SPECIAL REPORT

FROM THE EDITORS OF CropLife
PRECISION Ag PROFESSIONAL

Making Sense of **Sensors in Agriculture**

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For agriculture service providers, evolving sensor technology is viewed with a sense of endless possibilities, mixed with a bit of trepidation.

Sensors can seemingly do about anything on the farm. Measure soil characteristics with electrical current? Check. Monitor soil moisture and irrigation activity? Check. Track rainfall, wind, and other weather conditions? Check. Transmit data points 24/7 to a central database for deep analysis? Check. Report on planting, application, and harvesting efficiency? Check. Ride on a drone or a satellite and provide in-season feedback on crop and farm conditions? Check.

Become one of the farmer's trusted advisers? Uh, not so fast. Sensor capabilities are robust and growing, but not likely to replace "boots on the ground," at least for the foreseeable future. The better bet is that sensors will allow agronomists and consultants to help farmers make better decisions, and invite contributions from equipment and seed dealers who provide vital advice and services to the farmer.

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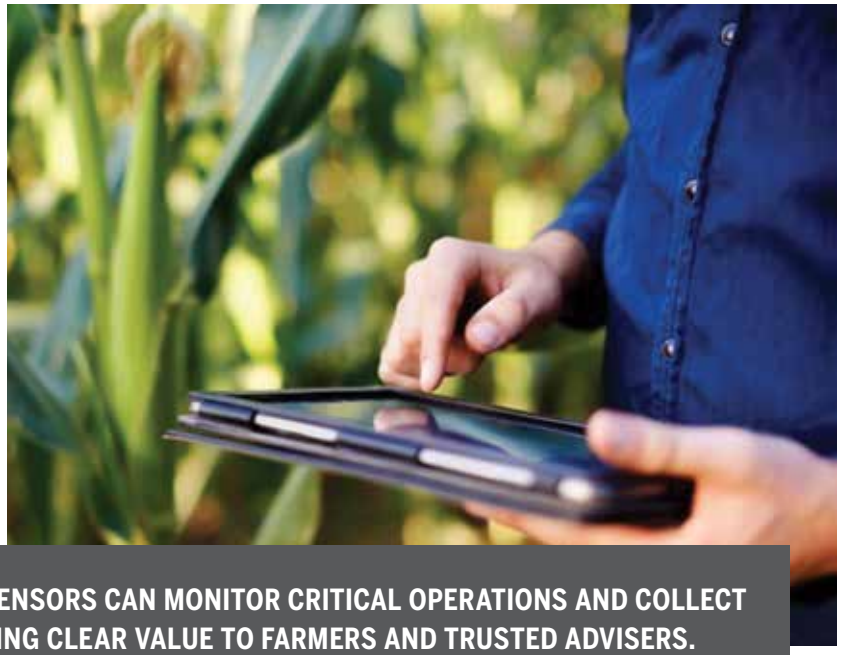
Sensors On The Ground: **A Network of Knowledge**



COORDINATED, GROUND-DEPLOYED SENSORS CAN MONITOR CRITICAL OPERATIONS AND COLLECT MASSIVE AMOUNTS OF DATA, PROVIDING CLEAR VALUE TO FARMERS AND TRUSTED ADVISERS.

SENSORS ARE CERTAINLY nothing new to agriculture. Although they are getting more and more robust, on-board sensors have been providing feedback on the operation of machinery for many years. Liquid tank monitors on bulk chemical tanks have been tracking quantities and sending out the call to manufacturers for refills for a decade. Weather stations have been positioned all across rural America and collecting vital data for some time.

But the advent of wireless connectivity through cellular bandwidth has been a game-changer. Sensors collect data and continuously report back to a data storage receptacle in the cloud, increasing both the quantity and the virility of the data. Phone apps and laptop dashboards pull in data points and provide an easy-to-understand interface that provides feedback in a clear, understandable way.

SENSORS IN A SYSTEM

One organization that has worked to push forward as fast as possible on sensor data is Farmers Edge.

"For us, our product is really decision support," says Ron Osborne, Vice President of Innovation. "We combine a lot of disparate data into our farm command platform, and that data is the underlying information that we use to create analytics and help farmers make decisions."

Sensors are interspersed throughout the system, and ground zero for data is really the ground. It starts with good, old-fashioned soil sampling with a guy out on a quad or truck pulling cores. Then it gets more interesting.

Farmers Edge maintains what it calls supersites, where weather stations are connected to soil moisture probes and other types of sensing technologies, monitoring characteristics such as nitrogen, moisture, and electrical conductivity.

"We have to connect sensors to weather stations, so we try to consolidate the systems into one data transport layer through the cellular backhaul of the weather station, or through a 900-megahertz network we deploy," explains Osborne. "In that case, we are combining soil information with weather information."

The challenge is in the placement of sensors at a farm location that is safe from field activities, but close enough to provide accurate, meaningful data about that particular farm field. "It's a fine balance to find that location, make the installation, and calibrate it," says Osborne.

Thousands of Spectrum- and Davis-branded weather stations have been deployed for Farmers Edge, and the system continues to get more robust, he adds.

Farmers Edge also offers machinery data collection via a proprietary telemetry package that is installed on field equipment. "We have about 12,000 machines around the world equipped with our system, encompassing about 90 different equipment brands," says Osborne. Machines stream in data and provide valuable information on dozens of different field and machine values in real time.

At the end of the day, for Farmers Edge the key pieces of data are soil chemistry, field activities, variable-rate seed, fertilizer, and yield data. And machine info is as important as data files, as it helps the farmer understand and improve productivity. Mix in satellite imagery to help create and manage zones and monitor in-season crops, and Farmers Edge believes it has the closest thing yet to a complete precision package.

"I think we found a sweet spot," says Osborne. "Scalable technology combined with on the ground experience — that is what farmers need."

IRRIGATION CONTROL

Existing ag technology manufacturers as well as a slew of newcomers to the industry have rushed into the sensor business in hopes of delivering the next big thing for agriculture. One area that's developed rapidly in response to con-

IRROmeter's IRROmesh soil monitoring sensor.

cerns about water availability and quality has been irrigation.

Wireless telemetry and improved soil moisture and weather monitoring have led to the development of a number of systems for farmers and professionals with responsibility for irrigation. Irrigation pivot manufacturers have led the charge in developing the base systems, and one of the leading decision-facilitating dashboard tools is Field Commander from AgSense.

In its most robust form, the Field Commander package allows users to remotely monitor and precisely control center pivots and pumps, along with monitoring flow, pressure, and weather, says Steve Sveum, Vice President, Sales and Marketing. Capabilities include variable-rate irrigation and custom prescription programming, and soil moisture monitoring can also be added.

IRROmeter, another long-time player in the ag irrigation industry, recently introduced a solar-powered wireless soil monitoring system called IRROmesh. Capable of in-field measurement of soil moisture, temperature, and other parameters, sensor data from each system node is routed through an interactive mesh network, then centralized to the web for uploading to a PC or mobile device.

The payoff for irrigation control has proven out, says Tom Penning, IRROmeter's President. "The benefits of irrigation scheduling based on proper interpretation of soil moisture data are primarily increased yield and quality," he explains. "Other influences are water savings, labor savings, fuel savings, fertilizer savings, and pest and disease mitigation. Typically most users find the equipment cost recovered in the first season of use if using manually read devices. If automated data collection is involved, then the return on investment takes a little longer."

Sensing in the Bin

Aside from field and equipment-deployed sensing, the other end of the spectrum is sensing in the grain bin. From the perspective of the local cooperative storing and marketing its grower-customers' grain, success here is absolutely vital in keeping that relationship copasetic.

That's where IntelliFarm's 3G Plus Cable sensors and its BinManager system can be leveraged to demonstrate a higher level of service on grain storage, according to Todd Sears, President.

"BinManager uses the temperature and moisture readings coming off the 3G Plus Cable sensors to automate when and how long the fans and/or heaters run to move the grain toward temperature and moisture targets set by the user," Sears explains."The system takes on that decision-maker role."

Another aspect of this grain management ecosystem that should be noted is IntelliFarms' SureTrack platform, which Sears describes as a "facilitator of communication between the growers and cooperatives."

"With growers' consent, readings from the growers' grain bins can be shared with the cooperative," he says. "The cooperative can't manage the grower-owned bins, but with the ability to see what quality and quantity of grains are across its grower base, it can anticipate supply gaps and make business decisions."

It's all part of a well-rounded, grower-focused effort from the service provider to help manage as many aspects of the operation as the grower-customer will allow.

"Technology like these sensors is helping to connect the dots between how the seed you select will not only perform in the field under certain conditions, but also how they can be stored for quality, and ultimately, meet premium requirements," Sears says. "The end goal is always to help growers produce a safe, quality product."

BIG PLANS FOR IOT

Relatively green Internet of Things (IoT) player infiswift is in the midst of its sophomore campaign after the Bay Area-

infiswift's diagram of IoT sensor networks at the farm level.
(Graphic source: infiswift)

based enterprise solutions provider incorporated just over a year ago.

Will Shippee, Senior Director of Sales and Business Development, says the company at the moment is focused on working with OEMs and technology providers in the agriculture vertical. (Infiswift also has customers in the distributed energy field.) Its IoT platform and professional services for precision farming is an "umbrella" for all of its work within the ag industry.

Will Shippee

"We're a technology enabler," Shippee says via phone from the company's San Ramon, CA, offices. "Let's say, for example, a sensor manufacturer comes to us, it doesn't matter what they're measuring, be it pH, soil moisture, or whatever it may be.

"So, they come to us and they say, 'We want to drive a new generation of connected sensors, where we can have from two to 2,000 of these sensors out in a field, and we want them to communicate amongst each other, but also provide various controls, functions, or rules combined with other technologies, say flow pumps or other hardware devices out there.'

"What we would do," he continues, "is we'd evaluate exactly what those requirements are that the customer wants to achieve, and then we would work with them to ad-

vise the right hardware — this can be a printed circuit board and a chip that's the size of your pinky nail — and that will be deployed amongst each sensor to enable not only the communication between these sensors, but also our embedded software-stack, logic, and business rules that are unique to what the customer wants to achieve."

Infiswift sees the precision agriculture market currently in the midst of a shift in capabilities, from Precision Agriculture 1.0 (cloud-based storage, datalogger and cell modem-enabled data transfer) to the oncoming Precision Agriculture 2.0.

"What we want to do is break down a lot of those data silos. Rather than relying on capturing data and sending it up to the cloud via cell modem, let's apply unique, IoT-based solutions to the problem," Shippee argues.

By applying in an MQTT-based (lightweight messaging protocol) solution around the data, devices can share the data or send it to the cloud depending on what the user requires. Shippee says this MQTT protocol approach allows infiswift to drive down computing power requirements and associated costs while driving up communication capabilities in low-bandwith areas.

"If you're pulling data from one type of sensor and you really want that to be integrated with, for example, a meteorological feed from NOAA, we're able to then pull that data in from that third-party server and then provide your own cloud-hosted architecture. From there, you will be able to pull in that third-party data along with the data you're generating in your own operations, and drive actionable data off of that.

"We don't want to just give you ones and zeros, we want to give you actionable data that results either in an efficiency increase or some kind of cost savings."

Although Shippee declines to name specific companies in agriculture that his outfit is working with at this time, he agrees it's situations such as are found in his home state of California, where a statewide farmworker minimum-wage increase has producers antsy about the future, that will drive operations to look more closely going forward at the adoption of automation.

"That really dives into the broader need to increase efficiency in the face of a lack of resources, and a lack of eyeballs on an operation," he says. "The question is, do you have John go jump in his pick-up and check on X, Y, and Z, and then radio back if it's good? Or do you take that operational knowledge and apply it to those needs, automate that process, and then drive learning off of that moving forward — so John can spend his time managing other things?" ■

EC Gains Momentum

Veris' electrical conductivity (EC) system for grading soil types has endured for years on the strength of its true believers and slow, steady growth. Used as the foundational test for zone management schemes, Veris has gained users with the increasing popularity of zone management, coupled with the expansion of the system's capabilities.

Veris also gained a nice market boost last August when it announced a partnership with The Climate Corporation. High resolution soil maps from Veris on-the-go soil sensors are now a key data layer for the agronomic models in the Climate FieldView platform.

"Lots of folks know us as the EC technology," admits Tyler Lund, Director of Sales and Marketing, "But now we can provide data on organic matter, and on the go pH — it's a more complete view of the character of the soil in a field."

As zone management increases in popularity, and input costs continue to increase, Lund says it's critical for agronomists and consultants to have as deep of an understanding of the soil as possible. "When you're talking to the farmer about his fields, you have to be able to tell the difference between high-and-low performing areas of the field, and make the right recommendations about hybrids and varieties and seeding rates," says Lund. "If your discussion doesn't match up to the farmer's experience, they won't have faith in your recommendation. Veris data makes it possible to manage zones and variability effectively."

In The Air:
Doing It With Drones

HOW SERVICE PROVIDERS CAN LEVERAGE SENSING TECHNOLOGIES

FROM THE SERVICE PROVIDER standpoint, getting into the aerial imagery as a service game was once an either/or proposition: Either you partner locally with a fleet of aerial application planes for weekly fly-overs with a sensor payload, or you purchase a subscription as a provider of one of the many satellite-based imagery programs out there.

And it should be noted that there is — and remains — nothing inherently wrong or less effective with plane- or satellite-based aerial imagery services. In fact, for some situations where economic scale (i.e, 1,000-plu acre fields) or weather issues (high winds) make drone flights a tough day-to-day prospect, those methods of sensing can oftentimes prove preferable.

Yet with the ongoing advent of dramatically cheaper, easier-to-use unmanned aerial vehicle (UAV) technology capable of conveying agronomically powerful, real-time sensing technologies from the edge of virtually any field (or the bed of a pickup), at any time, almost anywhere (drones don't have to be "tasked," or scheduled days or weeks ahead of time, like satellites or manned craft), it can't be denied that there is opportunity for service providers to integrate drone-based imaging to demonstrate a higher level of service with grower-customers.

Sentera's Double 4K sensor enables NDVILive.

SENTERA'S NDVILIVE

Back in early-January, Sentera, a Minnesota-based ag tech startup that outfits UAV platforms with professional-grade sensing technologies, announced its newest advanced sensing offering to the precision farming market: livestreamed

Back On the Map: Satellite Imagery Emerges as a Valuable Tool

For many years satellite imagery was a solution in search of a viable precision agriculture system in which it could deliver value. In-season, on-demand imagery was often hampered by cloud cover and a dearth of available satellites for taking images. Until recently, as a stand-alone tool it hadn't carved itself a stable and consistent place in the crop production regimen.

Over the past decade, the number of satellites has increased significantly, improving the quality and frequency of the images available to agriculture. Planet Labs, which purchased BlackBridge and its RapidEye satellite constellation, is supplying Wilbur-Ellis and Crop Production Services with imagery to support their precision programs.

Planet also delivers satellite imagery to agronomy/technology consulting firm Farmers Edge. Ron Osborne, Vice President of Innovation, says that while they're doing some work with UAV imagery — specifically with Canadian drones-as-a-service company Green Aero — satellite imagery makes more sense for their needs.

"Remote sensing utilizing drones is very labor intensive at the moment, and that's not likely to change in the near future in our view," says Osborne. "It's a tough business to get into given the regulatory restrictions, and also difficult to automate."

Imagery is only one component of a wider precision system for Farmers Edge, which includes soil testing, a proprietary telemetry package installed on field equipment, and in-field sensors collecting weather and field data. In the context of the total value proposition, the imagery is a strong supplement to the value offering to growers, helping to create management zones and providing in-season detection of factors such as crop health, drainage issues, and pest infestations.

DEERE DEALER IMAGERY OPPORTUNITY

John Deere gave imagery a go on its own in the 2000s with its John Deere Agri-Services division, but got out of the business in 2008. Its recent agreement with Satshot indicates there's emerging value to be captured. "What we have been offering the John Deere dealer network is the ability to rebrand our Landscout Normalized Difference Vegetation Index (NDVI) data visualization via the company's Double 4K Sensor, otherwise known as LiveNDVI.

The GoPro-sized Double 4K sensor integrates with either Sentera's Omni quadcopter or the Phoenix 2 fixed-wing drone (for larger acreage flights) and in-flight streams real-time NDVI data, which is used to measure and quantify plant biomass at various stages of growth. Agronomists or crop consultants on the ground armed with an internet-connected mobile device can then immediately use the visualized data for directed scouting services.

Greg Emrick

For context, most competing NDVI imagery systems typically require a 24-hour post-flight waiting period for the imagery to be geo-stitched in post-processing, after which point the image is pushed to the cloud and then delivered to the appropriate platform for visualization. Sentera has streamlined that somewhat cumbersome process by pushing most of the post-flight computing power and image-processing algorithms onto the sensor itself, rather than waiting to do it on a desktop back at the office). It's an emerging trend known throughout the IoT world as "edge computing," or as Greg Emrick, Executive Vice President, Business Development, describes it, "moving those (data) analytics upstream."

Emrick sees the new capability as an "efficiency and productivity improver" for the precision agriculture professional already tasked with serving and stewarding five- or oftentimes six-figure acreages on an annual basis.

"We're the only NDVI sensor producer that has the ability to process data on the sensor and produce a result in real time," he explains. "That allows those agronomists or consul-

imagery scouting IOS app with their dealership name and brand for use for their customers," says Lanny Faleide, Satshot President. "Many dealers want a solution with their name on it."

Landscout allows growers to analyze their fields from the latest or archived Satshot image of their field, and allows them to merge, attribute, and export the zones to the MyJohnDeere system directly to the machine wirelessly, even while in the cab.

"We will be acquiring imagery every five days or better in 2017 from various resolutions," says Faleide. "For example, a user can immediately analyze a field and time up a fungicide application based on biomass levels after the image is acquired. This allows Deere dealers to provide the most up-to-date sprayer crop information to handle this application."

Variable-rate seeding and nutrient maps can also be created by the user immediately based on crop health biomass analytics, he adds. This allows the user to do variable-rate applications at much more cost effective levels. "Using Landscout also allows all acres to be done by variable rate, not just a portion of their acreage," says Faleide.

"So far we have seen very good interest from the Deere dealers," he notes. "Many dealers are starting to add agronomy services within their framework, and this allows information to be paired with the machine."

tants to not have to walk the whole field; now they only go to the relevant spots that they need to look at, and it just reduces that time that it takes them to help someone make a decision."

Sentera's UAVs are currently the only drone-based aerial sensing platform that is fully API-integrated with John Deere and the MyJohnDeere Operations Center, and the NDVI data — usually spit out in the form of a heat map — can flow into myriad farm management information systems. Emrick lists SST Software, Ag Leader SMS, ADAPT-N, John Deere's APEX, EFC Systems, Farm Works, and Pioneer Encirca when asked for specific software platforms that will process the real-time NDVI imagery.

"That professional agronomist might have 25,000 acres annually under his advisement. Now with a UAV he can maybe double that amount of acreage, while still providing the same level of service throughout the season," he points out. "The other thing I think crop consultants will find is, there's a fascination with drone technology that will at the very least earn them an opportunity at the table with that grower."

MULTISPECTRAL WITH MICASENSE

Seattle, WA-based MicaSense also markets a drone-mounted, ruggedized sensor for precision ag professionals with its

A MicaSense Atlas-generated Chlorophyll map. Plants with a red tint indicate early stage symptoms of chlorosis.

RedEdge five band multi-spectral sensor. The RedEdge system consists of a down-ward-facing, 5 spectral band capturing sensor that mounts on virtually any drone, as well as a smaller, top-mounted and upward facing "irradi-ance sensor" that allows the post-processing software, in this case MicaSense's Atlas image processing software, to compensate for sunlight and reflections (which can cause false readings) in the imagery.

Gabriel Torres, founder and CEO, says the key difference in what a grower-facing agronomist or consultant can do with RedEdge imagery compared to your standard NDVI imagery is in helping the service provider see and quantify what's going on inside the plant, and then using that data (combined with tissue and soil sample data from the ground-truthed areas) to provide management recommendations that go far beyond what one can see with the naked eye alone.

"There are some limitations with NDVI – it's useful for mea-suring leaf counts and quantifying the amount of green leaves in the canopy, which is good for plant health status – but the combination of that Red Edge band, plus other multispectral bands allows us to generate ouputs that are indicative of chloro-pyll in the leaves," Torres explains.

That "snapshot in time" of plant chlorophyll content can be useful in many ways, including early identification of chlo-rosis, a deficiency of chlorophyll in the plant leaves that can signal a host of potential agronomic problems. The agronomic service provider armed with an Atlas-generated Chlorophyll Map can potentially base several management decisions off the data, according to Torres.

"We can use that data to guide nutrient applications – chlo-rophyll content is much more closely correlated with nitrogen uptake than NDVI alone, and so for cropping systems using variable-rate nitrogen it is a more accurate way of determin-ing which parts of the field are likely to need more nitrogen and which areas won't."

Torres, is quick to caution that RedEdge imagery data is "not a magic wand" and the role the agronomic service pro-vider plays in the data interpretation and subsequent decision making process will continue to maintain value, even as sens-ing technology increases in artificial intelligence, and auto-mation going forward.

"I think it's important for service providers to understand the technology in general goes beyond drones and beyond sensors, the value is in the combination of the ability to cap-ture multispectral data with a good quality sensor and with the proper workflow that correctly optimizes and processes the data, and then that is combined with the expertise of an agronomist or crop consultant who can generate a prescrip-tion or action based off the data that we provide. That's where the true value proposition comes into play." ■