below $1000 USD. The newer models offer features such as radar positioning and return-to-home feature, precision flight, stable hovering and a range of camera tilt options. The Phantom 2 Vision+, shown below, has an extremely stable 3-axis camera gimbal and can display real-time flight parameters onscreen. It also has the ability to film straight down.
DJI’s Phantom 2 Vision+ weighs only 1242g (with battery and propellers) and can fly as fast as 15m/sec though that speed is not recommended. Maximum flight time is 25 minutes.

DJI also offers a series of larger vehicles called the Spreading Wings Series. They include both hex and octocopters. These are strong, stable camera platforms with a large payload capacity, foldable arms (most models) for portability and allow a wide range of shooting angles. Their most advanced octocopter to date is the S1000+ shown below.

The S1000+ weighs 4.4Kg and has a maximum takeoff weight of 11.0Kg which means it can carry up to 6.6Kg of payload, allowing for large or multiple cameras. Flight time is up to 15 minutes with 15000mAh and a 9.5Kg takeoff weight. Shown with landing gear retracted.
According to Gary Forister, Design Engineer at Infrared Cameras Inc. (ICI) in Beaumont, Texas, the company (www.infraredcamerasinc.com) plans to market a UAV camera system in the very near future. The system will consist of an infrared and or visual camera (or multiple cameras) and a microprocessor that will manage the collection and storage of image data. ICI does not plan to sell UAVs at this time. They have several cameras currently available for UAV mounting; NIR and visible cameras are in the works. The SWIR 640 P-Series camera operates in the short-wave infrared region (900nm-1.7um spectral response) and contains a 15um FPA (InGaAs) radiometric imager with a 640x512 pixel array. It is small in size (less than 3 cubic inches overall), low power and weighs less than 120 grams without lens. The 9320 P-Series camera consists of a 17um FPA Vanadium Oxide 320x240 pixel radiometric imager with a 7um-14um spectral response (long-wave infrared). It weighs 37 grams without lens, operates on less than 1 watt of power and is less than 2 cubic inches in overall dimension.

The SWIR 640 (left) and the ICI 9320 (right) are small, lightweight (aluminum enclosure) and low power infrared cameras perfect for use with Unmanned Aerial Vehicles.
The FAA has recently announced a list of proposed rules that will open the skies to the commercial use of UAVs— to a certain extent. These rules will apply to vehicles that weigh less than 55 pounds but do not include model aircraft or other aircraft operated by hobbyist. First of all, drones will have to be registered with the FAA. Operators will have to be at least 17 years old, obtain a drone operator license which includes passing a written test and be retested every 24 months. No medical exam or “flight” test will be required. Flights can take place only during daylight hours and must be under 500 feet, at speeds of no more than 100 mph and visibility of at least 3 miles. Aircraft must be visible to the operator at all times. While drones will be allowed to be flown using their own navigation system, the operator must still have the craft in sight and be able to take manual control at any time. All flight rules will still apply. No flights over people will be allowed although the FAA is considering a category of drones under 4.4 pounds that can be flown over crowds.

These proposals will not likely become law for at least another year or more and will certainly continue to evolve once they do. Until then, commercial operators including farmers, will have to apply for an exemption. Maintaining the outstanding safety record of commercial aircraft here in the U.S. is of uppermost importance in the mind of the FAA. Drones have already come dangerously close to other aircraft, interfered with fire, disaster and crime scenes and have crash landed in various places including on the White House lawn! According to recent polls, a large percentage of people are in favor of the commercial and public use of UAVs but still have safety and privacy concerns. However, most agree that these regulations will be a good first step to integrating UAVs into the market place as well as into everyday life.