



The Truth about Drones in Precision Agriculture

They're great scouting tools, but can they unseat the incumbents?

By Colin Snow, CEO and Founder of Skylogic Research

Image credit: Colby AgTech

Introduction

Over the past few years, the press has emphasized how much unmanned aerial systems (UAS) will be used to improve farming. From [Australia](#), to [Canada](#), to [France](#), to [England](#), and [the U.S.](#), the assumption is that drones provide cost savings for inputs — and in particular provide more accurate data for use in variable rate technology (VRT), so farmers who use drones will experience increased yields. All of this hype goes back to the March 2013 market study produced by the Association for Unmanned Vehicle Systems International (AUVSI) titled “[The Economic Impact of Unmanned Aircraft Systems Integration in the United States](#),” which says precision agriculture and public safety will make up more than 90% of the market growth for unmanned aerial systems. The report confidently states, “... the commercial agriculture market is by far the largest segment, dwarfing all others.”

“You know, farming looks mighty easy when your plow is a pencil, and you’re a thousand miles from the corn field.” —Dwight D. Eisenhower

But truth be told, it’s yet to be proven just how effective UAS will be in helping farmers increase yields. As the Federal Aviation Administration (FAA) closes in on finalizing commercial regulations for small UAS, the question still remains how drones will affect agriculture beyond being a great scouting tool and providing some great aerial images very quickly at a lower cost than conventional options. Beyond that, their ROI for use in precision agriculture remains uncertain.

In this paper, we’ll look at how drones have been used as remote sensing devices in agriculture thus far, review competitive and traditional approaches using incumbent technology, discuss the opportunities and challenges posed by the technology itself, outline the lessons learned, and discuss what’s next for drones in agriculture.

Use cases

Precision agriculture is a farming management concept based on observing, measuring, and responding to inter- and intra-field variability in crops. Precision agriculture uses detailed, site-specific information to manage production inputs like water, nitrogen, and pesticides. Information technologies enable segmenting a farm into smaller units to determine the characteristics of each individual segment. The farmer’s and/or researcher’s ability to locate a precise position in a field lets them create maps with as many factors as can be measured (e.g. crop yield, terrain features/topography, organic matter content, moisture levels, nitrogen levels, pH, etc.). These factors are at the heart of precision agriculture and are key to defining amendment strategies, or ‘recipe maps.’

Precision agriculture has been enabled by technologies like:

- crop yield monitors mounted on GPS-equipped combines;

- VRT applicators like seeders, sprayers, etc.;
- an array of real-time vehicle-mountable sensors that measure everything from chlorophyll levels to plant water status;
- and multi- and hyper-spectral aerial and satellite imagery, from which products like [Normalized Difference Vegetation Index \(NDVI\)](#) maps can be made.

Most of precision agriculture depends on the use of VRT applicators like the one shown in Figure 1 below. Farmers generally apply more agrochemicals on the chance that good weather leads to bumper crop yields. Amounts are determined based on plant requirements. Applications of a remedy over a field are based on a precise GPS- and GIS-based prescription. This typically leads to less usage of expensive inputs. For example, the less N (nitrogen) and pesticides applied, the lower chance that excess N or pesticides get into the environment.

Figure 1 - Variable Rate Applicator



Image credit: Colby AgTech

The main goal of any precision agriculture remote sensing is to detect something in time to make a correction. Examples of things that could need correction include irrigation, plant disease, drainage, and crop damage. Drones have the capability to provide remote sensing data in near real time in the field, rather than the resulting lag from satellite and aircraft-based imagery. It’s this increased speed of the imagery from drones that has the biggest potential for changing how growers respond.

But drones equipped with sensors acquire data, not information, and users – especially growers - want information, not data. So whatever data the drone captures needs to be converted into useful information for farmers. But good information is only as good as the accuracy of the underlying sensor data. The good news is UAS are flexible and can be flown with different sensors that can be configured to detect pests, plant diseases, weeds, irrigation efficiency, and soil erosion. The deliverable product may be a geographic information system file for variable rate application.

Farmers aren’t the only players involved in using drones for agriculture. Key players include:

- Producers / growers
 - Row crops (corn, soy, wheat, etc.)
 - Fruits, nuts, vegetables, specialty crops
 - Livestock

- Agronomists / crop specialists
- Academic researchers
- Local equipment dealers / retailers
- Crop insurance companies
- Seed companies

Drones can have many uses in agriculture in general, but there are five major application use cases. I'll list them here in order of increasing complexity:

1. Simple crop scouting – This involves nothing more than flying a drone over a field to view, capture, and playback color images or HD video, which can deliver a lot of useful information. Rather than make lengthy drives of the entire property to find problem areas, growers can see in a short time the areas that might need attention (see Figure 2). They can then go to that area and investigate further.

Figure 2 - Simple Crop Scouting Example



Image credit: Colby AgTech

2. Irrigation inspection – Managing multiple linear or center pivot irrigation systems is a labor-intensive task — especially for large growers who have many fields spread out across a region. Once crops like corn begin reaching certain heights, mid-season inspections of irrigation nozzles and sprinklers become a hassle, requiring inspectors to wade through crops to find the troubled ones. This is a very time-consuming task that can be done with a small off-the-shelf prosumer camera drone (like the one used to capture Figure 3), but it's best done with professional drones that have camera zoom functionality.

Figure 3 - Pivot Irrigation Nozzle Inspection



Image credit: Colby AgTech

3. Precision spraying – The DJI Agras MG-1, ZEROTECH Guardian-Z10, and Yamaha RMAX are three examples of remote control drones designed for precision variable rate application of liquid pesticides, fertilizers, and herbicides. Unmanned spray helicopters have been used in Japan for years, but only in April 2016 did the Federal Aviation Administration (FAA) give clearance to RMAX use in the U.S. Use of these of drones in agriculture has been lauded by AUVSI as “a safer and more cost efficient way to manage crops.” But the fact is, they don't hold much liquid (only 10-20kg). That's fine in Japan where usage is largely restricted to spraying rice paddies in small allotments on hilly terrain. But fields are much larger in the U.S. and require a lot more liquid, so adoption of this use here would be small at first.

4. Maps of individual fields or segments – Creating maps of individual fields or segments requires a bit more operator knowledge and expertise than just drone flying and pressing the record button. It requires knowledge of how “orthomosaic photos” or “orthophotos” are created. An orthomosaic is an aerial photograph geometrically corrected (“orthorectified”) such that the scale is uniform: the photo has the same lack of distortion as a map. Unlike uncorrected aerial photographs, an orthophoto can be used to measure true distances (like field segments), because it is an accurate representation of the Earth's surface. It's been adjusted for topographic relief, lens distortion, and camera tilt.

Typically, an orthomosaic is a composite of individual photos that have been stitched together to make a larger one. This technique for capturing images to create maps is not unique to drones. Orthomosaics have been created by aerial photographers in manned aircraft for years and used by lots of industries. The good news for agricultural users is there are drone apps that automate the whole process like DroneDeploy and Pix4D.

5. Insurance claim forensics – Drones provide a great new scouting approach for investigating weather damage and monitoring loss over time. There are 17 companies designated by the USDA Risk Management Agency to provide crop insurance coverage. State Farm, AIG, Allstate, and others have received FAA approvals under Section 333 for commercial operations and are currently working up use cases. Most of those will include the accurate measurement of damaged areas using 3D photogrammetry.

Photogrammetry is a technique which uses photography to measure the environment. This is achieved through overlapping imagery. Where the same site can be seen from two perspectives, it is possible to create 3D images of terrain and calculate measurements. Again, this technique is not unique to drone imagery, but there is some good news here. Off-the-shelf software, like Agisoft PhotoScan and SimActive, is plentiful and fairly easy to learn so adoption for drone use should be vigorous.

6. Crop vigor assessment and the use of prescription maps – This is far more complex than all the other use cases, but is the most often cited for drones. These assessments involve acquiring NDVI images, thermal or stereoscopic images from sensors

Figure 4 - Advanced Crop Scouting Workflow

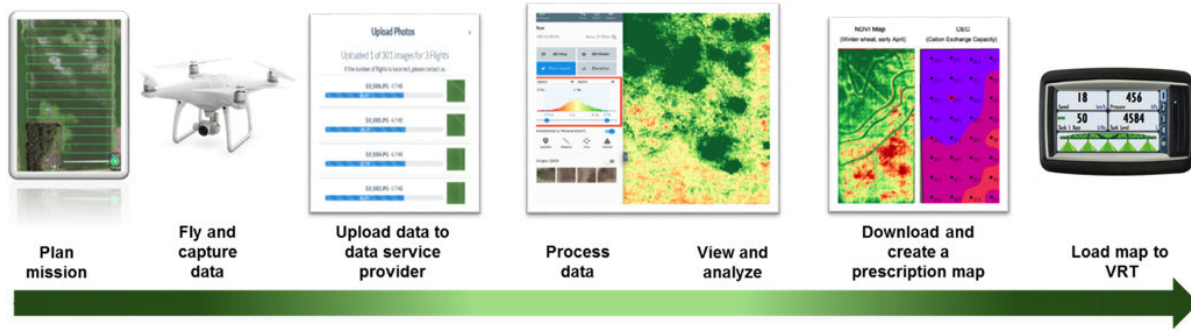


Image: Skylogic Research, LLC

mounted on a UAS and then processing and evaluating the data for potential use in VRT.

A strong correlation has been demonstrated between yields and NDVI at certain crop growth stages, as described in [this research](#). NDVI allows agronomists and producers to identify problem areas and make timely decisions. Scouting maps can be requested at key dates as guidance for field visits. NDVI-based scout maps show variations in the field, so users know where to look in the field to determine where corrective or preventative measures are needed. Users can plan their field visit locations, take it to their GPS or a printable pdf report, and accurately evaluate the reasons for in-field variability.

To be clear, much of the workflow and data processing happens outside of actual drone use and is much more complex than is shown in Figure 4 above. This workflow applies to the

most common varieties of row crops (wheat, corn, soya bean, etc.). [SenseFly](#) has outlined a complete step-by-step guide that explains how drones fit within the precision crop scouting workflow.

Opportunities

Today, farmers have access to low-cost drones with cameras and image sensors on board. These can be purchased for a few thousand dollars and flown by farmer themselves, or if they are lucky — and regulations aside — a local service provider. Basically, these drones can produce the same NDVI images and maps that specialized satellite or manned aircraft image specialist do — only now with much higher resolution images.

You would think farmers would be thrilled with the combination of higher resolution images and more precise GPS coordinates since it lets them identify problem areas within a few feet of accuracy. In some cases, that is true, and others it is not. A higher resolution means you see more detail — detail that actually may detract from the usefulness of the image, like when it shows a shadow. Is that a shadow or a bad crop area? Hard to tell from the picture. For that, you need to see it with your own eyes, as is done with ground-based crop scouting.

Ground-based crop scouting — the act of inspecting crops to look for problems such as pests, weeds, irrigation issues, and so forth — is generally done today via a simple drive-by in a pickup or an ATV. Scouting is not a perfect science, and neither farmer nor service provider can assess every plant's health and crop pressures. However, small drones are portable, and users can fly them over a field and see real-time images on a monitor. Since many farmers go out and scout their crops every couple of weeks manually, a drone crisscrossing the air could perform that work much more effectively. This helps cut down on the time identifying areas that need detail scouting and helps give the proper inputs on where to eventually spray weed control or pesticide, or even determine when it is time to harvest.

Competitive traditional approaches

Aerial image acquisition and its use by growers is nothing new. Satellite and manned aircraft image services have been available to growers for years. These are the incumbent players. Since the launch of the [Landsat 1](#) in 1972, satellites have collected data in visible and near-infrared. As time progressed, it was natural to sell this data packaged up in maps to farmers. Today growers and agronomists can request satellite NDVI-based scout maps from almost any dealer at key dates and use them as guidance for field visits.

Besides satellite-generated images, farmers also have access to more resolute imagery taken from manned aircraft. They can subscribe to a service like [Terravion](#), [GeoG2](#), and [GeoVantage](#) to get NDVI maps multiple times a week if they like. The greater the frequency, the lower the cost per acre. And the cost is quite low even when compared with drones — which everyone seems to assume has the lowest cost. In fact, they don't always, as detailed in this comparison.

Challenges

For the most part, recent technology advancements in small UAS equipped with good sensors support the farmer's and/or researcher's ability to locate a precise position in a field, observe it, and create maps of as many variables as can be measured — but only on a small scale. That's because under current and proposed FAA rules, all observation and measurement would have to be done by a drone that is within visual line of site (VLOS) of the operator. The problem is that fields and farms are bigger than VLOS. According to [this report](#), there are approximately 2.1 million farms in America. The average size is 434 acres. Small family farms, averaging 231 acres, make up 88 percent of farms. That's 1.85 million farms that could benefit immediately from VLOS operations. But large family farms (averaging 1,421 acres) and very large family farms (averaging 2,086 acres) make up 36 percent of the total farm acres in the U.S., so most of that would require beyond VLOS operations.

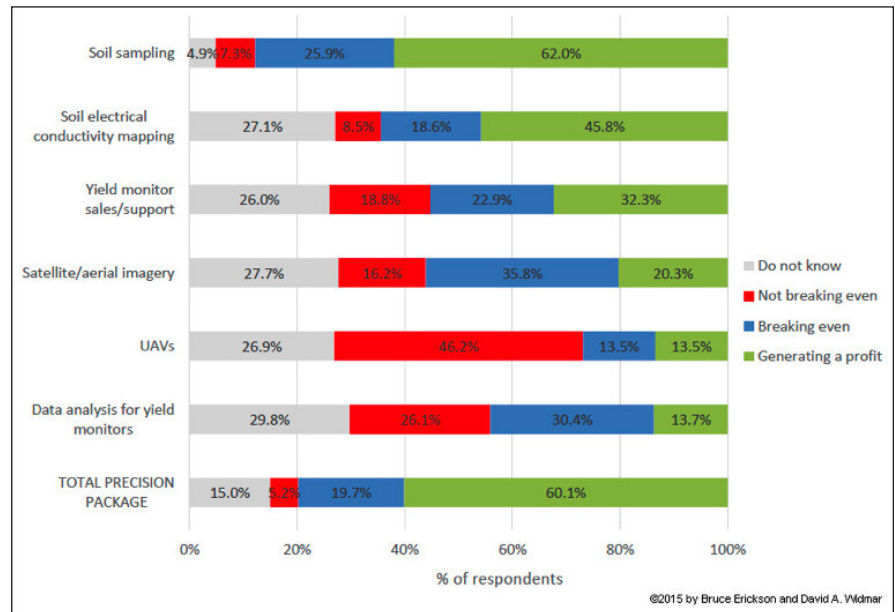
Sure, operators could conduct many operations in a day by moving section to section to section and stitching together larger maps for large or very large acre farms, but this is costly — both in terms of manpower and time. Even if it was cheaper, the market potential for drones in precision agriculture still needs more vetting. Despite the ROI studies like [this one](#) by the American Farm Bureau Federation and Measure, it's not yet clear how a sUAS can deliver more usable data to a farmer or provide a cost benefit over the existing manned aircraft or the satellite image solutions available to them today.

And this uncertainty is easily eclipsed by a larger one — the impact of falling commodity prices and revenues. By and large, falling prices creates an environment within agriculture where growers are increasingly reluctant to spend their hard-earned income on anything beyond their basic needs. A quote from [this article](#) expresses how this points to trouble for overall precision agriculture usage:

“At \$7 corn, I have room to wiggle and spend more to increase my yields,” said Jeff WanderWerff, a grower from Michigan at the Dow AgroSciences panel discussion.
“But that's not the case at \$3 corn.”

Here's another rub: use of aerial imagery all sounds great until you start to look at the numbers. According to [this report](#) by Departments of Agricultural Economics and Agronomy at Purdue University, only 20.3% of service providers (referred to as dealers in the report) who offer satellite / aerial imagery say it's profitable. And with UAV services, it's even less. Only 13.5% of dealers say they're profitable (see Figure 5). Keep in mind the scale here. There are an estimated 1,934 agriculture retailers in the U.S., and only 16% offer UAV services, whereas 51% offer satellite/aerial imagery services.

Figure 5 - Profitability of Precision Service Offerings



Source: 2015 Precision Agriculture Services Dealership Survey Results

Lessons learned

Perhaps the best lesson learned comes from the U.S. Department of Agriculture. In [this video](#), Raymond Hunt of the USDA discusses his research in agricultural mapping using sUAS systems to image crop conditions and damage. He explains how much detail is required for agricultural mapping and how data must be processed to be useful for those in agricultural production. Of particular interest is the topic of 3D mapping and stitching. Plant height from image point clouds may be a better indicator of plant health and more important for management and pest detection than NDVI. He also believes agronomists might be well served if they used photogrammetry techniques instead of only walking fields.

The other great lesson learned comes from [Digital Harvest, Inc.](#) They approach precision agriculture imaging in a technology-agnostic fashion. They work with satellite, manned, and unmanned aerial aircraft as well as ground-based sensors – so, not just drones alone. Additionally, they combine these technologies with software algorithms to provide growers with leading indicators as opposed to traditional reactive crop management like NDVI which is based on lagging indicators. Currently, Digital Harvest is the only private company in the U.S. working with the Yamaha RMAX UAV platform in agriculture.

Bottom line: Demand for turnkey drone systems will increase as farmers and service providers work within the FAA small UAS rule constraints for commercial operations. However, the big caveat is that drone usage alone will not “transform agriculture” just yet. For that, we would need to see a change in the adoption rate for variable rate technology (such as applicators)

Key questions for agricultural drone service providers

- What's the incentive for a farmer to adopt a new imaging technology when most farmers in the U.S. don't use what's available to them now and dealers countrywide say it's not profitable?
- How will drones change that equation? Why will farmers or crop consultants invest the money, time, and expertise analyzing UAS-derived datasets if they aren't doing the same with the manned aircraft or satellite-derived data they can already purchase?
- How will UAS service providers convince farmers that their data is more valuable, more actionable, and has a high ROI when so many farmers seem to be relatively uninterested in data in the first place?
- Are farmers prepared to adjust their field operations and personnel to be data driven, and how will they make this happen?

— which is currently down as reported in the book [Precision Agriculture Technology for Crop Farming](#). An [earlier USDA report](#) confirms:

“Despite the potential for improved production efficiency, farmers have been slow to adopt variable rate technologies, and the expected impacts on farm structure, employment, and environmental quality have not been fully realized. Research suggests that low adoption rates may be due to uncertainty about the economic returns from large initial investments in precision equipment, the complexity of these technologies, and the need to make integrated use of several precision technologies to obtain cost savings.”

So, if you are banking on precision agriculture drone data services, you will continue to see competition from incumbent satellite and manned aircraft data service providers and slow adoption for now.

What's next for drones in agriculture

With the total value of our nation's crops estimated at \$212 billion per year, even a modest improvement in yield would have a substantial aggregate economic impact. However, it's not yet clear how a UAS can deliver more usable information to a farmer or provide a cost benefit over the existing image solutions available to them today.

What seems to be missing from today's drone data service providers is the expertise to interpret the data, verify it with what is actually happening in the field (aka “ground truthing”), and recommend a course of action. Services that deliver aerial imaging can provide the data, but someone needs to invest the time, money, skills, and software to get actionable insight from it. Right now, it appears that's not being done well by the dealers who already offer imaging from satellites and manned aircraft. What's not clear is how that's going to change when they start offering imagery from drones.

Despite those issues, the technology used in agriculture drones and aerial imaging processing is progressing rapidly — more rapidly and at lower costs than satellite or manned aircraft. For example, the four major players of drone image sensors today, [MicaSense](#), [Parrot](#), [Slantrange](#), and [Tetracam](#), are working to tackle the concerns over the lack of calibrated imagery from drones. Calibrated imagery provides the added value of monitoring crop changes over time. They are also working to solve the issue of images taken with cloud cover and differing sun positions. In a perfect world, data would come from a sensor with RGB, various light bands, and an ambient light sensor. Keep your eye on this space for more innovations.

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