Agricultural Drones: What Farmers Need to Know

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Using drones for agriculture is a hot topic these days, and for good reason. These unmanned aerial vehicles (UAVs), as they are sometimes called, are rapidly becoming a core tool in a farmer's precision equipment mix.

Today’s farmers have to deal with increasingly complex concerns. Issues such as water – both quality and quantity, climate change, glyphosate-resistant weeds, soil quality, uncertain commodity prices, and increasing input prices to name a few.

Growers are turning to high-tech tools, often under the banner of precision agriculture, to respond to and mitigate these and other concerns. Precision agriculture divides a field into zones that can be individually managed with a range of GPS-equipped precision machinery. Technology enables farmers to collect, store, combine and analyze the layers of data that drive precision nutrient and irrigation management.

There are a variety of sources a farmer can use to build these data layers. Yield monitors, soil sample results, moisture and nutrient sensors, and weather feeds are all useful data sources. In addition to these historical data sets, new technologies, like drones, can provide a view of the current condition of the in-field crop.

Options for Collecting The “What’s Happening Right Now” Data Layer

Whole field, in-season, current condition data is one of the most valuable pieces of information in a precision program. With this data a farmer can spot problems early and rapidly select appropriate interventions.

Spot-checking, the most common method used to get this information today, does not accurately capture conditions across an entire field. With very large fields, the problem is exacerbated; scouting the perimeter cannot reveal issues deep within the field, and the time to scout grows proportionally with acreage.

Manned surveillance flights and satellites using near infrared cameras (also called NDVI cameras) and RGB cameras are the incumbent data sources for whole field condition assessment, but they aren’t one-size-fits-all solutions. These sources are best suited for surveying tens of thousands of acres at a time, where the time and resources required to schedule and scout by these means justifies the expense and complexity.

Agricultural drones represent a new way to collect field-level data. The most compelling reason for using drones is that the results are on-demand; whenever and wherever needed, the drone can be easily and quickly deployed. A grower or service provider can have a drone in the back of the truck and get actionable, field-level information the next day or sooner. It’s hard to beat the immediacy and convenience of planning the
mission, collecting the data, and getting near real-time results; only drones offer these benefits.

Drones are affordable, requiring a very modest capital investment when compared to most farm equipment. They can pay for themselves and start saving money within a single growing season. Operation is relatively simple, and getting easier with every new generation of flight hardware. They’re safe and reliable. They are easy to integrate into the regular crop-scouting workflow; while visiting a field to check for pests or other ground issues, the drone can be deployed to collect aerial data. Yet, the real advantages of drones are not about the hardware; the value is in the convenience, quality and utility of the final data product.

Drone-enabled scouting is a convenient way to collect the “what is happening right now” data layer. There are three main elements to using a drone effectively to do this: getting the sensors above the field, the sensors themselves, the data analysis. Finally, there are the regulatory and business aspects to consider.

**Getting a sensor over a field: Fixed or Rotor**

Many types of drones are available today, but not all are good candidates for farming. Those suitable for agricultural applications fall into two categories: fixed-wing and multi-rotor drones. The cost and payload capacity of both types is similar, and the hardware is becoming commoditized quickly.

Fixed-wing drones have long-range flight capacity, an advantage when a large area is to be covered. They are also crash tolerant; the one shown here is made from high durability foam. Because fixed-wing drones can cover great distances, they can be challenging to keep in the operator’s range of sight, a requirement under current FAA rules.

Multi-rotor drones are faster to set up in the field and can take off and land vertically. The mission set-up is simple; there is no need to plan takeoffs and landings into the wind as must be done with a fixed-wing. For inexperienced operators, they are the easiest way to get up and running quickly.

There’s a preconception that multi-rotor drones don’t have the range necessary to cover large row crops, and historically, people looked at fixed-wings for that reason. Multi-rotors actually have many advantages: they’re easier to operate, require no advance wind planning, and have the ability to fly more precisely (for example, to turn sharply where fields abut adjacent highways). There are a number of exciting data products in development which will require low altitude flight to capture extremely detailed images; here again, the multi-rotor has the advantage. Furthermore, range is no longer a
practical issue. Under new FAA rules, operators can only fly to edge of line of sight, effectively negating the argument for long-range fixed wings.

With either type of drone, the actual flight process is relatively straightforward. Using software on a ground control device (typically, a tablet, laptop or smartphone), the operator draws an outline of the area to be surveyed on a Google map type of view. The software programs the flight, overlaying lines on the map to show the drone’s flight path. The information is uploaded to the drone over a wireless link. Takeoff, flight and landing are completely autonomous (manual override allows the operator to avoid unexpected objects in the flight path, such as a manned plane).

Although historically, drones designed for recreational purposes were not suitable for use as agricultural drones due to lack of range, low payload capacity, or poor flight planning capabilities, they are rapidly advancing. Some farmers have been able to successfully employ the more recent models to collect agricultural data. This is an area to watch.

**Sensors**

Inexpensive consumer drones can be used out of the box to take a video or still photo from above a field, which may spot some problems. To really obtain value from an agricultural drone, however, other types of sensors must be considered, as well as tools to fly the drone in a pattern over the entire field and software to combine the sensor readings across the field into a single layer that is then analyzed and geo-referenced. Only in this format can a user then use a GPS-enabled smartphone or other device to walk to and inspect specific problem areas or combine the information with other data layers.

Drones collect information largely based on the light reflected by the crop below. For agricultural purposes, using a specific type of sensor can help growers collect data that indicates where issues exist so that they can take appropriate action.

Plants, of course, capture visible light to drive photosynthesis. However, near infrared (NIR) photons don’t carry enough energy for photosynthesis but they do bring lots of heat, so plants have evolved to reflect NIR light. This reflection mechanism breaks down as the leaf dies. Near Infrared sensors take advantage of this property by monitoring the difference between the NIR reflectance and the visible reflectance, a calculation known as normalized difference vegetation index or NDVI. A strong NDVI signal means a high density of plants and weak NDVI indicates problem areas on the field.
NDVI reports are useful for a variety of agricultural purposes. An NDVI can clearly distinguish areas of the field where a crop is growing well from those where it is not, enabling zones to be created to target the right amount of fertilizer application to each spot on the field. Due to the way the plant reacts to stresses, an NDVI image can also reveal the presence of weeds, pests, water damage, and other problems giving the grower the information necessary to identify and quantify problems mid-season and then determine how to best address them.

There are two schools of thought about choosing an NDVI camera. One approach is to use a multi-thousand dollar, purpose-built, camera that captures precise wavelengths. The added value of the additional narrow-band frequencies captured by these purpose-built cameras typically is not enough to offset their high price, except for a few specific use cases.

The preferred approach is to convert a high-quality consumer camera for agricultural imaging, which involves removing the lens and replacing a filter and sometimes replacing the lens itself. Agribotix has achieved excellent results by modifying $600 GoPro cameras. The imagery is similar or superior to what a $3,000 camera captures. Any equipment limitations have no negative impact on the agricultural applications.

While both approaches deliver high quality NDVI data, we recommend getting started with a converted camera and only considering a purpose-built camera if the results are not adequate.

There is a lot of research activity focused on using other types of drone-mounted sensors for agriculture. The two most commonly mentioned are thermal cameras and hyper-spectral cameras.

Thermal sensors can read the radiated temperature of an object, and some of the newest models are light enough to be carried by a small drone. A thermal sensor might help identify how plants are using water, as those with access to more water appear cooler in an image. The challenge is that these temperature variations are minor and can be difficult to distinguish from the other factors that might heat or cool the plant, such as breezes, sun exposure, etc. More research is needed in this area.

Hyper-spectral sensors record many wavelengths of both visible and invisible light. Although the size and price of these cameras are coming down, they are still large and expensive. The promise of these sensors is that they might be able to identify the specific type of plant merely by measuring the color of light that it reflects, which would
make it easy to pick out things like herbicide-resistant weeds. However, calibrating these cameras to work on a low-flying drone in a farm environment where the light conditions vary as much as they do is a problem that needs to be solved before hyperspectral cameras can deliver.

Data Processing and Analysis

When a drone collects data over a field, the camera takes several hundred still images as it flies a “lawnmower” pattern back and forth across the field. These images then performed to make the results useful.

A computer with specialized software can process the images locally, which can be time consuming on several levels. Gaining mastery of the software initially and achieving repeatable results, flight after flight, can be a steep learning curve. The processing itself can tie up the computer for hours each time new data is loaded, suppressing productivity and requiring the operator to be present to monitor progress.

Alternatively, processing can be done using a purpose-built, web-based service. In this model, the operator performs the flight, runs software that automates image collection, and uploads to the cloud. There, the images are processed rapidly and returned to users. The advantages of the software as service model are several: the operator is free to walk away and do other things while processing happens in the background; there’s no need to invest in pricey hardware or software; and, users are always benefiting from the latest release and the newest reports.

One of the most useful reports that a drone can produce is an NDVI image. This takes the stitched images from an NIR camera and applies a “false coloring” to highlight problem areas. While there is no standard color scheme for these reports, Agribotix colors the image with the strongest signals appearing green, transitioning to yellow, then red, and eventually to gray for the weakest parts of the field.

Different services will supply the results in different formats. Almost all will provide results in a GeoTiff download, which is an image file with GPS coordinates. Another common format is KMZ, which enables viewing the images in Google Earth.

A less common, but a very important format is the shapefile. These images divide the field into zones and assign a value to the crop density in each zone. This format is useful to have, as it can be read directly by many farm data packages, allowing the drone layer to be easily combined with other data sources to create prescriptions for variable rate application. Finally, some services supply the results directly on a map in a web browser, in some cases allowing users to use a smartphone to view their location on the results while in the field to ground truth.
Case Study: Missouri Corn

Without the benefit of aerial imagery, the farmer in this study had been applying fertilizer uniformly at 50 lbs/acre. The farm had variable rate equipment but they lacked current condition data required to generate a prescription that represented what was happening in the field at that moment.

A single, 20-minute flight captured 254 images to create the picture shown at right. Looking at this image, it would be difficult to make a prescriptive decision; clearly there are differences across the field but the differences are subtle. The NDVI image, however, makes these subtle variations very obvious and makes it much easier to create a fertilizer prescription. Green areas show where the corn was chest-high, while yellow shows knee-high growth, and red areas are only ankle-high.

Using a GPS-enabled tablet, the farmer’s agronomist was able to double-check the results in the field by comparing the observed NDVI results with the crop state on the ground. This ground truthing process was simple and quickly accomplished.

In addition to the image, the software also produced a shapefile that divides the field into 1, 5 or 10 meter grid squares and assigned each square to one of five levels of health. This current drone-collected data was combined with historical data (soil type and yield maps) to assign an amount of nitrogen fertilizer to each level. The resulting prescription was uploaded to the tractor for variable rate application.

With this, the farmer was able to take full advantage of his variable rate equipment to apply the precise amount of fertilizer needed, where it was needed. The approach produces a better yield and lowers the total cost of inputs. Straight rate application is comparatively inefficient and has negative environmental impact. Our calculations show a potential yield boost of about 5 bu/acre with precision application of the nitrogen fertilizer and a potential reduction of 30-40% in fertilizer use, a number backed up by academic studies\(^1\).

\(^1\) Moving from Uniform to Variable Fertilizer Rates on Iowa Corn: Effects on Rates and Returns by Bruce A. Babcock and Gregory R. Pautsch, 1998
Other Data Product Examples

There are a variety of ways to utilize drone-enabled agricultural intelligence to decrease cost of inputs and to increase crop yields. The images below depict some of the applications:

- **The blue lines in this cornfield are weeds.**
- **Nothing is growing in dark bulls-eye at the center of the field. Ground truthing revealed clogged nozzles on the center pivot irrigation system.**
- **The red areas show where hail damage has occurred and provides documentation to share with the insurance adjuster.**
- **Thermal imaging is used to identify hot spots within piles of beets. The processor uses the information to locate and extract fermenting beets to prevent spoilage from spreading.**
- **Digital surface modeling of an oil palm plantation in Sumatra helps landowners determine the best placement for roads. This type of imagery can also be helpful for placing drainage tiles in hilly fields.**
Regulatory Considerations

The Federal Aviation Agency (FAA) oversees commercial drone use in the United States. A company can apply for a “333 Exemption” to be allowed to use drones commercially. The process is similar to getting approved to handle hazardous farm chemicals. This process takes 2-3 months, and there are companies that will help with the process if the drone the operator is using a drone that has already been approved under another 333 Exemption (as Agribotix drones have been).

Insurance

There are companies that offer liability insurance for commercial drone operators to cover damage caused by accidents. Typically, this is done on a per-drone basis and runs a few hundred dollars, per drone, per year.

Return on Investment

Today, growers around the world are finding that a drone provides a quick way to identify problems in their fields. Agribotix has flown more than 40 different crops across 30 or more countries. We’ve heard from some of our customers that they are getting in the neighborhood of $15/acre ROI. For high value crops that are prone to disease, such as potatoes, citrus, almonds and bananas, the financial benefit could be significantly higher. We’re also hearing that a drone can pay for itself in the first half of a season.

Those are compelling benefits for agricultural producers, who must contend with increasing costs, falling commodity prices, and increasing demand for productivity with fewer acres in cultivation. If you want to better understand the payback for your situation, try our return calculator, and plug in your own numbers.

Key Decisions for Farmers

With no sign of the current pressures on farmers abating, it makes sense to consider seriously any tool that can boost productivity, mitigate input costs and ultimately, improve the bottom line. Drones are still considered a new tool for agriculture, but their demonstrated utility for assessing in-field crop health and their potential for compelling return on investment make them an attractive addition to the precision toolkit.

Whether farmers purchase and fly their own drone or hire a drone service provider to fly for them, drones cost-effectively capture aerial imagery with accuracy and unrivaled immediacy. When the window of opportunity for intervention is small, as it is in farming, ease of use and fast turnaround of data is key. Waiting for manned aircraft or satellites to provide images after a weather event or to monitor stand count is impractical for most; however, these situations are handled with ease by a multi-rotor agricultural drone fitted with cameras modified for farm applications.
Obtaining understandable, actionable data in a timely fashion is essential. Software that can handle a large volume of images quickly and return analytics that both identify issues and make recommendations for intervention and variable rate application can mean lower input costs, a bigger yield, and increased profit. Look for options that provide a range of specialized agricultural intelligence and produce outputs in formats compatible with precision equipment. The key is to choose a software platform is easy to use and won’t require the user to monitor processing.

The financial considerations surrounding agricultural drones are simpler than some might initially believe. Case studies attesting to the value of using a drone-and-data solution throughout the growing season abound, and calculators are available to help determine potential ROI for individual situations. The enhanced Section 179 provision can also make a drone package more attractive to farmers.

Agricultural drones are here to stay. Farmers that embrace the technology and integrate it into their precision programs will wonder how they ever got along without it.

Tom McKinnon served as a professor of Chemical Engineering at the Colorado School of Mines for close to 20 years before founding Inventworks Inc., a rapid prototyping and limited run manufacturing firm, in 2009. He holds a PhD in Chemical Engineering from MIT, has authored dozens of scientific papers, and holds several patents. He leverages his expertise in electromechanics, propulsion, and battery technology into designing and improving Agribotix hardware.