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The No-Till Authority Since 1972

Special No-Till Management Report No. 60

Banking on Progressive Precision Practices to Improve ROI

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Capture the Benefits and Minimize the Burden of Ag Tech

Technology has come a long way in simplifying the way no-tillers navigate fields, plant seed and apply fertilizer. But precision technology is also more complex than ever, creating a push-pull split between cautious optimism on the promise of robotics and autonomy and the challenge of turning collected data into calculated decisions.

It's a transformative time to be sure. Long gone are the days when auto-steer was a just a novel new technology. Today, most farmers wonder how they ever managed without it.

Will the same be said in 15 or 20 years about small-scale remote control planters or sprayers running 24/7 in the field? Time will tell.

Before we get too ahead of ourselves with next generation technology, it's worth reflecting on how the industry got to where it is today and why it's headed where it is tomorrow.

No-Till Farmer editors crunched the numbers on 10 years of data from our Operational Practices Benchmark study. In addition to cropping rotations, fertilizer application strategies and economic evaluations, the report also looks at no-tillers' adoption of precision farming technology.

Nearly a decade's worth of precision adoption analysis revealed some interesting trends that concluded precision equipment is being purchased and utilized by more *No-Till Farmer* readers today than ever before.

✔ Taking the place of lightbars for many farmers is tractor auto-steer. While only 34% of *No-Till Farmer* readers used that technology in 2010, some 60% of no-tillers now use tractor auto-steer.

✔ Field mapping has become far more popular with 36% utilizing the technology in 2010, compared to 55% in 2019.

✔ There has been considerable debate regarding the tangible payback of variable-rate, but no-tillers are buying into the value. Variable-rate seeding increased from 14% to 32% since 2010, while variable-rate fertilizing jumped from 27% to 45%.

✔ Use of satellite aerial imagery has more than tripled since 2010, from 8% to 27%. This is bolstered by the majority of no-till benchmark study respondents utilizing yield monitor and data analysis, 56%, as of 2019.

Precision adoption is trending upward among no-tillers nearly across the board, which would indicate that not only are they seeing a return on their investment, but they are willing to push production and profitability by embracing technology, not avoiding it.

Within the 48 pages of this report, you will get perspective and direct experience from other no-tillers, strip-tillers, researchers and industry experts on how current precision tools are paying off and how to prepare to make the most of the innovations of the future.

Sincerely,

Jack Zemlicka, Technology Editor

In This Special Report:

NO-TILL FARMER — The No-Till Authority Since 1972

Produced by *No-Till Farmer*… Serving no-tillers since 1972.

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Digging Into the Definable Value of Precision Farming Data Analysis

Knowing the 'how' and 'why' of data collection practices are essential to analyzing information and making agronomic decisions.

By Diana Dombrowski

Jeremy Wilson takes logging data, and using it to make decisions, very seriously and has perfected it over the years.

As a no-tiller in Olney, Ill., and senior vice president, field data solutions at EFC Systems, Wilson has learned how to effectively leverage technology in data collection and how important it is for his operation.

Importance of Data

Simply put, data "gives us the necessary information for analytics and reporting," says Wilson. He started logging data with his dad, Wade, on their 1,200-acre grain farm when they began using their first yield monitor in 2001. Until that point, they logged bits and pieces of data but never had the solid foundation to make decisions based on it.

Building a history of data over time makes the data more useful, but building the foundation has to start somewhere. Reporting to crop insurance agents or the FSA, or tracking manure management plans, are just a few situations where Wilson says data is important.

He uses data he collects to understand the agronomic changes on his farm. While he says they don't make a lot of major farm management changes, the data does help them look at many different things to make tweaks.

"It may be something as simple as a different post-applied product," he says, noting that accurate data allowed Wilson to make sure the Liberty Link system for soybeans he uses for weed control was the right decision.

"We used planting data, herbicide application data and yield data to compare the Roundup Ready system to the Liberty Link system in soybeans," Wilson says. "We compared seed cost and herbicide cost to yield. This comparison showed the profitability from each system was equal."

He uses yield data for fertilizer applications, except for wheat. Wilson grows wheat for his recreational cattle, in addition to corn and soybeans, and if yield data shows he had an extremely good wheat year, and soybeans before wheat were also good, he will sometimes apply potash ahead of double-crop soybeans.

Accurate data may have even further-reaching implications aside from helping farmers make educated deci-

FINE-TUNED FARMERS. Olney, Ill., no-tillers Jeremy Wilson (l) and his dad, Wade, have long utilized precision farming strategies on their 1,200-acre grain farm, starting with a yield monitor in 2001 and advancing to variable-rate seeding and fertilizing.


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sions. Wilson believes that one day the value of his land might be higher because he has documented results of productivity. He sees the database management tools offered today that can forecast what land is worth. "I'm building my database already. I don't need someone to guess for me," he says. "I can already tell you I've got 10-12 rock solid years of data that I can document to any person who wants to purchase the land I've got for sale what the productivity is. I've got it documented."

Calibrating ROI

Data calibration is an underutilized tool but it's very important to make proper management decisions, Wilson says. "Uncalibrated data might as well be left on the field," he says.

He adds that collecting calibrated data is the most valuable resource in making agronomic decisions. "If you're not collecting calibrated yield data, you've just left the most valuable resource laying on that field that we never have a chance to pick back up," he says.

While there is no way to go back and recreate the calibrated data, Wilson says it's possible to back into the yield information using uncalibrated data. He lists yield and variability as the measurements he works hardest to gather to address any variations in the field.

To get the most accurate data possible, Wilson says it's important that all people within a farming operation have as much commitment to data collection as they do to a hydraulic drive on your planter.

Operators should also call farm owners as soon as they see something that looks wrong. "What's out of the ordinary? That's wide open," Wilson says. "In the case of planting, if you see a swing of 3,000 seeding population, give me a call."

In addition to calibrating data at the start of every season, Wilson says no-tillers should do the same when there are extreme changes in crop or planting conditions.

Recalibrating when changing crops is also important. It may seem like common sense, but Wilson is surprised by the number of growers who begin to collect data without recalibrating, only to realize the mistake after it's too late.

"It just blows my mind how many times we have the most beautiful corn data you have ever seen in a million years and we get to soybeans and it's the biggest pile of junk you've ever seen," he says. "And it's just from the fact that we only calibrated the monitor for corn. It makes a big difference."

Wilson's Ag Leader InCommand 1200 allows him to retire calibrations when necessary. "When I have a calibration that looks like it's kind of out of line and maybe not right, I'll normally go to my existing calibration and add one load to it and look at what the error is and make a decision."

If the error is 5% or more, Wilson says he retires the entire calibration. Retirement, instead of deletion, it is a safer option as old data may still be associated with it.

Wilson estimates that he has retired a calibration every year in the past 3 years. Before that, Wilson says he ran the same calibration for about 3-4 years. "In some of these monitors if you get too many calibration loads in them, it's going to cause you problems," he says.

> *"Uncalibrated data might as well be left in the field..."*
> *— Jeremy Wilson*

Making Informed Decisions

Before Wilson makes decisions based on data, he wants a substantial amount of it first. He suggests having 3 years worth of data before starting to evaluate it, and 6 years of data before using it to make decisions.

"Looking at data more than 6 years old doesn't always make sense," Wilson says. When looking at spatial trends, he only looked at the past 6 years of data instead of the 12 he had documented.

"I looked at every bit of yield data and it told me it looks the same whether I use 6 or 12 years," he says. "I just went back 6 because in my mind, hybrids and varieties have changed a lot in 12 years, I've changed some cropping practices and I've done some different things in my no-till approach on some vertical tillage."

ACCESSIBLE STORAGE. USB sticks, personal computers and cloud-based tools are viable options for storing data. But whichever data storage method is used, Jeremy Wilson says they are all important in providing a place to store and catalog data.

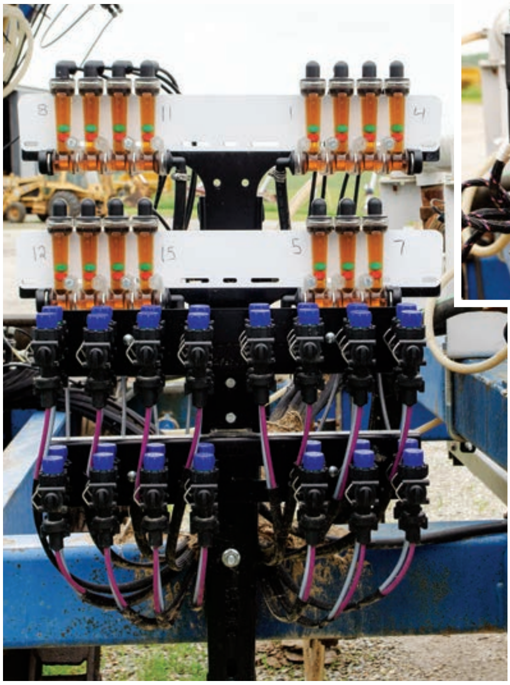
Using the past 6 years of data allowed Wilson to identify the yield potentials of each area of his farm. On Wilson's farm, he uses advanced planter monitoring data for analytics and reporting.

"We do a lot of work in the elevation layer for water management, pulling that primarily from planting data or harvest data," he says. Since weight increases on the hopper and the tires sink, his harvest data is not as good as his planting data, he says.

Wilson records all of his crop protection applications for reporting. Wilson says he uses cover crops on about 75% of his farm, which he also tracks for analytics.

He also uses scouting data for crop protection application recommendations, primarily when cutworms are present. "It seems like it's not really a question if we're going to have to deal with cutworms. It's how many," he says.

However, the data usually tells him that widespread insecticide application isn't financially justifiable. "It's always a smaller situation we have to deal with, but we'll use these scouting reports to drive applications of insecticide and then occasionally replant as well to touch up what we've lost," he says.



ALL SYSTEMS GO. Adding variable-rate technology and conducting field trials have become valuable data sources for Jeremy Wilson, both on the seeding and application side of his 1,200-acre operation. "We have done 3 years worth of nitrogen trials," Wilson says. "On average, we're seeing about a 14-16 bushel yield advantage by spoon feeding another pass of N at V8 to V10 stage."

Planting data helped Wilson understand corn hybrid selection and testing those varieties proved to produce higher average yield on his farm. One with the lower yield — 21 bushels lower — was sold to Wilson as "the next up-and-coming rock star," he says.

He thought this particular new hybrid would yield 20 bushels more than the one he was already using. So he split planted the hybrid they had been using with great results for 2 years in anticipation of the new one being less effective than they hoped.

"We wanted to get it across multiple soil types so we properly positioned that hybrid because we anticipated for this," he says.

"On average, we're seeing about a 14-16 bushel yield advantage by spoon feeding another pass of N at V8 to V10 stage..."

Anticipating Application Needs

Wilson starts every year planning on at least 3 applications of nitrogen (N) during the growing season. He uses spring-applied diammonium phosphate (DAP), since it has the cheapest N available.

Most of the time, he also uses a starter fertilizer along with a pre-plant anhydrous ammonia application. "We just used the variable-rate anhydrous in most cases to even out our variable-rate DAP application," he says. "So when that toolbar pulls out of the field, I've got an even rate of N across that entire field."

Sometimes data doesn't always give a definitive answer to make a decision. Wilson did a research trial on N stabilizers, comparing no stabilizer, N-Serve and Nutrisphere-N from Verdesian. They had already switched from N-Serve to Verdesian throughout the entire farm.

Wilson ran soil tests throughout the summer, but the weather was perfect that season and all 3 showed similar results. Though he wasn't able to use the data to make a decision between the two N stabilizers and using none, he kept all the analytics because soil tests didn't show a good reason to throw them out.

Wilson says his dad is a minimalist when it comes to N. "We have done 3 years worth of N trials," Wilson says. "On average, we're seeing about a 14-16 bushel yield advantage by spoon feeding another pass of N at V8 to V10 stage."

Data has also shown Wilson the temporal stability of his farm. This tells him the likelihood that the yield will vary. Using the mapped out data, he knows exactly where the most stable parts of his farm are.

Looking at spatial trends and temporal stability together, Wilson sees the areas that are above and below average yield and whether or not they are stable. Looking at these together, he can see the area where he has a water issue.

The data has shown him that some areas of his farm have always been low yielding no matter what he has done. "I've got areas of this field that the economics for planting corn today tells me don't plant corn because it is saying I am always well below average and I have a stable yield," he says. "So everything I've thrown at that field has not made a difference. It's always been low yielding."

When Wilson saw his data revealed 90% of yield drag came from the outside 24 rows of his field, he decided not to plant the outer 24 rows anymore.

He calculated that while planting those outer 24 rows he lost $54 every acre. "If I put that in CRP (Conservation Reserve Program), earn $147 an acre give or take, I don't lose $54," he says. "I've just thrown $210 profit back to that farm per acre in those 5 acres I take out."

Proper Storage

USB sticks, personal computers and cloud-based tools are all viable options for storing data, Wilson says. He lists AFS Connect, AGCO Fuse Technology, Ag Leader, AgFiniti and ClimatePro as just a few cloud-based options.

Whichever data storage method used, Wilson says they are all important in that they provide a place to store and catalog data.

"These systems allow us to share data to their trusted service providers who can be more than input crop suppliers," he says. "Maybe it's a crop consultant or even your equipment dealer, but that data needs to be shared."

Wilson chooses to share his yield data, but he also chooses to give trusted advisors most of his hybrid and variety data. He says to make sure the terms and conditions are clear before using a cloud-based system.

Data privacy conditions are not the same among the different systems. Mobile applications for data are growing as many people shift to cloud-based analytics, he says.

Banking on 'Brainware' Puts No-Tiller on Pathway to Improved Precision Performance

A properly outfitted strip-till bar, RTK guidance and self-propelled sprayer help Cade Bushnell tap into the mechanical and analytical potential with his 1,300-acre operation.

By Ian Gronau

As Stillman Valley, Ill., farmer Cade Bushnell rolls out newer technology on his 1,300-acre farm, he's had a lot of success with mechanical alterations.

But one areas he's struggling with is tapping the potential of precision data, especially analyzing data pulled from equipment to make more informed adjustments to his operation.

"The amount of data we're generating and have generated over the years requires a lot of time and energy from someone to go through," says Bushnell. "Quite frankly, I don't do a very good job of it. I'm a farmer because I enjoy raising crops, not because I enjoy sitting at a computer."

Despite this, Bushnell is a great believer in bringing precision technology, new implements and farm management changes to the operation. He even has a personal philosophy on the rate at which farmers should be adopting technology.

"We really need to be using all the technology that's available," he says. "I don't want to be the first person to get it, but I don't be the last person to get it either. I want to be an early adopter, but not a pioneer. Pioneers are stuck working out all the bugs. But if you don't adopt early enough and use the technology, it becomes standard and then you're at a competitive disadvantage with your neighbors."

Going Strip-Till

This philosophy led Bushnell, in part, to break from a history of strictly no-tilling when he made a transition to strip-tilling continuous corn. The change was mostly to improve soil health on several fields with low levels of organic matter.

LEARNING CURVE. Strategies Stillman Valley, Ill., farmer Cade Bushnell uses to get the biggest return from his erodible and low-organic-matter soils include paying close attention to residue management and using precisely timed and calculated nitrogen (N) applications during the growing season. The changes he's made have been worth the effort, he says, as he's averaging 200 bushels per acre on his strip-tilled corn-on-corn fields.

Some of his fields had organic matter content as low as 0.7% dating back to 1962, and it's taken nearly 50 years to boost those levels to about 3.5%. He uses an 8-row Dawn Pluribus coulter strip-till rig exclusively for corn-on-corn.

"I still no-till all my soybeans and corn following soybeans," he says. "I'm at about 80% highly-erodible land (HEL) so I've got a lot of erosion potential. With the low residue left over from the soybean crop, I cannot strip-till and avoid the erosion."

Two other strategies Bushnell uses to get the biggest return from his erodible and low-organic-matter soils are paying close attention to residue management and using precisely timed and calculated nitrogen (N) applications during the growing season.

The changes he's made have been worth the effort, he says, as he's averaging 200 bushels per acre on his strip-tilled corn-on-corn fields, which is comparable to his no-tilled fields. In addition, he's seeing more consistent stands with strip-till, which he attributes to planting into a cleaner seedbed.

The system also lets him reap the soil-enhancing benefits offered by leaving residue on the surface. As he's upgraded equipment and looked into changing strategies, though, he's found he needed assistance from his dealership.

Technical Difficulties

Owning the right equipment for the job is only half the battle for Bushnell. The other half is making sure it's set up in a way that makes the most sense for his operation.

For instance, a planter that comes preset to plant in a tilled environment will need modifications if it's to be successful on his fields.

"If the planter is set up for a tillage-only environment, occasionally you're going to go off the strip," says Bushnell. "I'm using Martin closing wheels, John Deere single disc fertilizer openers and Dawn residue movers. They're nice and heavy. Also, in a strip-till environment, the closing chains pull the furrow shut a little bit."

Equipment guidance is also crucially important, especially since he's using an 8-row strip-till bar matched to a 16-row Deere 1760 no-till planter. If fields were perfectly square, guidance is less of a problem, but this is hardly ever the case, Bushnell says.

"I use RTK extensively because I don't have square fields and I'm not that good of a driver," he says. "With RTK I'm probably on the strip 99% of the time, but I go off on the headlands. It's the corners that raise issues. Even though my strip-till rig is a coulter-style machine, it does not like to turn a corner. It's worse than pulling a planter around a corner. It's on the three-point hitch too, which makes it even harder to go around."

Solid Base

Even though RTK is nearly ubiquitous now, especially among strip-tillers, Bushnell recalls a time when a request for increased accuracy was largely ignored.

> ***"I'll spend $20 an acre on a late-season foliar application to make an extra 90 bushels of corn…"***

"I'm using Deere's GreenStar system because that's what I started with," he says. "I have my own base station now. A decade earlier though, I went into the dealership and I said I was having trouble with accuracy even though I wasn't strip-tilling at the time.

"I wanted to buy a base station and they said, 'What the hell do you want that for?'

"Talk about short-sighted. Now they have domes and base stations all over, so times have changed as farmers continue to demand a lot more accuracy."

Accurate guidance isn't only important for lining the strips up with the planter though. If a farmer is applying N through his strip-till bar and planter, as Bushnell does, failing to place seed at the appropriate distance from the band will negate the whole effort.

"If I'm off the row, I'll take a huge yield hit," he says. "If I get 8 inches away from the N, it might as well be 2 feet. The N needs to get to that young plant as it's growing."

Bushnell also has Deere's passive implement steering system set up on his planter to help keep it in line. He notes that the steering, overall, works great and gives him added control, but occasionally gives him issues on curves.

After getting closer to where he needed to be with accuracy, Bushnell started upgrading section control systems on various implements. He was pleased with how quickly the systems paid for themselves.

"Swath control doesn't end up costing anything," he says. "It saves me money. It only took me 2 years to pay for my first swathing upgrade, which cost about $6,000. If only I could get a payback that fast on everything. I have swathing on the planter, the sidedress bar and the sprayer."

Bushnell rounded out his planter's precision hardware by installing Precision Planting's vDrive system. "I added the systems and they've been doing an excellent job," he says. "There are no chains, no shafts and no bearings. Their row shutoffs work great and I'm using it on the planter to record hybrids as well."

In 2018, Bushnell furthered his precision investment on the planter to increase application accuracy and harvest more field data. He added Precision Planting's DeltaForce automatic down force control, vApplyHD row-liquid control and SmartFirmer sensing technology.

Another important modification he's made is to his combine. Because his task is to raise soil organic matter, residue management is crucial and that starts at harvest, Bushnell says.

"It's been extremely important for me to use Calmer BT Choppers on the head," he says. "I used to have a lot of issues with plugging when I'd get a long stalk in the strip-till bar and it would catch a lot of residue because 200-225 bushel corn is a lot to flow through.

"The head has done a nice job processing it because the stalk-roll processing is not a lawnmower. It doesn't redistribute residue evenly across the field. It concentrates it in that old corn row so I have a lot to sweep out of the centers of the row."

Problem-Solving Precision Pain Points

No-Till Farmer interviewed farmers from across North America to find out what their biggest point of pain is when integrating precision farming technology into their farm operations.

Q: What is your biggest point of pain with precision farming technology, and how are you working to overcome this challenge within your operation?

Cade Bushnell, Stillman Valley, Ill.: "There's no question that my biggest point of pain with precision farming is analyzing the data. Filing it, being able to access it easily, being able to sit down with the specialist and go through it. It just takes time. The biggest pain is the time. By the time I'm done with harvest, we've generated reams and reams and reams of data. But the real push comes to shove when I put that together with my harvest data. It's just time, time, time and time. I'm a farmer. I use a computer like a hammer. Some people are in love with computers and will spend an hour designing a spreadsheet for something I could do in 15 minutes by hand. I'm just not that kind of guy. I'm a nuts and bolts guy. It's the specialist's job to analyze the data and devote the time to it."

Mark Richards, Dresden, Ont.: "My biggest point of pain is teaching the older generation how to run this stuff on my farm. I kind of say that tongue in cheek, but generally, that is the biggest pain I have. The same goes for trying to get part-time operators up to speed on how to run it. Another point of pain is getting my operators to understand the importance of using the technology correctly and once they understand the importance, knowing how to get there and get it done without having to call me 3 times."

Willis Jepson, Orlinda, Tenn.: "I hope as time goes by, the industry standard will change to where that gets easier. But at the same time, each company wants me using all of its equipment so it's like I have to pick a road and pretty much stick to it. I've also got four sets of eyes looking at my farm data right now, including my dealer and my agronomists. I've been able to get all of them in the same room before to talk about how we're going to move forward and what we want to do. It's helpful when I can physically get everyone together and on the same page and say, 'Look, this is what we're trying to accomplish; this is why we're doing all this.' Ultimately, all of this has to make us a dividend. It has to help us make better decisions and it has to make money to pay for the effort and pay for the hardware and software and everything involved."

Bret Margraf, McCutchenville, Ohio: "My biggest point of pain is when I bring other people in for a day or a weekend to work on the farm. Sometimes it's even my dad. There are generational gaps. They have to be retrained. I make all the decisions and all the purchases when it comes to the equipment and technology, so I know exactly why I'm adding certain functions in a system to meet a need."

Sprayer Payback

Having the ability to react quickly to circumstantial changes is one of the main cases Bushnell makes for a farmer to own his own sprayer.

"I think everybody needs to own a sprayer or have a very cozy relationship with their sprayer operator," he says. "I need to be able to get in the field and treat with herbicides when weed problems pop up. I don't want to call someone and wait 2 weeks."

Seeing the potential of the worthwhile investment is what convinced him to purchase a Hagie sprayer, but crunching the numbers on the cost of custom application vs. his fertility program's goals is what really drove the idea home.

"The custom application rate in our area is about $8 per acre, which might be a little cheap. But for my strip-tilled corn I do a burndown, a herbicide application early post and a post-emergence application with Roundup. And I also use a lot of glyphosate and do a late-season N application on about 750 acres," he says. "That costs about $24,000, and I also do some foliar N application when we have a wet spring."

Bushnell says one of the fastest returns he's gotten from the sprayer investment is being able to make late-season foliar applications to treat wet spots in cornfields that are under N stress. While the application won't help break any yield records, it can "take 60 bushel corn and make it 150 bushels per acre," Bushnell says.

"I'll spend $20 an acre to make an extra 90 bushels of corn," he says. "But you have to be able to do it on a timely basis. The real advantage of owning a sprayer is controlling when and what time of day I make those applications."

Data Expectations

Bushnell sees a future in which the copious amounts of data pouring in from his precision equipment will enable him to make more and more real-time, crucial field-level decisions. The problem is understanding what message the data is conveying.

A self-described "nuts and bolts guy," he laments the amount of data he must crunch while coveting the practical information it can provide.

"There's no question that my biggest point of pain with precision farming is analyzing the data," says Bushnell. "Filing it, accessing it easily and being able to sit down with the specialist and go through it just takes time. By the time I'm done with harvest, we've generated reams and reams of data."

Trying to get a handle on using the data pouring in from all his implements, Bushnell frequently looks to his dealership for support. He says every time a dealership holds a training or education course, he attends even though his expectations aren't very high. He considers it a great success even if he walks out with one new insight.

He benefits particularly when dealers focus on what he calls "brainware," or when the training revolves around users' interactions with precision equipment and fundamentals rather than just on everything the equipment can do.

"Dealers need to offer the hardware, the software and then the brainware support for operators," he says. "They can save themselves a lot of work by getting some of the dumb questions out of the way early on. Anybody who uses precision equipment occasionally has brain fade."

On top of having difficulty combing out actionable information, Bushnell also wonders about how all the data he's currently collecting, but not using, will come in to play in the future.

"I think the expectations will be changing, but also the way we analyze the data will change, too," he says. "For example, down force monitors on planters produce data that I hadn't gathered in the past. It may be pertinent in the future, but I'm not sure what I'm going to do with it now.

"As we move forward, we may be able to understand more of the interrelations between the data we're gathering and dealers ought to help us make those connections."

Precision Problem-Solving:
No-Tillers Dissect Progress & Aggravations

Platform compatibility, finding optimal supplier partners and technology pain points are analyzed by select group of farmers.

By Jack Zemlicka

Precision farming tools are a part of many no-till and strip-till systems, and while technology often improves efficiency and productivity, it can also pose adoption challenges.

Our editors assembled a diverse group of farmers to discuss strategies, objectives and outcomes of utilizing precision farming systems. This also included influencing factors when making precision purchases and the significance of having a reliable support network.

At the table were Kerry and Angela Knuth from Mead, Neb., Jeff Reints from Shell Rock, Iowa, and Tim Leischner from Parkston, S.D.

Q: What are some of the precision tools and strip-till strategies you have utilized on your farm?

Kerry Knuth: "We've been strip-tilling all of our corn since 2005 and before that, we were doing full tillage. We also no-till our soybeans. We transitioned into strip-till with a triple-coulter system and I liked it, putting nutrients in the strip. We were working with a 12-row strip-till rig and a 36-row planter, so we definitely needed technology to stay on those strips in spring.

"At the time, we were at about 4-inch accuracy and when we missed a strip it wasn't working very well. Then we went to an 18-row strip-till machine, another one from Ray Rawson, so we could at least be half the planter size. We moved from spring to fall strip-till and have a Blu-Jet machine and RTK on both the planter and the strip-till machine so that we're one-inch accuracy and hitting the strip perfectly.

"We had been primarily John Deere with our equipment, but have more of a multi-colored fleet with AGCO and Claas machines. We actually prototype-tested John Deere's I-Guide implement guidance systems in 2008 in terraces and hills and it worked really well."

Jeff Reints: "We're in northeast Iowa and started no-tilling back in the late '80s. We moved to a Rawson coulter cart with our planter behind it. We were fall strip-tilling corn through 2007, but in 2008 did the opposite of what Kerry did. We went all spring strip-till with Dawn Pluribus units on a Harvest International bar.

"We started with a 16-row unit we ran for about 6 years and then went to a 24-row rig. We strip-till a day ahead of the corn planter, applying all our phosphorus (P) and potassium (K) and about a third of our nitrogen (N). We're still no-tilling our soybeans in 15-inch row spacings.

"We're pretty much all Case IH with our equipment and run a Trimble FMX 750 or 1000 display for the strip-till bar's passive implement steering. There's a receiver on the back of the toolbar communicating with the globe on the tractor.

"When we started strip-tilling in the mid-90s, we had no auto-steer or anything. We had an 8-row shank strip-tiller and an 8-row planter. We just followed it and 97% of the time we were on the strip, but if we got off, we could definitely see the difference. We're on fairly rolling ground, with about a third of our acres flat, a third B-slope and a third C-slope."

Tim Leischner: "We're in southeastern South Dakota, about an hour and a half west of Sioux Falls. We don't currently strip-till, but we've been no-tilling since 2002. We're pretty multi-colored with equipment and run two 24-row Kinze planters with Precision Planting systems and no-till all of our soybeans and probably 40-60% of our corn."

Q: Where do you see the greatest technology void in your farming operation, or need for improvement on the precision side?

Reints: "It would be nice if one monitor could control everything within our Case IH tractor and our 24-row planter. We have a Pro 700 monitor now in our tractor cab. I think companies are getting closer to where we can also run our 24-row strip-till rig, which is a Harvest International UltraMax 60 series 60-foot toolbar with Dawn Pluribus coulter-style row units, with a Montag high output dry fertilizer delivery system. But at the time we got it, the software wasn't available.

"We're a single-mix application and we can change the rate of that mix, but we can't change the ratio of P and K on the go. That would be beneficial."

TECH EDUCATION. Running a 48-row John Deere DB120 planter on his 2,200-acre operation in Mead, Neb., strip-tiller Kerry Knuth is meticulous with the precision technology he uses and the supplier support partners he chooses.

PHOTO: KERRY KNUTH

K. Knuth: "Communication between machines. What I really want is the day that I can control where a piece of equipment goes in the field before it even goes there. For example, having the ability to monitor my sprayer operator in the field so he doesn't have to make up his mind which direction he wants to go.

"Everything needs to be compatible with the software I use back in the office, so everything can be drawn up into one platform. I don't even know how many different software platforms we use. But if we could just have one program for all our prescriptions, whether it's seed, fertilizer, path of the field or guidance lines, that would be ideal.

"My wife, Angela, can have everything loaded before we get to the field vs. saying, 'I did one part in Precision Planting for your planting, but now I've got to go work with the Trimble system for the guidance lines.' It's just stressful."

Angela Knuth: "It would be nice not to have to take a USB stick out into the field because I forgot to upload something. It's usually the field that's farthest away. Another challenge is sharing data between the different colors and different monitors with some of the background software packages. We know it's coming, but it needs to happen."

K. Knuth: "We've had steering issues with our sprayer as well because a Trimble system in a Deere sprayer doesn't work very well. The sprayer is going 10-11 miles per hour and it looks like it will just eventually slide over and then it will come back on the row."

Reints: "When we switched in 2008 to spring strip-till and went to the 16-row unit, steering was an absolute disaster. I had a New Holland tractor at the time and its Super Steer guidance system with the Trimble 500 monitor were totally incompatible. When I started to turn left, the frame of the tractor shifted right a little bit. It's almost shifting the frame of the tractor on your front axle and that just totally goofed things up."

Q: Thinking about some of the technology investments you've made, what are some of the biggest influences in those purchasing decisions?

Reints: "We look first at the dealership, at how long our specialist or salesperson has been there and the quality of people. We need that dealer support.

"Our precision technician isn't a planter or strip-till expert, he's not a combine expert and he's not a data expert. But he understands the entire ball of wax and can come up with a solution for the system, compared to somebody who's more or less trying to sell the equipment and the support is just a piece that goes with it."

K. Knuth: "I'm going to go on just the side of the technology. We like to be innovators, but we're not just looking for the next shiny, new toy. It's got to benefit us.

"We've got the yield monitor in our Claas combine connected to Precision Planting's 20/20 system for our 48-row DB120 John Deere planter. We get very good accuracy out of that with an iPad. We don't necessarily like the data going to the cloud, but we have to have that. We can see when one row is messing up and we'll catch it.

"We've been prototyping it in our wheat. It's going to be great in the corn and soybeans. We'll be able to export the yield data from the 20/20 so the planter information will be back in the office and it will merge really well."

A. Knuth: "And down the road, that will be more important when we're variable-rating or whatever. That will make a big difference, if we want to go back and have a check when we're out in the field, because otherwise, we don't get back to it in the wintertime as often as we should.

"But we had to educate ourselves initially because we got tired of being charged for data transfer and downloading or uploading files by our supplier. We were never taught how to use it, but we were getting charged for it. Once we figured it out, we were able to work with our local dealer in the system."

Q: What do you see as the next game-changing innovation that will benefit your strip-till operation?

Reints: "I don't think it will be in my lifetime, but the autonomous planter. Right now, we're running a 24-row Case IH planter and there's a lot of weight and mass to that machine. If I can downsize to an autonomous 8-row machines behind a 90-horsepower tractor, that will hardly leave any footprint in the field."

A. Knuth: "Sensor data or sensors would really help direct our daily activities during the seasons. Then the ability of an autonomous little drone going out and diagnosing problems in the field would be valuable. Is it an insect problem? Is it a fungicide problem?

"A lot of sensors are going to be out in the field, but right now they're not cheap enough to get enough of them out there to manage problems to the level we want to."

Leischner: "It's all about money."

A. Knuth: "Absolutely. Right now, we use the moisture sensors. But we can only afford one out in the field. We can get electrical conductivity (EC) readings map our soils, but that doesn't tell us what's going on day-to-day."

Leischner: "That's true. I guess I really wonder, speaking from an old-school perspective, how fast do we have to keep going? I mean, it seems like every year, we have to do twice as much twice as fast just to stay even. And where is the breaking point? I know technology will do a lot of it. But on the human side, where is the breaking point?"

Reints: "And on that same line, at what point are we just in an information overload? We've studied every yield map, layered them in for all the years we've been collecting them. There are megabytes of data sitting in our computers that probably could be analyzed. And every 2 or 3 years, when we trade combines, it's a different software that might not be compatible with what we were using.

"At some point, there's just the good old seat-of-the-pants, you-know-how-to-farm mentality. It's still a hell of a lot more fun to grab a 6-pack and the wife and go count corn at night. You can't do that with an iPad and a sensor."

"We like to be innovators, but we're not just looking for the next shiny, new toy. It's got to benefit us..." — Kerry Knuth

AUTO ADJUSTED. Because of his farm size, tillage practices and highly variable soil types, Bradgate, Iowa, farmer William Cran is an ideal user of automatic down force technology. He recently upgraded from the manually adjusted pneumatic down force system on his 16-row Case 1250 planter to Ag Leader's automatic hydraulic down force system.

Whip Tough No-Till Fields into Shape with Automatic Down Force

Farmers, engineers and manufacturers weigh in on the benefits of auto down force and the soils and tillage systems offering the best payback.

By Ian Gronau

In a few important ways, William Cran, who farms 1,500 acres of corn and soybeans with his father Robert, represents the ideal demographic for automatic planter down force.

The technology is a good fit for Cran's operation just outside Bradgate, Iowa, because his acreage is large enough to exploit the economy of scale. He has both no-tilled and conventionally tilled fields, and much of his ground is comprised of highly variable river bottom soils.

"We can go from hard-pack clays to sandbars within 100 feet of one another, all across the field," says Cran.

In early 2016, Cran upgraded from the manually adjusted pneumatic down-force system on his 16-row Case 1250 planter to Ag Leader's automatic hydraulic down-force system. Although he's only used the new setup for one planting season, the benefits have already been obvious.

Partly due to the inconvenience of adjusting his old system in the field, Cran admits that he would usually only alter his down pressure two to three times per season. He'd usually leave it set around 100-120 pounds of pressure.

But while planting earlier this year with the new system, he noticed the sensors on his down-force system would often call for as high as 250-300 pounds of pressure at various points in the field to maintain seed depth.

"The system really shines on the no-tilled ground because those are our poorer soils to begin with, and the leftover corn stalks and bean stubble preserve extra moisture," says Cran. "We could tell early on that our payback was going to come a bit quicker from these areas.

"I saw everything come out of the ground at the exact same height," says Cran. "That was especially surprising to see on the farm drives where all the grain carts and tractors come and go from the field and compact the soil. In past years, it would be assumed that those spots, and others like it, would just not grow much. Plants would come up late or not at all."

What is Automatic Down Force?

To glean the optimum benefits from auto down-force systems, prospective users should look at several important factors to decide if the investment is a practical choice for their operation. To start, this means building an understanding of exactly what the technology is trying to accomplish.

One of the main variables down force technology attempts to control is seed depth.

When a planter row unit applies less down force than needed, a seed may be planted too shallow, which will likely cause germination problems. If a row unit has too much down force, seeds may be planted too deep and have their development choked by compaction.

On a field with fairly uniform soil types and a consistent texture, a less sophisticated system can be set manually that will reliably plant seeds at the desired depth. But few fields have such perfect conditions.

Mark Hanna, retired Iowa State University extension ag engineer, points out that there are several grades of precision and adjustment methods when it comes to down force options.

"The older method, which is still the stock option on some planters, is with pressure springs," says Hanna. "The step up from there is a pneumatic system that uses an air bladder to regulate pressure on the gauge wheels. The newest version uses hydraulic fluid instead of air to make adjustments with positive displacement.

"Older systems are usually adjusted

"I saw everything come out of the ground at the exact same height..."

manually, but the newer automatic systems use a load cell sensor to measure and regulate contact force while the planter is pulled through the field."

Even though pneumatic and hydraulic systems can both be fitted with automatic control, there are still differences between the two systems, primarily in response time and control type.

Hydraulic down force systems can respond faster across field conditions, and some systems offer automated adjustments for individual row-by-row control.

"From an adoption standpoint, whether it's retrofit or a new planter, automated down force is becoming kind of mainstream," says Bryce Baker, integrated marketing manager for Precision Planting. "It's no longer a question of 'Does it does it pay or not?' It's more about 'Do I need it from a row-by-row, planter-wide perspective.'"

Baker estimates that as of 2019, over half of new planters have automatic down-force systems installed and upwards of 90% are sold with new or retrofit automatic down-force systems on them.

"Farmers who are buying split-row planters only for soybeans might forgo that expense, but on your traditional, 30-inch corn only planters, it's pretty much all of them," Baker says. "It's one of the quickest paybacks that there is."

HYDRAULIC SPEED. William Cran's older pneumatic system required manual adjustments to down force. These adjustments had to be more or less estimated based on planting conditions. He says this system was vastly inferior to his hydraulic system from Ag Leader, which makes down force adjustments in the field while in motion and is significantly faster than a pneumatic system.

Return on Investment

Although many manufacturers offer estimates about the potential yield increase an automatic down-force system can offer, it's well known that benefits of the technology are highly dependent on a few key variables.

The results of a 5-year study conducted by a third party found a yield advantage of 11 bushels an acre or more in corn with Precision Planting's DeltaForce system.

However, engineers and farmers caution that these benchmarks are probably not the best figures to build an expectation around. The manufacturers themselves are quick to note that farmers will probably see the technology at its most beneficial only if they've properly deduced the need for it on their farms.

Baker notes that down force control is part of a system to manage soil density around the seed. One of the reasons why soil density matters is because if the soil is extremely loose it can't hold water and then if you have changing density, it's going to have a negative impact on root development.

"That's one of the values of no-till because you are not coming in and with horizontal tillage and changing the soil density," Baker says. "But when you get to more of a microenvironment the weight that's carried by the gauge wheels can actually create a soil density change.

"If you have loose soil in the seed furrow, and then your gauge wheels have created compaction and a density change, that's going to cause roots to turn."

Cran admits that without knowing exactly how much yield the technology would add to his operation, he had to appraise his farm and the need for the upgrade more closely before making it.

"Eventually, we felt comfortable making the investment because we have such variable soil types and compaction," says Cran.

The factors that came in to play for him were soil types, the tillage environment and overall acreage. Hanna notes these conditions are usually the best predictors of how fast the upgrade will pay for itself.

"If soils are reasonably uniform, the payback can be slower. You can even get by with adjusting your existing system manually for those conditions," says Hanna. "When you get into heavily variable soils where moisture level or texture vary significantly throughout the field, you'll need adjustment with much more regularity and an automatic system is a better way to do that."

By maintaining seed depth across the field regardless of soil conditions, a farmer can be assured they're reaching more yield potential. For fields where this is already possible with stock planter down force, the difference a hydraulic system will make is negligible, experts say.

Additionally, if a farm is smaller, regardless of how variable its soil types are, the payback rate will be slower. Rodney Arthur with Dawn Equipment, which manufacturers the RFX hydraulic down-force system, highlights the importance of scale.

"If you're farming 250 acres of corn with an 8-row planter, investing in a good row cleaner or better closing wheels would probably be much better than an automatic down-force system," he says. "But, if you're farming more like 2,500 or 5,000 acres with a 24-row planter, you might actually be costing yourself enormous amounts of money by not having such a system."

Using different tillage methods is another possible consideration to bear in mind when weighing the potential return on investment. Although Hanna is skeptical about the extent to which down force technology performs better on strictly no-tilled farms, he does believe that it helps farmers adjust to planting conditions.

"If soils are dry, adjusting for firmer contact in no-tilled soils may be advisable whereas this amount of pressure may be excessive if loose soil has been fluffed up in tilled areas," says Hanna. "I wouldn't say that it's always the case, but no-tilled soil usually holds more moisture and is denser, firmer and more structurally sound where tilled areas compact with excessive pressure."

Settings and Learning Curve

Automatic down force is often marketed as a fairly easy-to-use solution that helps remove some management deci-

"The down pressure needed for a field will change with wet or dry soil, no-tilled or tilled soil or just large areas of a specific soil type…" — Mark Hanna

sions during planting time. However, in terms of using it to its greatest effect, Hanna says there are still some field decisions the farmer should make.

"This technology does automate the system as a planter crosses the field, but it doesn't take away the responsibility to decide what down-pressure setting a farmer needs in given circumstances," says Hanna. "For example, research has shown that because wetter soils are more compactible, you'll want to back off on some of the down pressure in those conditions."

Even though an auto down force system will adjust itself in the field, it's still governed by the manual settings that the user has specified, he notes. These settings are usually several degrees between low and maximum, depending on the manufacturer.

"You want to avoid just setting it and forgetting it. Instead, make a conscious decision for the field and moisture conditions you encounter," says Hanna. "The down pressure needed for a field will change with wet or dry soil, no-tilled or tilled soil or just large areas of a specific soil type."

SPEED LIMITATIONS. Experts say that although hydraulic down force has already significantly increased reaction time on planters, the speed at which the system makes adjustments based on its sensor readings will likely remain a challenge. Sensors may be able to pull readings from the soil many times per second, but making the called for adjustments instantaneously has some intractable limitations from an engineering standpoint.

Even with the settings, Cran feels that the learning curve with the technology isn't very steep. He says spending some time to familiarize himself with the system, and remaining conscious of the planting conditions, were enough to ensure proper use.

"For our system there are 5 settings from low to max," says Cran. "We did 90% of our acres on the medium setting and tried running with a bit less down force on some of the conventionally tilled fields where there just wasn't as much needed.

"From a user interface standpoint, once the system is installed it's really easy to use. We spent about 10-15 minutes learning how it worked and how to run the display and haven't had an issue."

The Future of Down Force

Being a fairly new technology, automatic down force is still evolving.

There are some perceived limitations, experts note, when it comes to the top speed at which down force can be applied in response to a signal from the system's sensors — but it would appear that the direction it will continue to evolve in is more precise engineering.

For instance, Arthur says a strain gauge alternative can offer more precise measurements.

"Strain gauges are temperature dependent and if you swing 30 degrees from a cool morning into a hot afternoon, we're talking about 50 pounds of offset difference," Arthur says. "With our system, Reflex, we did away with the strain gauge and went to a pressure transducer, which is temperature invariant.

"We also have a check valve in the hydraulic cylinder that allows it to relieve pressure when it gets over a certain threshold. This way, we're able to dampen the input signal and linearize the force."

With these improvements, Arthur says a clearer signal of required down force is displayed regardless of the temperature and orientation of the gauge wheels, and the response to that information is filtered mechanically.

Despite the fact that hydraulic down force has already significantly increased reaction time on planters, the speed at which the system makes adjustments based on its sensor readings will likely remain a challenging hurdle to overcome, experts say. There may be engineering limitations that make further improvement tricky.

"When the planter goes across the field, the ground contact load can vary quite quickly," says Hanna. "In field tests, we've measured differences of 100 pounds of contact pressure in distances less than 5 feet. It's one thing to be able to sense the load — the sensors will read it many times per second — but it's another thing to actually make that adjustment.

"Remember, you're moving the whole planter unit up or down to either relieve or increase that contact force. Making adjustments like that very quickly is mechanically challenging. I think we're going to see more sophistication as time goes on in trying to maintain that load."

Baker adds that the key to overcoming skepticism with the technology is validating the results.

"Some farmers really like the technology, but just put it on and go, without checking anything or getting out and digging," he says. "They didn't make any adjustments and so it's important to understand that technology in general, and especially automated technology requires some validation.

"There's no one setting that across an entire planting season is correct every single day. It might be a little bit tacky, but the calendar says I need to plant, so be sure to adjust your setting different than what you would use if the conditions are perfect."

When Will Artificial Intelligence Become A Natural Ingredient In Ag Equipment?

Manufacturers, educators and engineers weigh in on where AI technology is now, where it's going and how it'll change the ag industry's production process.

By Ian Gronau

For many, considering the effects artificial intelligence (AI) may soon have on society is a source of both anxiety and wonder. Agriculture, as much as any industry, is in line for big changes. Farm equipment may soon have a mind of its own.

The term AI, as it relates to agriculture, is often lumped in with other emergent technologies like autonomous equipment and field sensors. But, AI-based equipment is distinct in that rather than being programed to perform a function, it's being designed to interpret data pulled from the field, act on it and teach itself best practices in the process.

The reason the terms are conflated is because AI will likely provide the foundation on which truly autonomous equipment is built and fields sensors will be its eyes and ears.

The first step to incorporating a new technology is understanding it. Educators and engineers weigh in on how AI is reshaping the agricultural industry. Where is the technology today? Where is it headed? What obstacles lie ahead?

Why Is AI Important?

Just because you can do something doesn't always mean you should. AI is meeting this argument in many of the industries it's beginning to penetrate. Kraig Schulz, president of Autonomous Tractor Corp., thinks the agricultural industry will embrace AI and the resulting autonomous equipment because farmers' margins are becoming razor-thin. He claims that if the average price of a bushel of corn is stacked against the average cost of producing it since 1980, the average income is negative $0.01 per bushel.

"Costs are up 60%, prices are only up 40% on average over that time period," he says. "If you talk to the pundits, most don't think this situation is going to get a lot better in the foreseeable future. Our view is that we have to keep trying to cut costs."

Labor and equipment account for about 25% of farmers' expenses, he says. Smarter, more efficient equipment can

SPOT ON. Blue River Technology and John Deere have developed "see and spray" technology that identifies individual plants to determine whether they are weeds or the crop, and then takes action based on that information, says Alex Purdy, the head of John Deere Labs, based in San Francisco.

stretch the dollar in both categories.

If AI-based equipment results in smarter farming, it can cut costs in inputs as well. Scott Shearer, an Ohio State University ag engineering professor, says this is already being done with herbicide application. He points to the example of Blue River Technology, recently acquired by John Deere, and its development of machine learning in agricultural spraying equipment.

"They're recognizing weeds and only treating the weeds in a field rather than a blanket application," says Shearer. "This is a technology that really could change and reshape plant genetics and how some companies are focused. Tests have also shown about a 95% reduction in herbicide usage and being able to still control the weeds using only 5% of chemicals that we've traditionally used."

Where Is AI Today?

It's a misconception to say that AI is coming to farm fields because, to some extent, it's already there. Alex Purdy, the head of John Deere Labs, based in San Francisco, says the equipment manufacturer has already been using machine learning to make real-time decisions in the field for several years. Purdy points to Deere's interactive combine adjustment capabilities as an example.

"The Interactive Combine Adjust product takes information from cameras that are embedded in the combine that sense things like grain damage and quality, straw condition, engine settings and operational characteristics," he says. "Then, it runs an algorithm to make recommendations to the operator to change certain settings to maximize the growers' desired outcomes whether that's to increase fan speed or make another important combine adjustment.

"That process is already impactful today and affects the final yield. You get a lot less waste in the grain tank and you get less lost corn. That's an example of this technology already at work."

Purdy also speculates that the pace of advancement in agricultural AI is about to quicken as driverless car technology paves the way.

"Graphic processing units and sensors are becoming much more affordable, and that trend will continue being led by the driverless car segment," says Purdy.

Also championing Blue River Technology, Purdy claims that its sprayer solution allows farmers to go beyond making decisions at a field and sub-field level all the way down to the individual plant level. He notes that cotton farmers are already using the technology with some success.

"Using the same kind of AI technology that phones do for facial recognition, Blue River is helping cotton farmers identify individual plants like identifying palmer amaranth apart from cotton plants," he says. "Then, the machine can go and take an action based on that information. I think that's a clear example, but only the tip of the iceberg on ways that we can enhance the farmer's ability to execute the job very effectively in the field at a plant-by-plant level."

> ***"There's going to be more reliance on equipment dealers and technology specialists to make sure AI in equipment is working the way it should…"***
> *— Matt Rushing, AGCO*

In addition to the implications this has for input costs, Purdy says less experienced operators could still be ensured optimal results if they're supported by a battery of AI-based equipment that has its own experiences.

"You can have someone who's new or who has a hired laborer in the cab and you can have confidence that they're going to be doing the right thing because they're backed up by a system that has traveled hundreds of thousands of acres and has that experience behind it," he says.

The real-time sensing equipment on the market already does a good job of determining field specifications such as required down force during planting, he says. But, with AI analyzing conditions and teaching itself the optimum responses, equipment will soon be able to offer the farmer highly informed suggestions.

"Today we set the specification once and then run the equipment at that," Purdy says. "We think there's an opportunity to adjust the specs continuously based on real-time conditions. There is significant opportunity for optimization there."

What's On the Horizon?

Industry leaders seem to agree that we're still years away from a swarm of light-weight fully-autonomous planters and combines rolling across the field 24/7 with crop scouting and spraying drones buzzing overhead.

The industry will likely first see "supervised autonomy" as AI creeps into agricultural equipment.

"These are going to be machines that have a human watching over them," Shearer says. "But, hopefully we get to a point where that human watches maybe 10-15 machines at once. I think that's going to be the progression. As we learn more about how to give that machine in the field intelligence, we'll reduce our reliance on the human monitor."

Matt Rushing, AGCO's vice president of the Global ATS product line, also believes the slide into AI-based agricultural equipment will be a slow progressive one. He says advances in sensors are already laying the groundwork and that eventually, data pulled from the field will be fed into algorithms and real-time analytics engines that will calculate the optimum response to field conditions and act automatically.

"In the future, we're going to see additional expansions with sensor technologies and the algorithms supporting them so eventually a human doesn't have to even see the raw data or recognize that something's happening before an action is taken in the field," he says. "If sensors show there's better moisture or organic matter in an area of the field, the technology will determine that a planter should raise its seeding population and notify the operator that it has done so.

"Or maybe a sensor will detect a pest

on a leaf, and instantly apply pesticide? The sensors will supply the information and through the technology on-board, the equipment will react with an appropriate course of action."

Shearer believes as AI in farm equipment improves, it'll likely help transform drones into the valuable crop scouts the industry has always hoped they'd become.

"I truly believe there's going to be opportunities with AI to get closer to identifying what some of the crop health problems are with fly-overs," he says. "That's not going to be the only thing though. We still rely heavily on our crop scout to go into the field and walk it, looking in the crop canopy to make their assessment. How do we position machines in the future to do the same thing?

"A lot is going on with rapid infield phenotyping right now. People are looking at putting robots within the canopy if you want to think of it that way. But again, how can we do this in a practical manner and how can we be cost effective? Those are going to be the important things to consider in the process of adopting AI."

As to where AI innovations will come from in the future, Shearer thinks that tech startups from Silicon Valley in the mold of Blue River Technology will help lead the charge. But, he suggests that it may take an understanding of large scale farming to drive adoption.

Adoption Hurdles

Naturally, some of the biggest hurdles AI-based equipment will have to overcome are technological ones. New solutions will need to be rigorously field-tested and polished until they're mature enough for widespread commercial use. Purdy even suggests that the large amount of computing power AI solutions will require may necessitate more electrification on field implements.

"Electrification generally is going to be required for smarter equipment," he says. "The Blue River Technology that is pulled behind a tractor today requires electrical power and we expect the electrification of implements will continue to be an important requirement and enabler of tomorrow's smart machines."

Perhaps an equally large hurdle is a psychological one. Rushing notes that farmers are skeptical and not likely to leap out of the cab at the first mention of a smart machine that claims to know their farm better than they do. However, provable return on investment has a way of changing minds.

"Farmers can be the biggest skeptics in the world, especially when it comes to new technology," says Rushing. "So I think you've got to have something that's demonstrable and you have to have provable facts to back it up. I think once you have that, though, and can prove the waste and yield benefits, you'll see more and more farmers adopt it."

> ***"I'd expect to see tractor lifecycles reduced to about 5,000 hours. This is where technical obsolescence will meet mechanical life…"***
>
> *— Scott Shearer, Ohio State University*

How Will Business Change?

Farmers still have a crop to grow and dealerships still have equipment to sell, but what effects will AI have on their business relationship? In terms of selling the equipment, Rushing says, not much. Proving the value of a purchase to the farmer will remain the golden rule as long as there is equipment to sell.

"If you can show the farmer that there's value there, and it's got to be a value that's not just focused on waste, but more on yield, because they have realized they can't cost reduce their way to prosperity," says Rushing. "They're looking for ways that they're going to be able to somehow increase yields. If you can demonstrate the value of the sensors and technologies, farmers will use them and realize the benefits."

Rushing also believes AI-based equipment will likely add revenue to dealerships' service departments.

"Most of the revenue in a dealership is generated through parts and service," he says. "All these new capabilities realized on the machine will be coupled with additional value added services that you can include at the time of purchase.

"In the future, in addition to buying a new planter with all these valuable sensors and technology, they're also purchasing a recurring service package that ensures the machine and technology is optimized and available when it is needed. There will be more reliance on equipment dealers and technology specialists to make sure everything is working the way it should."

What AI-based equipment may mean for the industry long term is as unknown as the technology's applications themselves. Although, Shearer speculates that rapid advances and shrinking equipment may mean a shorter shelf life.

"We're probably going to go to a different service life for implements and tractors," he says. "Many of the tractors being built today probably have a life of 20,000 hours. I would expect to see that reduced to something like 5,000 to 6,000 hours. This is where technical obsolescence will meet mechanical life.

"Farmers in the future will purchase technology on agricultural field machinery to do specific jobs. But, newer technology may render the previous technologies obsolete."

Forecasting further, Shearer envisions a future where less equipment ownership is necessary on the farmer's end. That could come in the form of leasing equipment or contracting for the service of AI-enabled equipment, he says.

Either way, he feels that it's likely more manufacturers may end up marketing their equipment directly to the end user.

14 Tips for Effective, Efficient Analysis of a Soil Test Report

Ward Laboratories president, Ray Ward, offers a step-by-step explanation on interpreting soil test reports to aid no-till management decisions.

By Laura Barrera

Most no-tillers understand the importance of soil testing, as they typically serve as the baseline for fertilizer and lime purchases and application.

Thanks to variable-rate technology, growers can even use soil test reports to draw up exactly where they're going to apply a certain rate of fertilizer or lime.

But if someone were to hand you a soil test report, would you be able to read the information and understand what it means?

Most growers would probably say no. Given that fertilizer is historically one of the biggest expenses for no-tillers, according to the annual No-Till Operational Benchmark Study, they may want to consider learning how to read and interpret this data that can tell them what's already in their soils.

This may become especially important because of growing concerns about nutrient runoff in local waterways. It also allows no-tillers to check for any discrepancies in their results and ensure the fertilizer recommendations their agronomist or consultant is suggesting matches what each field needs.

No-Till Farmer reached out to Ray Ward, founder and president of Ward Laboratories in Kearney, Neb., who shared a recent soil test report from one of his farms and took us step-by-step through the report and interpreted it for us.

1 Soil pH 1:1. The 1:1 means soil-to-water. At our lab, we use 10 grams of soil and 10 milliliters of water, let it sit for half an hour and read the pH. In Nebraska, we have a state law for soil testing labs that says we have to report how we do the test. That's why the methods are identified on our report.

Soil pH 1:1
5.0

A pH of 7 is neutral. As the pH drops, soil becomes more acidic, whereas if it goes up it becomes more alkaline.

In most states when the pH gets below 6, we begin to think about applying lime. And for each pH unit dropped, like from 7 to 6, the hydrogen-ion concentration — which determines acidity and alkalinity — increases 10-fold.

This pH is 5.0, so we've dropped 100-fold in hydrogen-ion concentration, which means it needs to be limed as soon as possible.

2 Modified WDRF BpH. The WDRF stands for Woodruff, who was a soil scientist at the University of Missouri who developed a buffer method that we use in our laboratory because it estimates lime needs on sandy soils better than the SMP Buffer developed at Ohio State University.

Modified WDRF BpH
6.3

The difference between the buffer pH and the soil pH is the buffer pH measures the total acidity in the soil, while soil pH gives us the active acidity.

We use the buffer pH to determine how much lime to apply. We take 7 minus the buffer pH and multiply by 4 to arrive at the lime recommendation of 2.8 tons per acre, which you can see under the fertilizer recommendations listed in the sidebar on page 35.

That recommendation is what I call 100% effective lime. Most ag lime is 60% effective lime, so you would take 2.8 and divide it by 0.6 to come up with the amount of ag lime you need to apply, which brings us to 4.7 tons per acre.

3 Soluble Salts 1:1 mmho/cm. This is an electrical conductivity reading or EC reading. We still use the old term mmho/cm. The new term is mS/cm, but it's the same.

Soluble Salts 1:1 mmho/cm
0.26

Because we're in the western part of the Corn Belt, there are more saline soil conditions out here, and so we run EC on every sample. Because if we have a saline problem, we know it right away.

I also use the EC reading in reviewing the soil results because if I have a very high nitrate, sulfur, calcium or potassium (K) reading, I can look at the EC. If it's higher, then I know the soil test was run correctly. When the plant nutrient levels get too high, the soluble salt readings will increase.

If the soluble salt or EC reading is above 1.5, we have a saline condition. But if you're really low, it means you don't have much life in your soil. So you'd like to have that soluble salt reading around 0.3 to say you have a good, living soil.

If you're above 0.6 or 0.7, then you have to look around and see what's causing it to be out of whack, whether your nitrates or sulfates are too high, or something else is too high.

4 Excess Lime Rating. This is a way of determining if you have a calcareous soil, which is one that has free lime in it. And in the Plains and mountain region, we have a lot of calcareous soils. It's just a way to let the farmer know, 'Hey, this soil may have iron deficiency chlorosis' or something like that.

Excess Lime Rating
NONE

In the past, when we had more triazine-type herbicides, some were very sensitive to high pH or high lime, so we needed it to adjust the triazine herbicide rates. Well, those are almost all gone now except for atrazine, so we don't worry about it too much. It still might be important in some herbicide applications, though.

The "none" indicates that the pH is probably less than 7. It's possible you could have a soil pH of 7-8 and no excess lime. But you should not have any free lime if the pH is below 7. And if I see that when I'm reviewing results, I ask that the soil tests be checked again.

5 Organic Matter LOI-%. The LOI stands for "loss on ignition," which is how we determine how much organic matter is present. We dry the soil and weigh it, then we place it in the muffle furnace at 360 C, or 680 F, and that burns the organic matter off. Then we cool the samples and weigh them again. The difference between the two weights is the amount of organic matter that was present.

Organic Matter LOI-%
2.8

The important thing for farmers to understand is that each percent of organic matter contains at least 1,000 pounds of nitrogen (N) per acre in that 0- to 8-inch depth. This test has a 2.8%, so that's 2,800 pounds of organic N stored in the top 8 inches of soil.

We're trying to build up organic matter to make it better for the water-holding capacity, and it also helps us build nutrient levels. All the nutrients in plants are in organic matter. In really good conditions, we can get more out of the crop because we have higher organic matter.

6 FIA Nitrate ppm N and Depth Nitrate Lbs N/A. FIA stands for "flow-injection analysis," which is the method we use to determine the nitrates.

FIA Nitrate ppm N	Depth Nitrate Lbs N/A
	0 - 8 in
21.8	52

Nitrate is soluble, as we know, and it leaches if there is too much rain. But nitrate is available and we can quantify it. We can calculate pounds of N per acre, which we find in the next column.

We take the depth of the soil, which is 8 inches, multiply it by 21.8 ppm NO3-N and then multiply by 0.3. The 0.3 comes from the weight of the soil — each inch weighs 300,000 pounds per acre, which equals 0.3 million. This calculation gives us 52 pounds of nitrate per acre.

7 Method Phosphorus ppm P. The M-P3 underneath stands for a phosphorus (P) extract developed by North Carolina State University soil scientist Adolf Mehlich. This test is used by many soil-testing laboratories in the Plains and to the East.

Method Phosphorus ppm P
M-P3
36

We consider anything above 25 ppm high. We can see it's above that, so you wouldn't have to apply any P for a year or two. But we do recommend a starter fertilizer application of up to 50 ppm P.

For the irrigated or really high yield potential areas, like 250-bushel corn, I'd like to see that up to 35-40 ppm.

8 Ammonium Acetate: K, Ca, Mg, Na. Ammonium acetate means they're exchangeable cations. K stands for potassium, Ca is calcium, Mg is magnesium and Na is sodium.

Ammonium Acetate			
K ppm	Ca ppm	Mg ppm	Na ppm
180	1466	211	9

For most states, 180 ppm for K would be rated as high. Probably anything above 150 or 160 ppm K is high. If you're above 160, you can likely go without it.

But we like to see 200 ppm K for corn, which is why we recommend adding 20 pounds of K2O per acre under the fertilizer recommendations (see sidebar, page 35). We're just telling the farmer to put a little bit on to maintain the soil test where it is.

Calcium is at 1466 and I don't have a rating for calcium. Some people like to look at the base saturation (No. 14) on that and say it's too low. That's because the pH is very acidic. As the pH drops, normally hydrogen ions will replace calcium ions on the exchange complex and the calcium ions leach.

Magnesium is 211 ppm. We recommend magnesium application if the ppm gets less than 50 ppm. So if it's above 50, we consider that high.

And for sodium, we want low sodium. Sodium is bad for the soil. A lot of people associate sodium and salt together. Sodium is called a sodic soil and salts are called a saline soil. So there's a big difference in the terminology.

A high sodium ppm level is calculated by multiplying the CEC (No. 13) by .05 by 230. Sodium base saturation should be below 5% CEC.

9 Ca-P Sulfate ppm S. Ca-P is a calcium phosphate solution we use to extract sulfur. Sulfate is like a nitrate; it's soluble and moves around with the water.

Ca-P Sulfate ppm S
10

If we're below 12 ppm, we might consider putting sulfur on — partly because our atmosphere is so clean now we don't get much free sulfur anymore. So we recommend a little bit of sulfur on this corn (see sidebar, page 35), because we're below 12.

10 DTPA: Zn, Fe, Mn, Cu. DTPA is a chelate used to extract zinc (Zn), iron (Fe), manganese (Mn) and copper (Cu). Willard Lindsey at Colorado State University developed the test in the 1960s.

If you're above 1 ppm zinc, you're

Fertilizer Recommendations in Actual Pounds of Plant Nutrients per Acre

Ward Laboratories founder and president, Ray Ward, shared the fertilizer recommendations for the soil test report. While most of the numbers are straightforward, he explains how they determined the nitrogen (N) recommendation:

"We provide up to three fertilizer recommendations if the grower requests it. It can be one crop with three different yield goals or three crops and their respective yield goals.

"The subsoil number on the second line takes into account the subsoil nitrate test. It doesn't show it, but the nitrates in that 8- to 24-inch depth was 14.9 ppm. It's not mentioned on here, but that accounts for 72 pounds per acre. Combined with the 52 pounds in the topsoil, we have 124 pounds of N per acre.

"Corn uses 1.1 pounds of N per bushel. The yield goal is 150 bushels, so the corn requires 165 pounds of N per acre. Subtract the 124 we already have and it requires an additional 41 pounds per acre. We round to the nearest 5, so our recommendation would be 40.

"But if you had soybeans in there last year, as this report indicates, we subtract 40 pounds. We account for legumes in the rotation. I haven't figured out how to do that yet for cover crops, but it's important to evaluate the N supply by either the past legume crop or by the cover crop."

Crop	Yield Goal	Nitrogen N	Phosphorus P_2O_5	Potassium k_2O	Sulfur S	Zinc Zn	Magnesium Mg	Iron Fe	Manganese Mn	Copper Cu	Boron B	Chloride Cl	Lime, ECC Tons/Acre
Sample ID: N OF LANE	**Sub-Soil ID(s)** | **Depth(s)** : | 8 - 24 in							**Past Crop** : Soybeans				**N Credit** : 40	
(Ward) Corn, BU	150	5	15	20	6	1	0	0	0	0		19	2.8

probably OK. Some agronomists like to go to 1.5 instead of 1, but I believe 1 is adequate.

DTPA			
Zn ppm	Fe ppm	Mn ppm	Cu ppm
0.96	75.4	21.8	0.82

Iron is more soluble as the pH becomes more acidic, and this is a low pH, so the iron test is very high. We want the iron test above 4.5 ppm. If it's below 4.5, and you have a pH above 7, and high excess lime, you likely have iron deficiency chlorosis (IDC) problems.

For manganese, I want it above 3 ppm. Willard Lindsey's was 1. I'm not as sure about manganese as the other micronutrients.

On copper, we have 0.82 ppm, and we like to see it above 0.20.

11 Hot Water Boron ppm B. We run boron sometimes, but we didn't for this test because it has been high in the past.

Hot Water Boron ppm B

On corn and soybeans, we like to see it above 0.25 ppm. For alfalfa, sugarbeets and cotton, we go up to 0.5 ppm. But the rest we keep at 0.25. That's based on Oklahoma State University calibrations.

12 CaNO3 Chloride ppm Cl. This is chloride and it's an ion that has been found deficient in South Dakota and Kansas the last 20 years. In Kansas we like to see the chloride test above 6 ppm, so the 3 is a little bit low. We'd recommend some chloride.

Chloride is very important for the grasses like wheat, milo and corn, but not so important for the broadleaves like soybeans.

13 Sum of Cations me/100g (CEC). This is an indication of texture and the amount of organic matter in the soil. The clay and organic matter provide the CEC, and then the type of clay also affects the CEC or the sum of cations.

Sum of Cations me/100g
16.1

The kind of clays we have here in the Plains are much higher in cation-holding capacity than the clays in the Southeast. So you can't really tell the texture unless you know the location of the soil. But 16.1 would indicate a silt-loam soil, and this soil is in fact a Muir silt loam.

14 % Base Saturation: H, K, Ca, Mg, Na. Now we're on the percent base saturation. H is hydrogen and it's at 40%. I'd like to see that below 30%. If it's below 30%, I'd say you can get by another year without lime. But at 40% we need to put some lime on.

For K, I'd prefer to look at the K soil test instead of the base saturation. We're just on the border with 3%. I think some people would say it needs to be 5%.

Calcium is 46%. It's obviously low because the hydrogen is high. If we apply lime, the calcium will replace hydrogen. Some people like to see 60% or 65%.

% Base Saturation				
H	K	Ca	Mg	Na
40	3	46	11	0

Magnesium is at 11%. We're plenty high in magnesium at 211 ppm (No. 8). So I'm not too worried about that.

And then sodium is zero, which is great. If the sodium is above 5%, then we need to be thinking about applying gypsum to reduce it. Gypsum is calcium sulfate, and calcium replaces sodium and it moves down with the sulfate ion. Calcium replaces sodium on the exchange complex.

And because of the size of the ions — sodium is a bigger ion in the soil in hydrated conditions — it's easier to remove. So calcium kind of kicks it off the exchange complex.

Because we're in the Plains states, we run sodium on everything when we run the cations. Sometimes sodium is a problem. If it's above 5%, it begins to become a problem. And by the time it's 15%, it's a real problem.

Carving Out a Nitrogen Management Niche with Crop Sensing Technologies

The ability to quickly calculate and make in-crop nutrient and crop protection application adjustments can put more bushels in the bin.

By Gene Armas

Optical sensors attached to sprayers and sidedress machines collect and use data in real time, giving no-tillers and strip-tillers the ability to tailor nitrogen (N) prescriptions for fields.

But while the evolution of the technology has the capability to give farmers the tools and data to make timely, sometimes real-time management decisions, some wariness, understandably, remains as to the true value of remote sensing technology.

At its best, information generated by sensor technology offers, "a real, well-rounded perspective on how the soil and plant are interacting within any given season, any environmental interaction," says Dr. Ray Asebedo, former assistant professor of precision agriculture at Kansas State University, and current agronomic consultant.

The ultimate goal, he says, is to keep the focus on farming, "and at the same time put technology to work by good agronomic sciences improving profit-per-acre."

Step by Step

Interest in optical sensor technologies, or sensor technology in general, has increased in precision agriculture because of rising input costs. With profit margins tighter, nutrient management specialists must have acute knowledge of nutrient variability seen on farms.

"What happens is, we have to be able make to nutrient recommendations that are just the right rate applied at the right time, in order to help reduce our input cost without sacrificing yield," Asebedo says, "which ultimately will improve profit per acre."

An understanding of the benefits of this technology for nutrient management requires a step back to first look at core fertility. Sensor technology or not, soil sampling is still a highly recommended practice that can improve the quality of nutrient management programs. "We're not to the point with sensor technology where we don't have to soil sample," Asebedo says.

Measuring soil pH, along with the levels of phosphorous (P) and potassium (K), are among the first important steps. "Soil pH is the most nutrient-limiting factor in the soil," he says. "If our soil does not have the appropriate pH levels, it can reduce the availability of nitrogen, phosphorous, potassium and on the whole, bring down our entire nutrient management program and reduce profitability."

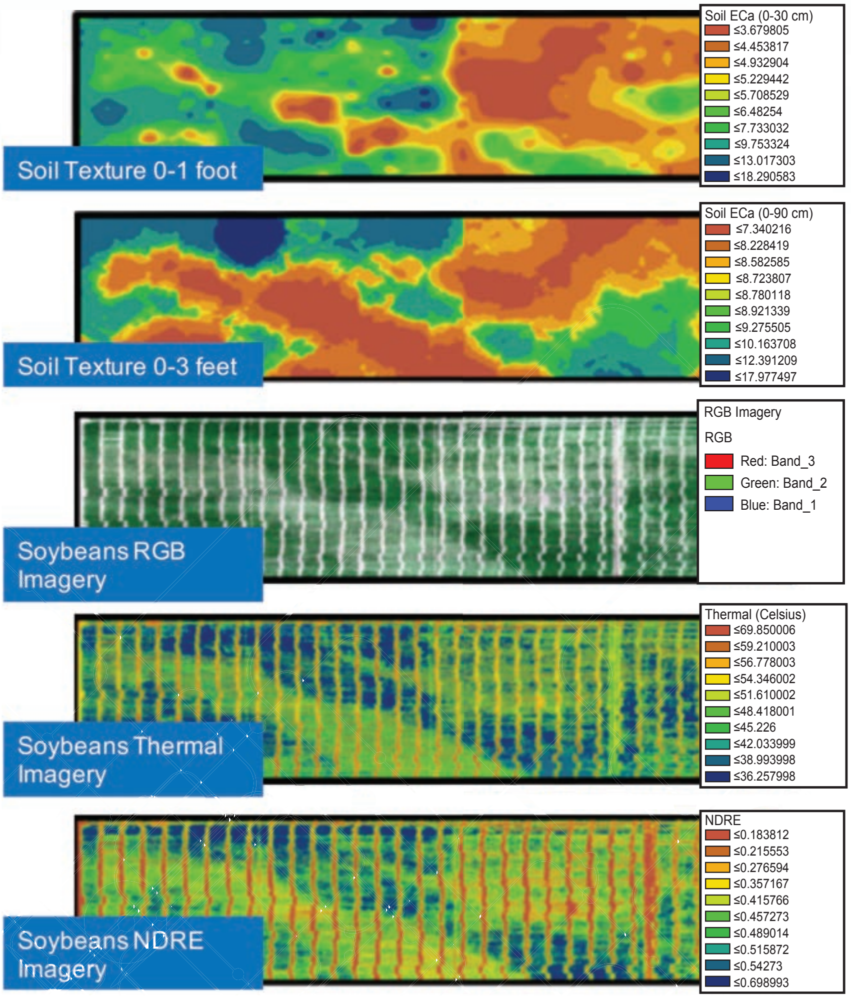
Non-mobile nutrients in the soil often require either grid soil sampling, or soil sampling by zone, or even a composite sample, which can help get no-tillers and strip-tillers on the right track for what they have for P or K levels.

Asebedo notes, this is a critical step, prior to applying sensing technology to N and sulfur management. "The temptation is to jump right into nitrogen and sulfur, or just nitrogen alone. But the deal is, if our soil pH and P and K are not in the right spot, no matter how good we make that nitrogen program, it's always going to be lagging in yield and profitability because the lower ranks of the nutrient management ladder haven't been taken care of yet."

He adds that if farmers don't have their pH, P and K in the right order, they're not going to see as much profitability from newer optical sensor technology, especially with N management and N prescriptions.

Next come secondary and micronutrient need, followed by in-season crop response. Optical sensor data collected from drones or sensing technology on a sprayer can show in-field variability to the crop's response to soil according to weather. For example, excessive rainfall in northern states in 2018 may have dras-

SENSOR OVERLOAD. With profit margins tighter, nutrient management specialists must have acute knowledge of nutrient variability seen on farms. Remote sensing technology is helping no-tillers identify and treat in-crop nutrient deficiencies in the field.



LOOK & LEARN. Dr. Ray Asebedo breaks down the different resolutions and data that can be derived from remote sensing imagery, including plant temperature, soil texture and yield variation.

tically changed N management plans for no-tillers and strip-tillers.

"If we were just doing a pre-applied fertility program, we would never be able to take into consideration what's happening in-season," Asebedo says. "By utilizing optical sensor technologies, we can read what the crop is telling us, and develop multiple nutrients and variable-rate applications. This is where we can really start to hone in to improving profit per-acre on the farm."

Visual Communication

For an agronomist like Asebedo, the science behind optical sensor technology starts with the premise that plants are visual communicators that "speak" in wavelengths of light. Lush greens are usually indicators of good health, a sign of enough N in the soil system. Yellowing can signal stress.

Optical sensor technologies go a step further and allow for the analysis of light beyond what's visible to farmers or their agronomists walking the field, scouting crops. For instance, near infrared light has a strong reaction with plant cells and gives a good gauge of plant biomass.

Red and red edge light commonly used from satellite technology, or Trimble's GreenSeeker or Topcon's CropSpec, can measure photosynthesis.

"Since red light is heavily absorbed by chlorophyll, it gives us a gauge of photosynthetic capacity," Asebedo explains. "So between red light, red edge, and the infrared, we can start to see how big that plant factory is, and how efficient it's operating at to produce yield."

Optical sensor technologies, then, can provide a broader view of what a plant is "telling" us about its interaction with the environment. Also, the introduction of drone technology as a tool about 5 years ago provided a bird's eye view of a field to get a better sense of variability, Asebedo says.

The ability to integrate data from different sources make machine systems more intelligent and bring them closer to thinking like an agronomist, he says. Results from different analysis can be layered visually atop a bird's eye view of a field on a monitor.

Using electrical conductivity offers a view of soil texture within the first foot or 3-foot depths across a field. In these cases, deep reds or yellows may indicate sandier soils, with lower water-holding capacity, while greens and blues indicate more loamy soils.

Data from electrical conductivity provides us insight to soil texture variability across a field. How we conduct nutrient management on sandier soils as opposed to silt loam soils will be considerably different due to differences in water holding capacity, water availability and nutrient loss factors.

Adding in optical sensor data sets, like thermal imagery, can show thermal signatures, or how much heat is coming up from a plant. Thermal imagery can provide critical data about heat and water stress and assist agronomists to make more informed decisions.

For instance, blues will indicate where plants are running cooler, which can coincide with loamier sections of soil, where more water may be available. There is a similar correlation in looking at near infrared (NDVI) and red edge (NDRE) imagery, which looks at plant biomass and photosynthetic capacity.

Loamier areas, typically highlighted in blue, indicate more productive plants getting plenty of water. Sandier areas will have lower biomass, likely indicates yield reduction if the plants don't get more moisture.

Practical Application

While there is still plenty of theoretical outcomes, farmers are most interested in practical impacts that sensing technology can provide. Asebedo explains how agronomists working with no-tillers and strip-tillers can leverage collected sensor data to refine fertilizer prescriptions through what he calls the "agronomist nitrogen recommendation algorithm."

"An agronomist uses this data, along with observations from scouting, to come up with a N recommendation," Asebedo says. "But input from the farmer will be just as critical a factor in the process. Some of the agronomist's first questions should be about yield, including, 'What's the average from year to year?'

and 'What's the current yield goal, and why?' Final grain yield is the end result of all the interactions observed between crop, soil and weather."

Then the agronomist will make a visual determination of N stress in crops. They will consider soil type, soil textural changes and soil test analysis data, if available throughout the field, along with weather.

But crop physiology is another factor to weigh, Asebedo says, because different growth stages are linked with specific yield determining factors. "For instance, with corn at V6 to V12 stage, I'm going to be very attentive to making sure that my corn crop is not nitrogen stressed during that period. Why is that? Because ear size determination takes place," he says.

Then it's time to decide whether the sensing data warrants additional N application. "Say we come in at V14 stage for corn and it's been clearly stressed, and was stressed through V10, through V12," Asebedo says. "Odds are pretty good that we have suffered permanent yield loss, and shouldn't be applying high rates of an additional 150 pounds of N because it's never going to improve our yield.

"I'd be better off pulling that nitrogen recommendation back and only apply N rates again for what we can actually truly obtain for yield."

"We're not to the point with sensor technology where we don't have to soil sample..."
— Ray Asebedo

Adoption Obstacles

While the benefits of sensing technology are emerging, there are obstacles to more widespread use. In-the-field computing power and connectivity have been limiting factors.

However, crop sensing tools including Topcon CropSpec, an active optical sensor technology, can connect to cloud platforms via APIs to transfer its data to be readily used by the farmer or agronomist. Easy access and use of optical sensor data will help farmers and agronomists find in-field variability and save considerable amount of time through more focused crop scouting.

An additional obstacle has been the lack of a unifying software platform, making analysis more time consuming, especially for farmers who don't have as much expertise in GIS and analytics.

"The complexity of old software required high levels of training to process each layer of soil data, imagery, yield and many others in order to integrate them together to generate agronomic outputs such as variable-rate nitrogen prescriptions," Asebedo says.

Today's systems are more seamless. Improvements in connectivity have made it easier to integrate sensors and create an "Internet of Things" in the field. This allows for better communication, more computing power and automated processing that could be beneficial for no-tillers and strip-tillers and help them focus on farming rather than the deep science.

CORN COMPARISON. In a remote sensing study, Dr. Ray Asebedo evaluated ear-size differences pulled in different spots of a corn field, based on different fungicide test strips in corn. Areas that received fungicide vs. those that did not, revealed as much as a 40 bushel difference in corn yields — 220 to 260 bushels per acre.

Broadening Value

One area where Asebedo sees potential is with crop protection. "One of the things that always bothered me when we were having a great looking crop and our nutrient management program was being managed to a T, is somebody would always forget to apply some fungicide when weather conditions were conducive for disease pressure," he says. "Then we would have some serious issues."

In one sensing study, Asebedo evaluated ear-size differences pulled in different spots of a corn field, based on different fungicide test strips in corn. He also evaluated kernel depth, and the physiological development and grain fill from R1 stage, to maturity and up to abscission, or black layer stage.

"I can't stress enough the importance of sustaining photosynthetic capacity all the way through to black layer," Asebedo says. "When we start looking at this, utilizing NDVI or our NDRE, seeing what we can't see with the human eye, there is still a considerable amount of photosynthetic activity that was taking place where we applied our strips of fungicide in comparison to where we didn't make an application."

The end result revealed as much as a 40 bushel difference in corn yields — 220 to 260 bushels per acre — based on where fungicide was and wasn't applied.

"At the time, the farmer whose field this belonged to, was completely happy with their 220 bushel yield," Asebedo says. "It was right on par with what they normally do. They thought they were doing great until we actually started utilizing our optical sensor technologies to determine if they were optimizing productivity across the entire field.

Even though they were doing their nutrient management right, there was room for improvement in protecting the crop and applying fungicide to more areas to increase production. "

The utilization of optical sensors can have a positive impact on multiple aspects of farming and help no-tillers determine where they need to make changes to their farm management practices.

3 Steps for Improving Accuracy and Accountability of Field Data

By Martha Mintz

When Steele Byrum returned to his southeast Virginia family farm after 8 years working for Smithfield Foods, he brought with him a skill many farmers struggle to master — data management.

His off-farm job had him sifting through a jumble of mismatched data that resulted from acquisitions of many other smaller companies. Byrum was tasked with making heads or tails of the mess and getting future incoming data to fall in line with protocols so it all matched. He found himself tackling a similar challenge when he arrived back at the farm.

"When I first got here I think the perception was that time at the desk wasn't a very good use of your time, but it is," Byrum says. "That's especially true today. We've got a lot more skin in the game so we need to know what direction we're going and how our yields and profits are trending as a result."

The internet, crop consultants and salesmen of a multitude of products bombard the modern farmer with suggestions for management and inputs, he says. "You need to be able to gather data and use it to see what works and what doesn't and what will actually help you profit at certain price points."

Here are three steps Byrum takes to effectively collect and utilize data from his farm.

1 Be Consistent

Building a good structure and plan for bringing in data is the first and most critical step. It may seem overly simple, but the first thing Byrum notes is that fields need to be named the same thing consistently. "We had the same field named five different things. Names were the same but spelled differently or sometimes capitalized and sometimes not. It's nearly impossible to pull all the data together and make sense of it when nothing matches," he says.

His solution is to make the family desktop computer the home base for data. Everything is routed through the desktop. They establish permanent names for all their fields at that point — 200 fields, with some as small as 2 acres. They input all the parameters of their equipment, drivelines and field boundaries and store them at that central location.

"When I'm going to the field, I pull a program onto my card that I'm going to plant fields A, B and C with these drivelines and these pieces of equipment," he says. "When I'm done, I bring the card back to the desktop and load into the software what's been done. That way I'm not using the tiny keyboard in the cab where I might struggle to type in a field name correctly."

2 Study the Data

Three data layers make up the Byrums' data picture. Because he and his father, Cecil, run two separate operations, they have billing data where they bill among themselves and their landlords. They have recordkeeping of all input applications for compliance data and then data they use to make management decisions, such as yield data and soil sampling results.

"We plot where we plant different varieties and then come back and collect harvest data to compare," Byrum says. They overlap that data with soil type information from soil sampling to create prescription maps for fertility and seeding rates. Using their recordkeeping data, they are able to assign actual loss numbers to spots they have long known were problem points.

"We know there is a wet spot or a spot where shade is a factor, but crunching the data tells us how much that spot is costing us and if we should do something about it," he says.

Byrum has spent a lot of time looking at the breakeven on their different crops. "The higher the inputs the higher the risks, so should I be putting those higher input crops in fields I know will only yield a sufficient crop 2 years out of 5? I'm not one to try to force a round peg in a square hole just because the rotation says that's the crop that's supposed to go there that year."

3 Consider the Size

Field size is another major consideration. "It takes a lot of time and management to get our big equipment into those small 2 to 10-acre fields," he says. "Depending on how many you plant to a crop that needs a lot of management — in our case, cotton — that can add an entire extra day to your field work, which is a problem if it starts to rain." he says.

To resolve this he looks at how many of those small fields he can plant to crops that require less management. "It may not make sense to plant those small fields to cotton when prices are $0.55 per pound, but when they go up to $0.85 per pound I'm more likely to plant them," he says.

More Online

Read more about the Byrum family's operation online at www.No-TillFarmer.com in the "What I've Learned from No-Tilling article, "No-Till, Cover Crops and Data Help Coax Yields from Thin Soils."

Sky's the Limit on Uses, Payback with Unmanned Aerial Vehicles

High-resolution imagery and data analysis contributed to a $20 per acre profit on silage corn and timely fertilizer applications for Wisconsin strip-tillers Eric and Megan Wallendal.

TAKING FLIGHT. Grand Marsh, Wis., strip-tillers Eric and Megan Wallendal's investment in an unmanned aerial vehicle (UAV) helped them make adaptive decisions for in-season nutrient application and for their variable-rate irrigation program.

By Jack Zemlicka

The motor begins to hum and the propellers begin their increasingly rapid revolutions. A gentle upward tilt of the joystick by the owner and the rotocopter is airborne — slowly elevating as it drifts over a cornfield to capture hundreds of images that will be processed and analyzed.

This was a recurring practice last year for Eric and Megan Wallendal on their family's 3,200-acre farm in Grand Marsh, Wis. The husband and wife are among a growing number of farmers experimenting with and applying unmanned aerial vehicle (UAV) technology on their operations.

But as agricultural interest in UAVs, or drones, has grown, so too have the number of questions about the practical payback and tangible benefits these tools can provide to farmers.

"I think there's a lot of misconception out there that farmers can fly a drone and it will immediately provide a solution to a problem," Eric says. "It's still trial and error, but we've found that the technology gives us a better tool to analyze what's going on in the field during the growing season, and also project ending results to manipulate future cropping practices."

Analysis of high-resolution imagery collected from their UAV system, in conjunction with variable-rate fertilization, irrigation and soil testing, lead the Wallendals to estimate a $20 per acre profit on 850 acres of silage corn, and a $5-$10 savings on application costs on 750 acres of soybeans in their first year with the precision tool.

Getting Off the Ground

Thorough research and setting attainable goals were the first steps for the Wallendals in selecting the right UAV for their farm. Two key features they wanted were ownership of the software and Normalized Difference Vegetation Index (NDVI)-quality images.

After researching nearly 20 companies, they purchased a $25,000 Pacesetter system from Indiana-based Precision Drone, which includes a software stitching license from Agisoft, a Russian technology developer.

The rotocopter has two mounted cameras: one that captures red, green and blue (RGB) images and the other captures near-infrared images.

"The importance of having NDVI images for us was to get an in-season picture of crop health at our fingertips," Megan says. "It was a substantial upfront cost, but for a 160-acre field, we can collect 1,600 images and, rather than spend up to $10 per acre to have them stitched together by a third party, I preferred to learn to stitch the images together myself.

"It's not that difficult to do and I can process images for a 160 acre field in about an hour."

This allows the Wallendals to make quicker, more informed management decisions on their operation. Farming in primarily sandy topsoils with light clay underneath, preserving water and fertilizer has long been a challenge for them. With largely stagnant organic-matter content between 0.7% and 1%, they leverage strip-till and other practices to help preserve soil health and increase crop yields.

Their operation includes a diverse rotation of silage corn, snap beans, soybeans, kidney beans and alfalfa. They also grow forage corn for a sizeable dairy operation and rent out about 800 acres for potatoes.

Megan says they are "guerilla farmers" because they partner with canning companies to grow the crop of choice any given season.

One of their initial goals with the UAV, was to better track production of their specialty crops. While they can use traditional yield monitors for corn and soybeans, it's harder to historically track yields for potatoes or snap beans. They also have their forage corn custom harvested and, more often than not, the combine doesn't have a calibrated yield monitor, or any yield monitor at all, Eric says.

"If we're lucky, we might get reliable yield data 2 out of every 5 years," he says. "So we wanted to find an alternative method to create our own maps and build some historical data."

Flying their UAV at 200 feet, Eric says the unit can record stand counts and at about 366 feet, can capture the NDVI imagery to overlay with their soil maps. They also use Veris carts and soil moisture probes to record organic matter, pH levels and water-holding capacity in their soils.

During the growing season, Megan flew some fields at least once per week to capture and compare plant development. This was especially valuable to monitor yield potential in a short-season crop like green beans.

"Using NDVI imagery and our soil electrical conductivity (EC) maps, we were able to identify our healthier plants on the heavier soils and less-healthy plants on the light soils," Megan says. "What we learned with a 55-day green bean crop is when we saw higher, healthier plants on a heavier soil, we need to plan on planting higher populations in those areas of the field because that's where our greatest yield potential is going to be."

Practical Application

Another goal the Wallendals achieved during their first year of UAV use was applying the imagery to identify and react to in-season nutrient deficiencies. All of their strip-tilled acres are under center-pivot irrigation, and NDVI analysis allowed them to adjust in-season water application.

Working with a local irrigation dealer, the Wallendals have begun to write their own variable-rate irrigation prescriptions to better assess water needs in specific strip-tilled fields, rather than arbitrarily applying water.

"Having detailed imagery helps us verify that we're using the right prescriptions," Megan says. "For example, we have a creek that runs through one of our fields where some of our soils would constantly get drowned out. Based off the aerial imagery, we adjusted the prescription so that every 2 degrees, the sprinklers would turn off."

This adjustment created less runoff into the creek and allowed them to decrease the amount of potash they typically apply in heavier soils near their waterways.

"It's hard to put an exact dollar amount on what that $25,000 investment in the UAV system has meant for our irrigation program," Eric says. "But when we have a $150,000 investment in variable-rate irrigation, and if those images are telling us that we're mismanaging application, that's pretty economical. We're looking at 10% of the cost in order to verify that we're using our larger investment correctly."

MAKING DECISIONS. When deciding what type of UAV they wanted, the Wallendals had two criteria: ownership of the software and availability of Normalized Difference Vegetation Index-quality images so they can make more informed nutrient application and planting decisions.

Return on investment has been more quantifiable when it comes to using UAV imagery to fine-tune their nutrient management practices. This past year, they conducted several trials on their silage corn to see what they could learn from UAV imagery and how to apply it to their fertigation program.

Making as many a seven nitrogen (N) applications throughout the season, they typically band a starter fertilizer blend of potassium, phosphorus, boron and sulfur 4 inches deep with their two 12-row Orthman 1tRIPr strip-till rigs in spring.

At V3 they broadcast 100 pounds per acre of ammonium sulfate (AMS) and fertigate another 60 pounds per acre of N at V8 or V10.

This past year, once their 850 acres of strip-tilled silage corn started getting close to canopy — about V4 or V5 stage — they flew the UAV to scout plant and field health. Flying at an average elevation of 366 feet, they noticed nutrient variances that correlated with their EC maps.

Putting "boots on the ground" to scout, the Wallendals confirmed that an area of the field was at least a leaf stage behind. They adjusted their in-season variable-rate fertigation prescription based on imagery that had revealed the imbalance in crop health, which they admit would have been difficult to detect without the aerial information.

On one half, they increased N application by 10% and then scaled back application on the other half by the same percentage.

"When I flew the field 8 days later, the entire field was even in terms of health," Megan says. "It was one of those pictures you want to see of your farm. I went out and scouted it and it was amazing to see the difference."

Figuring they had balanced out the nutrient levels, the Wallendals' next N application stuck to their flat-rate fertigation program. But the next batch of

"We're looking at 10% of the cost with our UAV system to verify that we're using our $150,000 variable-rate irrigation investment correctly…" — Eric Wallendal

images showed a deficiency again, and the field area where they made that extra application ended up yielding about a ton-and-a-half less.

"We don't know what the maximum yield potential of that deficient side is or if we decreased the yield on the other side, which is why in the future we want to have a controlled area," Eric says. "Rather than reallocating N to see if that's a higher-yielding area, maybe we didn't have to reallocate. Maybe it needed less to begin with and we could have just applied less to the entire field."

Stitching Together Profit

While the Wallendals are in the early stages of using UAV data to make long-term farm management decisions, their integration of imagery into their current practices directly contributed to increased corn yield, profit per acre and input cost savings.

On one of the fields where they variable-rate applied N, they only had a 0.3-ton difference between some high EC and low EC soils, based on an evaluation of NDVI images and soil test maps. In other fields where they applied a straight rate of N, they had about a 2-ton yield difference in the field.

Eric admits that there's still more work to be done to see how they can maximize high-EC soils and what the economic minimum is on the low soils. But at least they know there is a strong correlation between nutrient management and looking at NDVI imagery analysis.

"When we did our yield analysis at the end of the year, we found the biggest return from our UAV data came on our silage corn acres and soybeans," Eric says. "Besides some of the intangible value, we attributed a $20-per-acre profit to our silage corn because of our ability to detect and react to nutrient deficiencies more quickly.

"For our soybeans we're able to reduce the number of applications, specifically with having to treat our crops for white mold, because the aerial imagery we collected showed it wasn't needed. That saved us about $10 per acre."

In the future, he hopes to use NDVI data collected with the UAV to influence hybrid selection, planting population rates and furthering their variable-rate application program.

"We're definitely doing variable-rate planting based on soil test management zones, and altering our fertility practices to determine what the minimum and maximum fertility we can apply to stress the plant in either direction," he says. "We find that each soil type has to be treated differently, rather than treating each crop differently."

Rather than shooting for 300 bushel corn across the field, Eric says it's going to be more efficient to shoot for 300 in some areas, but closer to 220 bushels in others because it's not going to make sense to put on extra units of N and lower the overall economic return.

Megan adds that their crop diversity and soil variability gives them an opportunity for further experimentation with UAV data. One of her goals is to have the imagery serve as a "health check" for their crops throughout the year.

"That would be a huge benefit to us to be able to figure out what's going on in the field, hopefully fix it, and more efficiently plan for the next year," she says. "UAVs are one of those tools that become addicting and I don't know how we'd ever go back to not having this type of data on our farm."

Validating the Value of UAVs as an Operational Tool

With the ever-improving quality of digital cameras, not only can no-tillers capture regular images of farmland but they can also get multi-spectral images that provide information about plant health, soil health, plant population, water infiltration, pest outbreaks and more.

No longer are Unmanned Aerial Vehicles (UAVs) considered farm toys as they develop into decision-making tools, thanks in part to advanced software programs that can stitch images together to form a comprehensive view of large areas then uploaded into yield-mapping software and layered for additional insights.

"We're evolving from a farmer buying a DJI drone from Best Buy and adding a camera to take pictures because it's fun, to having UAV systems become a real part of farm operations," says Mark Dufau, director of business development for AeroVironment, which manufacturers the Quantix hybrid drone ecosystem.

Dufau suggests one of the most significant impacts UAV technology has had is with fertilizer application verification, with farmers able to aerially scout, identify and treat trouble spots during the growing season, in an efficient, effective way. The Quantix system can cover 400 acres in 45 minutes, a more timely alternative than visually scouting fields on foot.

"We had a farmer with a center pivot system that was creating rainbow effect on the inside of that pivot and they had set the wrong fertigation rates which were creating bands of infertility and heavy fertility on those inside parts of their pivot," Dufau says. "The farmer was able to identify the problem and go out and make those adjustments."

Even though UAV technology has become more sophisticated, systems have become more automated, making them easier to operate and more tailored, with packages designed for individual producers, or scaled to meet the business needs of precision service providers. But prior to getting serious about investing in a system, Dufau recommends that farmers get their Part 107 Remote Pilot Certification, which is a relatively easy process.

"It had been viewed as a big hurdle because farmers didn't want to have to go get a pilot's license," he says. "In reality, it's a 60-question multiple choice test that can be taken at your local airport. The certification is a requirement from the Federal Aviation Administration for anyone flying a drone commercially, which includes farmers, and covers the regulations, operating requirements and procedures for safely flying drones."

What is Driving Driverless Vehicle Momentum in Ag?

Robots won't yet be doing all the field work, but electric-powered equipment and smaller, self-guided implements are coming.

By Laura Barrera

Ask someone in agriculture what comes to mind when they think of autonomy and they'll likely say a driverless tractor.

But many experts in precision farming say that simply removing the farmer from the cab may not be the best purpose of autonomy.

"Building an autonomous robot that moves through the field is interesting," says Alex Purdy, head of John Deere Labs. "But if it can't go and execute the jobs like spraying or planting that a grower needs to do in the field it doesn't achieve what a grower actually needs and is more like a toy."

And while full autonomy may not exist yet in agriculture, it's not a new development to the industry — in fact, it's been around for decades, says Matt Rushing.

"We've automated so many things over the years, even though farmers don't necessarily recognize it as that. Too many people think that autonomy means removing the driver completely," says the vice president of the Global ATS product line, for AGCO.

For example, going from mechanical to electronically programmable hydraulics, manual steering to autosteering, and manual headland management to automatic headland management are all examples of autonomy in agriculture.

There's still a lot of progress to be made before farmers can have their equipment do all the work for them, but companies are making headway with autonomous solutions, which may have profound impacts on both farmers' and dealers' operations.

Replacing Tractors, Shrinking Footprints

Kraig Schulz, CEO and president of Autonomous Tractor Corp., says the true definition of autonomy is when a piece of equipment is on its own, driving and functioning completely separately, and all you have to do is observe the results of the work. But that's not likely to happen anytime soon.

"Autonomy works really well in repetitive, mundane tasks," he says. "I don't think you would get many farmers to say that it's the same thing every single time they go out; it changes every time. And that's what makes true autonomy extremely difficult. And not even necessarily the answer."

Schulz explains that data from Iowa State University Extension shows that for corn following soybeans, labor only makes up 5% of the total cost of production, which means that removing the farmer from the field isn't going to make a big difference to the profitability of an operation.

Instead, he says the problem with labor in a corn-soybean operation is having the right people on hand at the right time. And that's where he sees semi-autonomous equipment coming in.

"It doesn't have to go out while we're filling up our second cup of coffee and come back. It has to operate independently enough while we're within a reasonable distance of that vehicle, so that we can take care of all exceptions like we would if we had a driver.

"One might imagine that you wouldn't actually need as many tractors because you could have self-powered, self-propelled semi-autonomous implements doing the work alongside you in the field during the key seasons where you don't have enough labor."

AGCO already has one such solution that is now up to series-production readi-

SWARM TECH. AGCO's Fendt brand introduced Project Xaver, a swarm of a dozen or so small, autonomous seeding units, replacing one 8-row planter. The small autonomous units reduce compaction and are also designed so that if one goes down, another unit can step in to finish the job.

ness for its Fendt brand, Project Xaver — a swarm of small, autonomous seeding units.

The manufacturer first started the project by thinking about how to remove the driver from the tractor but realized there were still plenty of agronomic and logistic problems to solve, Rushing says, such as soil compaction caused by the tractor weight. It would also be inconvenient to transport.

"We looked at the whole planting process and thought, 'So what does it take to plant corn?'" Rushing says. "Well, you need a tractor, you need a planter bar, you need the row units that actually hang on the bar and that's what does the planting. But in reality, what really does the planting? It's the row unit itself. Everything else is just a necessity to propel the row unit through the field."

By replacing one 8-row planter and tractor with a dozen or so autonomous row units, Project Xaver not only reduces compaction, but is also designed so that if one row unit goes down, another one can step in to finish the job, reducing downtime. Unveiled at Agritechnica 2017, a swarm of 10 Xaver prototype units can plant about 2.5 acres per hour and are automated to refill and recharge batteries, which takes about a half-hour.

"Years ago we had lots of little machines going through the field and they were all manned," Rushing says. "Then all of a sudden we went bigger because it was harder to find labor to operate them. But then if we see a significant failure on one big machine, the farmer may have a significant downtime issue."

Ohio State University ag engineering professor Scott Shearer sees soil compaction being a big driver for smaller autonomous equipment.

"A lot of farmers today don't realize the compaction penalty as it applies to profitability of their operations," he explains. "I'm not going to disagree with the fact that farmers buy larger equipment to be timely, and that's a very important aspect in terms of profitability. But the other side of the coin is, I don't think they recognize the amount of yield reduction that is occurring because of the larger equipment."

He points to another company working on this, SwarmFarm Robotics, based in Australia. The company is also moving away from large equipment to swarms of small, autonomous equipment, such as sprayers and mowers.

With these developments, he believes that "supervised autonomy" will be the first adoption of autonomous equipment, where a human is monitoring a fleet of small machines, until artificial intelligence can replace that person.

"We're going to go from one person sitting on a machine to one person sitting in an office monitoring a machine, to a person in an office maybe monitoring a dozen or two dozen machines," he says. "And as we learn more about how to give that machine in the field intelligence, we'll reduce our reliance on the human monitor."

> ***"The need for power is higher than it used to be. We either have to go to bigger alternators, generators and motors or focus on making the whole vehicle electric…"***
>
> *— Matt Rushing, AGCO*

Automation Before Autonomy

As for the immediate future, Purdy believes more automation has to occur before agriculture starts seeing broad-based autonomy.

"Our group is focusing most of our attention on automating the tasks in the field to give the grower all of the tools to automate and improve the accuracy of important in-cab decisions. Not only will this increase precision and profitability for growers, it will allow for less-skilled labor to be in the cab and be as effective as a skilled laborer," he says. "We actually think that those automation questions instead of autonomy questions are more difficult to achieve and will be eventually required to get to a full autonomous solution."

He adds that John Deere Labs, a part of the company's Intelligent Solutions Group, based in San Francisco, is looking at what they think growers are going to want and need in the next 10-15 years. He believes that automation is the most important and critical piece of the puzzle.

"We're pretty excited for some of the automotive companies to really drive down some of the costs in full autonomy and drive down some of the challenges we're going to run into in full autonomy," he says.

Fuel of the Future

One development the automotive industry is driving with autonomous vehicles that experts believe will make a big impact in agriculture is electric motors.

Schulz, Rushing and Purdy all say that autonomous equipment will likely be electric due to the amount of power the equipment will require, as well as the precision capabilities it will provide.

For example, Schulz says there are some farmers pulling trains of equipment through their fields and overpowering their tractors. With electricity, those implements could have their own supportive power systems.

"You have greater precision of the implements because you're directly steering them," Schulz says. "Think about that from a precision standpoint. No longer are you dragging stuff through the field, you're carrying it. You can control and power the entire system, creating huge efficiencies on the precision side."

Rushing adds that in addition to precision control, electric would eliminate a lot of mechanical and service issues as well.

"The need for power is even higher than it used to be," he says. "So now we will have to either go to bigger alternators, generators and motors and all these other things, or we can focus on making the whole vehicle electric."

Purdy notes that the artificial intelligence equipment they have from Blue River Technologies, which Deere acquired in September 2017, requires a power source and agrees that electricity and electification of implements will probably be necessary as we move to smarter equipment.

Moving to electric isn't without challenges, though, the primary one being the cost of batteries.

"All the systems that are out there for electric cars are based off the premise that you're going to use a battery," Schulz says. "They don't like running off of generators, so we use batteries."

The problem is the amount of energy a tractor requires is much higher than an electric car. For a 200 horsepower tractor to run for 10 hours would require 1,500 kilowatt hours, Schulz says. That would cost $350,000 in lithium batteries alone and would weigh more than the tractor itself.

Schulz thinks the better option for agriculture is to find a way to couple a generator to the engine and use electric wheel motors without batteries to power the tractor.

But there are agriculture companies introducing battery-powered vehicles. Rushing says AGCO released its E100 tractor that uses a lithium battery, noting that it can run for about 5-6 hours without a recharge and recharges to about 80% within an hour.

"This stuff is coming," Schulz says. "The world is moving to electric vehicles, and I fundamentally believe it's going to have a huge impact on dealers' businesses because the traditional model is slowly going away."

Electric motors also last longer. The U.S. Department of Energy's average expected lifespan for an electric motor greater than 100 horsepower is 29 years, or 200,000 hours of use.

They're also more efficient. Statistics from the U.S. Energy Information Administration show that going from a gasoline-powered vehicle with a mechanical drivetrain to one that's gasoline-powered with an electric platform increases fuel efficiency by about 30%, Schulz says.

Rushing also thinks that as more "swarm" equipment like Project Xaver's autonomous row units and SwarmFarm Robotics' autonomous spraying solutions become available, ag service providers may begin offering these units as a service.

While dealers' parts and repairs business may decrease, Shearer suspects that farmers may trade their equipment out more frequently as new technology continues to render previous technologies obsolete. For example, instead of using equipment for 20,000 hours, a farmer may only use it for 5,000 hours.

"We buy new smartphones because they do more. We don't necessarily buy new smartphones because the previous one quit working," he explains. "So I think some alignment of mechanical life and technical obsolescence will be a key consideration when designing."

> *"If you can manage the liability of self-driving vehicles in downtown Los Angeles, we can probably learn to manage the liability in the middle of a corn field in Nebraska…"*
>
> *— Scott Shearer, Ohio State University*

Acceptance, Adoption of Autonomous Equipment

A major factor in the advancement of autonomous equipment and other smart technologies is adoption by growers.

Rushing doesn't think we'll see every farmer running out to buy something like Project Xaver because it's a different concept than what they're used to. But, in time, they will accept it as a tool to solve specific agronomic and logistic problems on the farm.

"You hear farmers say all the time, 'Hey, I like to drive my machine,' even though many haven't been driving for 15 years due to auto-guidance technology,'" he says. "But similarly, farmers in the early 1900s said, 'How could anything replace my mule?' But this was then disrupted by early mechanization. Similar adoption reservations and concerns will be seen as we move into the autonomous era."

Safety regulations will also play a role, but Shearer doesn't think it will be too big of a challenge.

"There are a lot of companies right now focused on automation in transportation," he says. "My attitude is if you can manage the liability on public thoroughfares in downtown Los Angeles, we can probably learn to manage the liability in the middle of a corn field in Nebraska."

While there are companies coming out with their own technology, such as AGCO, or acquiring Silicon Valley-type companies like Deere did with Blue River Technologies, Shearer questions whether some of the immediate autonomous technologies would be applicable to the Midwest.

"I'm not certain that Silicon Valley, if you would, understands Midwestern agriculture," he says. "That's not meant to be critical, it's just a fact of reality. I think they see things at times from a California perspective, and that's all well and good because there are a lot of high value crops out there.

"But I'm talking about the 200 million acres in the heartland, the corn and soybean type row crops, and that's going to take a bit of a different mindset. It's a much tighter margin in terms of profitability, but the acreage is there to support a decent market in terms of machine numbers.

"So are you going to build a few machines for very specialized markets or are you going to build a lot of machines for the more traditional row crops? It's going to be interesting to see how some of that unfolds."

Cutting Fertilizer Application Costs with a Precision Strip-Till System

Move to strip-till saves labor, fuel and up to $67 per-acre in nitrogen for High Plains Kansas operation Kramer Seed Farms.

By Dan Crummett

Ben McClure was a recent ag economics graduate from Kansas State University when he went to work for Kramer Seed Farms in southwestern Kansas near Hugoton in 2003. His arrival came just as the multigenerational family farm was about to embark on a series of changes that has radically altered its farming operation, and significantly boosted its financial well-being.

"That was the beginning of a long period of cultural change on the farm that is still rippling through the operation," he says. "It was a time when diesel fuel was very expensive and we were looking for ways to save trips across the field and cut expenses and labor. Before my time, everything was farmed conventionally, usually with 3-4 tillage passes each year ahead of the planter."

Quitting the Plow

By 2005 the operation had purchased a 30-foot DMI 2510 strip-till rig equipped with coulters, shanks and closing disks followed by a berm builder on the back. They ran that rig and moved to all liquid fertilizer for several years, and realized significant saving in fuel and labor expenses.

The farm had been grid sampled in 1998 and at the time of the switch to strip-till, McClure says the operation was moving into zone sampling and investing in more precise nutrient monitoring. "We were also using variable-rate fertility with Raven and Tee-Jet systems, and were moving into variable-rate seeding with our planters," he added.

What he didn't realize at that time, was the move to strip-till had set the farm up for an even steeper climb up the economic-efficiency ladder through then-emerging fertilizer technology.

A managing partner in the 3,500-acre cash-rent, predominately irrigated operation, McClure says a typical year's production includes about two-thirds of the acreage in corn with some cotton, grain sorghum or sunflowers included, and about one third of the land in winter wheat planted behind corn.

The wheat acres also include certified seed production for AgriPro Seed Wheat Associates and LIMAgrain Cereal Seeds — which adds value to the wheat crop.

BUILDING STRIPS. The original 30-foot DMI strip-till rig Kramer Seed Farms bought in 2005 features a coulter bar and high-pressure Exactrix fertilizer system. Building strips in heavy no-till wheat stubble is a typical chore for the equipment on the highly-productive southwest Kansas operation.

> ***"When I can take the fertilizer budget and cut it in half, that's a lot of money…"*** *— Ben McClure*

Fertilizer Efficiency

Strip-tilled corn yields average 220 bushels per-acre and can jump to 250 in "good-weather" years. But McClure says the money-maker today comes from the fact he and his crew are saving about $30-$70 per-acre on nitrogen (N) and phosphorus (P) with the efficiency found in their Exactrix fertilizer system.

The system includes a high-pressure (300 psi) anhydrous ammonia injector that delivers NH3 to the ground as a liquid. It also features a formulator which injects liquid P (potassium thiosulfate) and liquid sulfur (ammonium thiosulfate) simultaneously with the NH3.

The "collision" of the 3 formulations causes a distinctive chemical reaction and crystalline formation of TAPPS (tri-ammonium polyphosphate sulfate).

Exactrix founder Guy Swanson says the TAPPS concept provides a stable form of the three nutrients directly below the crop for improved nutrient uptake and crop performance. Tests show the system allows N recommendations from 0.6-0.8 of conventional soil lab rates based on application timing.

In 2010, Kramer Seeds Farms invested in the system, seeking improvements in fertilizer placement and efficiency.

"We added a 30-foot, 15-inch coulter bar to the DMI strip-tiller and equipped it with a modified mole knife from Shield Ag which allows the dual-injection of potassium and sulfur," McClure says. "The anhydrous injection nozzle is mounted adjacent to the mole knife.

"All of that is now operated by our John Deere controller and display since we consolidated everything three years ago and removed lots of clutter from the cab."

Double-Digit Savings

Since adopting the Exactrix system, McClure has tested and retested the it against 3 other nutrient management recipes and, even with drastically reduced N application rates, he has seen no drop in corn yields.

"These tests showed us we're saving between $27 and $67 per-acre on N inputs with the Exactrix system," McClure says. "Farming 2,500 acres of corn, that can mean the difference in $67,500 to $167,500 to cover depreciation, interest on fixed costs and profits."

An ag economist at heart, McClure says even with the lower return of $27 per-acre on 2,500 acres of corn production, the savings amount to what a producer would spend for the least expensive Exactrix system. "The second year, you can keep that bonus," he says.

McClure says Kramer Seed Farm is producing high-yield corn on about 140-148 pounds of N per-acre applied with the system. The same 15-inch coulter system is used to sidedress wheat in the snow and to fertilize sunflower stands in the spring.

"I know strip-till has saved us a lot of time and fuel on the tractors, but the real economic boost came from the way we operate today and the fertilizer savings we're realizing," he says. "I try to budget 12% of our gross operating expenses on fertility, and talking with various bankers in our area I

PHOTO COURTESY OF EXACTRIX GLOBAL SYSTEMS

PHOTO COURTESY OF EXACTRIX GLOBAL SYSTEMS

CHEAP & EFFICIENT. Anhydrous ammonia is the primary nitrogen (N) source at Kramer Seed Farms, which can provide ample N for crops at significantly lower rates than traditional lab analysis recommendations.

understand other growers are spending 20-25% for fertilizer.

"When I can take the fertilizer budget and cut it in half, that's a lot of money. I don't know how we could have stayed in business without it."

Residue Management

Although he is a believer in reduced tillage, McClure says the large quantities of corn residue behind high-yield crops, some years even after running cattle on the stalks, can blow into piles and windrows, which makes planting difficult.

"That's why we generally do a very light vertical tillage with a tandem disk Landoll ahead of strip-tilling," he says. "The stalks stand through the bulk of the winter to catch snow and after we pull the cows off around April 1, we till a couple inches deep to break stalks and get some dirt on the residue."

After strip-tilling and applying TAPPS, McClure says he likes to get a watering on the field, although sometimes planting with their 12-row Deere 1720 planter comes the day after strip-tilling. The planter runs Sunco trash whippers and a stock Deere row unit equipped with Precision Planting's eSet seeding spacing and depth control system.

"Most of our hybrids come from Phillips Seed Farms, and we mainly try to use 113-114 day maturity corn," he says. "Some places we plant 108-109-day hybrids to save ourselves a couple of passes with the sprinkler at the end of the season, and to get the field back into planting wheat quicker."

No-till wheat is custom planted by McClure's brother, who uses a Deere 1890 CCS drill equipped with Exactrix Wing Injection.

"It's not cheap, but savings on fertilizer is more than enough to pay for the custom planting," he explains. "Yields run 75-80 bushels per acre on average, and 100-bushel yields are not out of the question in a good year. But, as with the corn, the extra margins we have because of fertilizer savings goes a long way.

Strip-Till Nitrogen Application Comparison

Treatment:	All Dry	Dual Placement	Exactrix	All Liquid
	Urea and 11-52-0	NH3 and 10-34-0	NH3, 10-34-0 and 12-0-0-26S	________
Placement:	All applied with strip-till rig	2/3 applied with strip-till rig 1/3 sidedressed No N-Serve or N stabilizer	All applied with strip-till rig	2/3 applied with strip-till rig 1/3 applied through fertigation
Cost Per Acre:	$696.67	$674.64	$634.84	$701.94

STELLAR SAVINGS. After 4 nitrogen treatments were repeated on three separate areas of Kramer Seed Farms, manager Ben McClure says use of an Exactrix system proved to be the most economical with a savings of up to $67 per acre of N.

Anticipation Increases for Truly 'Plug and Play' Technology Solutions

Developers preview the future of ISOBUS, while farmers share their success stories and frustrations coordinating equipment.

By James DeGraff

The relationship between manufacturers and farmers has never been seamless, yet in an industry where the complexity of precision services and equipment setups continues to escalate, the two sides need to be on the same page more than ever.

From visions of universal, plug-and-play agriculture to tractor cabs free of unnecessary clutter, manufacturers are well aware of farmer expectations and remain optimistic in their progress to meet them.

In the meantime, farmers continue to capitalize on manufacturer successes as they come and maneuver through those obstacles that remain.

Developers Share Goals

As one of the top organizations for the progression of farm engineering, the Agricultural Electronics Foundation (AEF) directs initiatives and programs including the bi-annual AEF Plugfest event. Plugfest, dubbed "speed dating for ag nerds" by one attendee, brings together software engineers from around the globe to test a series of displays and installations for ISOBUS compatibility.

In a round-robin format, different groups of engineers collaborate in 30-minute windows, allowing each side to test the functionality of their platform against another. The variety of pairings is a key component to the development stage as it helps to detect any bugs or underlying issues in their software en route to eventual ISOBUS certification.

Certified AEF ISOBUS products are then added to a growing database — accessible both online and via a mobile app to farmers, dealers and developers — to see which devices are compatible with different equipment.

Among the unique aspects of Plugfest is the collaborative nature of the event, requiring competitors to balance internal objectives with external collaborative research to improve functionality across brands. Many of the same developers worked together to solve Virtual Terminal (VT) issues across brands and continue to make steady progress on the next stages of ISOBUS.

Speedier ISOBUS

Key to that seamless interaction are fewer manual steps connecting equipment and fewer support calls from the field, says Dave Smart, team leader for AEF's high-speed ISOBUS project. Platforms use CAN-based ISOBUS connectivity, which Smart notes is limited from a speed and bandwidth perspective.

Those limitations serve as the groundwork for AEF's high-speed ISOBUS project, designed for faster data exchanges through wider bandwidth. Smart says farmers will log and apply data more accurately through their machines.

"Many of the operations would still be the same, but now with high-speed ISOBUS on a planter, for example, I can determine if my set point is closer to

COMPATIBLE COMPONENT. After experimenting with different data systems, Kent, Ill., strip-tiller Seth Wenzel settled on the Ag Leader AgFiniti display for his Kinze 3600 16- and 31-row soybean planters, noting its interface and reliable functionality.

> ***"When it's April 10 and you have a problem and the part won't be available until April 15, that's valuable time lost that could have been avoided with some planning…"*** — Seth Wenzel

31,500 seeds per acre instead of 32,000," Smart says.

"We'll have the bandwidth to actually get down to row-level and see what each row is doing. From there, I can determine prescriptions that adjust row-by-row. With CAN, it's too constraining. With high-speed ISOBUS, I'll utilize analytics and create another control to reduce chemical application and save money."

Another goal with high-speed ISOBUS is improving in-field communication across differing brands and machines, which Smart notes is largely dependent on data standardization between equipment wireless points.

"There are scenarios where CAN wireless to CAN machine connectivity works, but there are many other cases where high-speed ISOBUS will be needed. These especially come into play when matching up grain equipment with combines from different companies during offloading."

Also set to improve is the compatibility and functionality of in-cab cameras and monitors. Differing from the standalone wire systems and cables that cluttered cabs and often made upgrades and installations impossible, Smart says high-speed ISOBUS will enable farmers to easily integrate cameras into implements and allow for real-time viewing of machines in action.

Growing Benefits and Anticipation

Farmers have enjoyed improvements to compatibility over the years from VT to CAN-based ISOBUS, yet the remaining ISOBUS shortcomings require them to experiment with various setups and anticipate inevitable challenges.

Seth Wenzel, who strip-tills 4,000 acres of corn and soybeans in Kent, Ill., also operates Harness Technologies, a precision sales and service business. Wenzel uses a variety of different brands depending on season and crop type, putting together different brands to produce the most consistent results,

On strip-tilled corn, for example, he uses two different strip-till rigs: a 24-row DB60 bar with Redball strip-till units and a 12–row Case IH NTX5310 equipped with a dual-cooler setup from Raven.

The differentiation continues into planting season, as Wenzel features different data transfer systems for his corn and soybean planters. For corn, his 24-row John Deere 1770 planter works well with his Deere GreenStar3 Controller and 2630 display for planter functions. He's also had success with an Ag Leader InCommand 1200 for RTK control on that setup.

He's discovered, however, that his two Kinze 3600 16- and 31- row soybean planters work better with Ag Leader's AgFiniti data transfer system than the John Deere interface.

"I like the display and interface with the soybean planter better. We have Ag Leader harnesses on the tractors and the combine, so we can swap out the monitors easily. The Deere interface works well with the Deere equipment, but I also need systems that work with more brands."

Even as an equipment supplier and servicer, Wenzel himself is still prone to compatibility issues. Regardless of which setups work best, he stresses the importance of planning ahead.

"The more you do up-front, the better off you'll be. Think through the systems. What could fail or need replacing?" Wenzel says. "What's the order time on some items? When it's April 10 and you have a problem and the part won't be available until April 15, that's valuable time lost that could have been avoided with some planning."

Bryan Biegler of Biegler Farms, a 2,500-acre corn and soybean operation in Lake Wilson, Minn., utilizes mostly Case IH for his larger-scale equipment. Although on the monitor and input side, he's used a variety of different brands to improve variable-rate control and autosteer accuracy over his 10 years of precision investment.

"We started out with Ag Leader and some original equipment from Case IH, but we have gone to a Trimble 2050 controller following an RTK signal for auto-steering and a Precision Planting 20/20 system to control seed rate in the spring and monitor yields in the fall," Biegler says. "I like the 20/20 unit because it is easier for me to use and sends the information directly to the cloud."

The Trimble-Precision Planting setup has proven consistent in recent seasons and he's since added a series of installations over the past year, including Precision Planting CleanSweep units for seeding accuracy and a third 2050 unit from Trimble for his Hagie self-propelled sprayer. Yet going forward, he hopes to reduce his number of cab monitors.

"It can get claustrophobic, but I chose the Trimble controller because it was the easiest to hook into the Case IH autosteering system," he says. "In the next 5 years, I hope to consolidate systems where I need only one monitor."

A notable disconnect Biegler sees between farmers and manufacturers is the wording used on troubleshooting websites. For seasonal equipment in particular, the lack of farmer-friendly terms in favor of engineering phrases can create additional confusion.

"One time, out of the blue, the autosteering system quit working. I shut off the system, then rebooted it and it still wouldn't work," Biegler says. "I finally broke down and called my Trimble dealer, and he suggested shutting off the tractor, too, then rebooting the whole system. That worked. A simple fix, but it required a call to the dealer to figure it out."

Tools of the Future? Naw … They're Already Here!

Here are 6 examples of recent technology developments that will dramatically change the way you no-till in the coming years.

A No-Till Farmer Staff Report

With the next generation of no-tillers looking for ways to improve productivity, the automation of many no-till cropping tasks makes more sense than ever. Auto-guidance, precision farming, driverless tractors and cabless combines are only a few of the inevitable steps coming with the need for increased efficiency.

To illustrate a few of the changes in store for agriculture, we've highlighted a few examples of recently available technology. Many more ag technology innovations will be coming between now and 2030.

Cabless Combines

In the future, a farmer sitting in a pickup truck or farm office will be able to control several combines or other self-propelled machines.

The cabless concept already being evaluated with Case IH and New Holland brands utilizes master-slave technology where other machines end up duplicating what one machine is doing in a field.

Other tractor manufacturers are researching similar concepts.

With this technology, tractors pulling tillage tools, planters or drills — along with sprayers, combines, forage harvesters and other self-propelled machines — can run without drivers or cabs.

Bigger Isn't the Answer

After spending over 25 years developing some of the world's largest seeding equipment, Norbert Beaujot has designed a more efficient smaller system for no-tilling various crops.

The long-term owner of SeedMaster Mfg. in Emerald Park, Sask., has come up with what he calls the DOT autonomous farming platform, where an implement is being carried rather than pulled through a field. The 160-hp diesel-powered, hydraulically-driven U-shaped tool carrier wraps around the implement such as a 30-foot no-till grain drill. With specialized guidance and software, the machine follows a computerized plan that offers the most efficient, fuel-saving field operation.

Not only does the 8,000-pound DOT unit eliminate the need for a high horse-

NO CAB, NO DRIVER. One operator may be able to control several combines, sprayers, forage harvesters or other self-propelled units while sitting in a pickup truck.

ROW RUNNERS. No-tillers may interseed cover crops a few weeks ahead of harvesting corn or soybeans with units that run between the rows under the growing crop.

power, four-wheel-drive extra heavy tractor, but it also eliminates the need for implement axles, wheel and hitches.

The 'Rowbots'

For sidedressing nitrogen late in the growing season or seeding cover crops a few weeks prior to harvesting corn, the Rowbot unit runs between the rows of a growing crop.

Powered by a GPS-guided diesel-powered hydraulic four-wheel-drive system, the 22-inch wide and 7-foot-long machines include a 40-gallon tank holding liquid nitrogen for sidedressing and a seed hopper for cover-crop seed.

Small enough to run between 30-inch rows, the crop canopy or height is not an issue with in-season nitrogen application or cover crop seeding. The developers calculate the machines can sidedress nitrogen for $10 an acre and seed cover crops for $15 an acre.

Compact Seeders

Replacing a traditional planter, AGCO Fendt has introduced a programmable autonomous seeding unit. A "swarm" of 12-15 of these compact seeding units could handle the same acreage as a single 8-row corn planter.

Using a telephone app, growers will be able to calculate variables, avoid other units in the field reduce costly overlaps and overplanting issues.

Driverless Farming

Combining the latest engineering and technology, Case IH engineers have developed an autonomous tractor that doesn't require a driver or cab. Onboard electronics account for implement widths, determine the most efficient field paths based on terrain, avoid other machines working in the same field and steer around posts, poles, ponds, rock piles and other obstructions in fields.

A remote operator can supervise and adjust field patterns from his or her farm office desktop computer or with an electronic tablet while sitting in a pickup truck. Through the use of radar and onboard video cameras, the tractor can sense stationary or moving obstacles in its path and come to a stop until the operator is notified by audio and visual alerts and assigns a new path.

What Link Will Farmers be in Blockchain?

Many consumers are comfortable spending money with a mouse click, smartphone swipe or voice command, so the concept of blockchain shouldn't seem all that foreign.

The constant compilation of encrypted transaction data (or blocks), timestamped and verifiable is both intriguing and intimidating as a new model for how business is done.

So where will farmers fit into the model as it is accepted and adopted in agriculture?

Doug Applegate, strip-till farmer from Oakland, Iowa, has been working with Ag Gateway on traceability, tracking grain from the field to the processor and tracking chemistries used on those fields.

"Blockchain is getting more traction in ag," he says. "We're seeing it first in the fruit and vegetable markets, which is logical. There's been the ability to track those crops, but blockchain gives the process credibility because it's a distributed database that is virtually impossible to tamper with."

Another entry point could be in the soil carbon inventory, particularly in a no-till or strip-till environment. Healthy, well-balanced no-till soil has a natural capacity to sequestrate soil organic carbon (SOC).

The rule of thumb is somewhere between 800-1,400 pounds of SOC per acre per year. The conversion of metric tons (mt) of SOC to mt of CO_2e is 1:3.67 or 33 mt of CO_2e per-acre, per 10-year contract. Some countries, like Canada pay $30 per mt of CO_2e, which suggest carbon sequestration enrollment of $80-$100 per-acre, per-year over a 10-year enrollment.

The value of this SOC inventory addition to an initializing benchmark is to be certified by annual detailing of no-till processes and the carbon model for the cropping system as well as annual records such as spatial yield, fertilizer, fuel and mid-season imagery for biomass.

Grid soil tests and other certified crop advisors are also considered certification that as accumulated will permit the issuing of carbon tokens for trade, sale or saving. Blockchain can offer many enabling tools as well as complementary features that permit the monetization of the soil carbon service.

There are 2 types of soil carbon credits that can be certified. Avoidance by shifting from conventional tillage to no-tillage (CO_2 savings from soil emissions not released, lower fuel bills, fertilizer and pesticide savings due to the no-till switch), and sequestration of carbon into the example of SOC.

Avoidance carbon tokens are less certain in their ability to offset carbon emissions needing offsets. Soil Carbon Sequestration have more permanence as well as being well protected from the no-till cropping practice. This has some complexity and is why a blockchain could be an valuable enabler to soil carbon inventory.

WHAT, NO DRIVER? Autonomous tractors will tackle planting and seeding duties with ease and while dramatically slashing farm labor costs. A grower sitting at a computer in the farm office or in a pickup truck with an electronic tablet will be able to control these driverless units.

While the technology is already here, the main thing holding back autonomous vehicle usage are liability and safety issues. Once government rules allow manufacturers to market fully self-driving autonomous cars and trucks to run without an operator having their hands on the steering wheel, driverless tractors, combines and other self-propelled ag machinery won't be far behind.

Grinding Away Weeds

Fed up with the traditional chemical means for getting rid of weed seeds, Australian farmer Ray Harrington found a novel way to overcome mounting concerns with herbicide-resistant weeds.

The result for the Darkan, West Australia, grower is the development of the Harrington Seed Destructor, a trailer-mounted unit pulled behind the combine that processes the resulting chaff and weed seeds.

The unit features a screenless, high-speed impact mill that pulverizes more than 95% of the weed seeds so they can't

HARVESTING WHEAT, KILLING WEED SEEDS IN ONE PASS. As small grain chaff and weed seeds flow into the trailer-mounted Harrington Seed Destructor pulled behind a combine, an impact mill pulverizes the seeds so they won't be able to germinate.

What Exactly are the 'Things' in the Internet of Things?

What does the phrase Internet of Things, or IoT, mean to you? For many, it's an ambiguous reference, yet at the same time, it's a complex concept. Some suggest it's a consumer trend that will have limited application in agriculture, while others say it's confusing and its application is unknown at this point.

How IoT will impact the ag industry is debatable, but industry leaders suggest that IoT integration could be a game-changer — rooted in simplicity and connectivity of technology tools to include voice activation systems — that will revolutionize farming through increased connectivity, automation and mobility.

But how far along is agriculture in its adoption of IoT concepts and what does the future hold for development of these progressive platforms? Our editors spent time with precision farming representatives from ag manufacturers to understand how they define IoT, along with the greatest opportunities and obstacles to moving conceptual designs into commercial development.

Q *No-Till Farmer*: IoT is a relatively new concept in agriculture and maybe a little abstract, but how are you defining this trend?

Luke Zerby, brand marketing manager, New Holland: "I'm not trying to define IoT at this point because it's going to continuously change everything with precision farming. It's more about defining the opportunities. Connectivity is one of the biggest goals as well as the capability to work with a lot of different groups with our APIs. We want to tie in more farm controls back and forth across platforms, so that's a priority for us."

Jim Ethington, vice president of product, The Climate Corp.: "The word I come back to is connected. Within that bigger category is the idea of a connected cab. How do I take whatever piece of equipment I have traveling through that field and whatever data is being generated by it and stream it seamlessly into one place? I think of a connected field, whether I have a soil moisture monitor, a rain gauge, a pivot or a trap that catches insects or moths, or something like that."

Cody Light, senior marketing specialist, AGCO: "It's getting the internet into the cab and making the machine smarter. It's not about browsing YouTube and looking at email. If we can provide direct connections to 2 pieces of data that are important to the customer, like commodity prices or weather, and integrate those into the machine, that's huge. That's where things are going to be more beneficial, instead of just having an internet browser on a terminal."

Q *NTF*: When it comes to data capturing and integrating or sharing collected knowledge, what is most important?

Ethington: "We've been asking growers for a while 'What are the main uses that you have for the data you collect?' By far the number one response is 'I am saving it for later when somebody figures out how to do something useful with it.' Making it easy to put all that data into one place and actually doing the hard work to figure out how to turn that into insights and better decisions is what we're working toward. It all starts with connected piece of machinery because it's really a lot of work to move data around all the time by hand and a lot of that data doesn't end up getting used."

Zerby: "If a farmer hears about an agronomist who lives in California, but he happens to be farming in Ontario, he can still work with that agronomist and get an answer right away. IoT is about making sure we have that flow and transfer of data and we're transferring the correct data."

Q *NTF*: IoT is ingrained in consumer technology we use today. What challenges does the ag industry have to overcome to advance IoT into mainstream farming?

Scott Brotherton, product marketing manager, John Deere: "We have to help farmers understand the why. Why does it matter? If you just tell me technology is cool, it's not going to be enough."

Light: "One of the biggest hurdles today is just data privacy and security. People want to know their data is safe, no matter what they're doing. When you start broadcasting things over the internet there are a lot of smart people out there who can tie into that the data. A priority is making sure data is secure and giving growers confidence everything's going to be okay in the machine and that nobody can tie into it and take control of their machine or their data."

INCREASING NO-TILL EFFICIENCY WITHOUT NEEDING A DRIVER. It takes only a few seconds for four independently operated hydrostatic wheels to lift specially-designed implements, such as a 30-foot no-till grain drill, onto the newly developed SeedMaster DOT U-shaped "prime mover" platform.

germinate. Tests under U.S. conditions are underway at the University of Illinois.

"Based on the success they've seen in Australia, we would be confident in saying the machine would be effective on some our larger-seeded weed species," says crop scientist Aaron Hager. "But we need to get a better feel of how it will work on smaller-seeded weed species."

Taking a look at other mechanical weed control options John Deere engineers are looking at several combine innovations that could capture weeds seeds. However, these attachments would likely require a combine to have an extra 10-20 horsepower.

As problems continue to worsen with herbicide-resistant weeds, adding some type of innovative mechanical weed control for use along with herbicides may definitely have merit.

Harnessing Data, Tweaking Inputs Pushes No-Till Production to New Heights

Variable-rate technology helps North Dakota's Chad Rubbelke better utilize precision data to apply nutrients precisely and boost crop yields.

By Chad Rubbelke
As interviewed by Martha Mintz

I was born into no-till, you could say. It's really all I've ever known. My grandfather was a big proponent for the environment and was an advocate when my Dad pushed for reducing tillage on our farm in the early 1990s.

We're on the edge of the Prairie Pothole region right on the continental divide just southwest of Minot, N.D. Our farm is hilly, and we have a mixed bag of soils. On the hilltops, we've eroded clay soils that transition to heavy clays in the bottoms, and everything in between.

Our climate is fairly dry. However, the farm is situated at a slightly higher elevation than the surrounding area, which keeps our temperatures a bit cooler than the rest of the region. We raise canola, soybeans, durum and hard wheat currently, but have raised a wide array of crops in the past, including sunflowers and flax.

The number of crops we grow has dwindled a bit as some of the specialty markets we were growing for have backed off, especially for high-oleic crops. We still grow premium crops like durum to hit those higher price points. Quality, yield and profitability are all targets on our farm. No-till protects our highly erodible soils and our soil moisture.

The hills and dry soils were drivers behind our move to no-till. My father helped a neighbor farm a bit and eventually took over his farm. This neighbor was one of the first to push no-till in our region, as he purchased one of the first no-till box drills that came out in the 1980s.

We've long since moved to full no-till and more recently have been advancing in other areas, such as by digging into applications for variable-rate technology.

Again, due to our hills and wide ranges of soil types and conditions, we've found using variable-rate technology has helped push our yields further than ever before. By intensifying our operation through variable rate and other strategies we've increased our Actual Production History (APH) for crop insurance by 100% across the farm over the last 10 years. Our yields

DIGGING FOR IMPROVEMENT. Soil and tissue testing have helped Chad Rubbelke identify nutrient deficiencies to help him tweak his inputs and maximize yields. Recently, they started applying molybdenum to soybeans to improve nodulation and yield, both of which can suffer in their slightly high pH soils.

keep increasing on all our crops and we're still looking for the top.

We're also paying a lot closer attention to what nutrients are in our soils and which ones are truly being made available to our plants. It's all working toward higher yields and hitting higher quality points, especially with our specialty crops.

Shifting Fertilizer Gears

Dad started no-tilling in the 1990s, but it wasn't a zero-till situation. He would knife in anhydrous in the fall or spring and no-till crops with a Morris no-till air drill. Dad's focus was shifting to soil health and it seemed to him that anhydrous was sterilizing our soils, as they were more compacted and lifeless. You couldn't find an earthworm.

In the early 2000s, he stopped using anhydrous and started applying urea for his nitrogen (N). The neighbor we were farming with had a spreader, so Dad started spreading urea in spring ahead of planting.

Yields not only held their own but improved. We've been using urea ever since but have switched up how and when we apply to maximize benefit on various crops, including precision applications.

Our latest no-till air seeder helped us take the next step with our fertility program by allowing us to do variable-rate fertilizer applications.

I became more interested in variable-rate fertilizer while raising durum and realized the overall grain quality wasn't as high as it should be. I realized this was likely due to the variability in our soils and nutrient availability. Some areas were producing top quality while others were lagging in both yield and quality. .

We've been using variable-rate. With that technology and tweaks in hybrid selection and using micronutrients, yields have increased and continue to increase. It's a bit hard to assign exact yield increase to as we've dealt with drought, but in 2017 our durum crop was well above the county average.

Our quality is increasing, but because quality and yield are a tradeoff based on nutrient availability, the quality hasn't moved as quickly.

Once we dial in our top yield we'll be able to push the crop quality higher, too.

DIGGING DATA. After years of collecting raw data with little application for it, Chad Rubbelke is now using the Climate FieldView app to compile data from yield monitors to aerial imagery. The data is then displayed in a user-friendly way that Rubbelke can use to make fact-based management decisions.

Our setup is a 43-foot John Deere 1895 air drill with three ranks. The first is a rank of discs we use to mid-row band fertilizer. The next two are seed ranks. When using both seed ranks I can plant 10-inch rows, or I can lift one to plant in 20-inch rows depending on the crop.

We mid-row band about a third of our N at planting and come back and top-dress with the balance of the urea later. Both applications are variable-rate based on the farm data we've collected.

Over the years I've done both grid and zone soil sampling. We also have 20 years worth of aerial images and our combine yield maps. All the data was layered together to come up with variable-rate prescriptions for urea, phosphorus, potassium and sulfur based on our yield goals and the potential of the acres we're planting.

The drill has hydraulic seed and fertilizer cartridges which I control with my Deere GreenStar 2630 monitor to control our variable-rate applications, coupled with the Climate FieldView app to record everything we're doing and compile this information with the rest of our data.

Success In Simplicity

I feel the FieldView app will help propel our farm forward faster than ever before. For years we've collected raw data but didn't know what to do with it in most cases.

With FieldView, I use Bluetooth to wirelessly transfer data from our sprayer, air seeder and combine to my tablet. A user-friendly displays what technologies, hybrids or varieties and inputs are working for us.

I'm able to track down where there are production increases and cross reference them with other data, like weather history of the field and soil type, to pinpoint exactly what's driving yield.

The app also helped with on-farm research. I do variety trials to determine which ones will perform best in our conditions. In past years, I'd have to wing it with data collection by observing the yield monitor and weighing out the grain in the field. Then I'd roughly calculate which variety was better based on that information alone.

With the app I can get the yield data and layer in soil maps and other data to get a better picture of a variety's performance. What I've discovered is one variety may perform better in our heavier soils while another does better on the tougher hill soils. Just looking at the total yield wasn't a great indicator of which variety was the best.

Now I can now select the variety that will best perform on a field-to-field basis. A field with mostly heavy bottom ground will get a different variety than one consisting of mostly eroded hilltop soil. Eventually I hope to have multiple varieties in my drill and switch within a field to get the right variety on the right acres.

For now, though, the more detailed data collection and simple display will cut years off my variety trials. And help me dial in more quickly and precisely to figure out what's occurring in those plots.

The same is true for my on-farm input trials. I'm a "show me" person. I'm willing to try a lot of different things to help push yields, but they must prove themselves.

There are a lot of products that don't work, so my answer to salespeople is to give me enough product to do a trial and I will return any results to them. If it works, I'll use it and they can use the data to help make more sales. I've got tests on the farm for everything from seaweed extract to products used to increase foliage in greenhouse production.

It's been a bit difficult to accurately evaluate some of these applications as the benefit is often just a couple of bushels. With FieldView, though, we should be able to get a far more precise look and be able to better crunch the data. I've also started working with In10t, a digital ag company that partners with farmers and compensates them for research.

I partnered with them this past winter and now have multiple farm trials out for them. It's exciting because they have me trying chemistries from throughout the U.S. that aren't typically used or available in my area. I'm getting to work with companies outside my usual circle and try out their products while getting paid to do it. I see this being very beneficial to us finding new products that work for us in the future.

A Closer Look

As we push for higher yields and improving quality, we've realized utilizing data and testing is necessary to push forward. This includes soil and tissue sampling.

For soil sampling we mainly do zone sampling. It's been helpful, but you're pulling multiple samples from the same zone and that can include hilltops and bottoms. In some cases it's not giving an accurate picture of what's going on in the field.

As we looked at variable-rate technologies we've done a couple rounds of grid sampling. Those are really eye opening because it gives you not only what each area of the field needs, but gives you a general idea of what the entire field is truly made up of. I feel getting a detailed look at your soils and applying what's needed, where it's needed, is a cheap and easy way of increasing your yields.

Testing can also help identify problems, especially when combined with tissue testing. Our heavy clay soils have always tested high for potassium, but tissue testing showed it was lacking in our plants.

BETTER CROPS. Chad Rubbelke credits precision fertilizer applications for overcoming challenges with variable soils, nutrient availability and improving yields and quality for durum wheat. Durum yields on his farm in 2017 were well above the county average.

We started using potassium chloride to get plant-available potassium to the crop and get the added benefit of the chloride. Chloride helps increase the health of your plant, making it more disease resistant and giving it better standability. That really opened our eyes to the fact we needed to take a closer look at micronutrients.

Our soil testing helped us discover zinc could give us some benefit. We now use it with our wheat either as a seed treatment or a foliar application. Zinc is a nutrient wheat uses at the tillering phase. Adding zinc seems to get wheat out of the ground faster with better early growth and more robust tillering. This gives a great head start toward higher yields.

Molybdenum Boost

Soybeans are another crop where we've put micronutrients to work. Our high-pH North Dakota soils are far from ideal for soybean production, but we can raise a crop thanks to improving genetics.

This year we started applying molybdenum to our soybeans, which is supposed to improve nodulation, and in turn, improves yield. We've done a lot of root sampling and it looks like the moly applications are really promising.

It's not all micronutrients. We've also looked at herbicide and fungicide applications to improve yields. With no-till we strive to keep clean fields, running our Deere 4830 sprayer in spring and fall to keep weed pressure down, using different modes of action to help hold off resistance.

In our durum I'm trying to do more flagleaf fungicide applications. The goal is to protect the flagleaf, giving it more green, healthy surface to harvest the sun and produce yield.

However, wet conditions in recent years have demanded instead that I stick with an application after the head emerges to protect against head scab. I want to produce a big crop but I have to look at cost, too. On wet years it makes more financial sense to do the head application instead of the flagleaf application. Doing both is cost prohibitive.

We want to be more efficient both for profitability and as we look at the carbon footprint of our farm. I've punched our data into the Field to Market program calculator which tells you how much carbon your practices are adding or removing from the soil.

I want carbon to be sequestering more carbon and no-till and better use of fertility are ways to accomplish that. I think a farm's carbon footprint and overall sustainability are things that will continue to grow as big topics in the industry in the future so I want to stay ahead on our farm.

I'll continue to look forward and seek out those little tweaks that give us an advantage in yield, quality and sustainability.

No-Till and Precision 'Scripting' Improves Yields from Sandy Soils

Family's collective inputs help improve soil health through cover crops, nutrient management and yield mapping in Wisconsin's "Frac Sands" region.

By Mark McNeely

In an area of northwestern Wisconsin known for its teeming fracture sand mining industry, no-tiller Jeff Lake, his wife, Kelly, and son, Jake, are carving out a successful no-till operation on 1,500 acres of irregularly-shaped, contoured fields.

Despite the porous nature of their sandy loam/loamy sand soils, the Lakes are beginning to see improved soil organic matter and soil health with their switch to no-till practices.

Originally a dairy farm dating back to the late 1800s, Jake represents the 6th generation on this family-owned farm, where he's immersing himself in the precision and prescription aspects of the operation.

After exiting dairy operations in 1999, Jeff would run a disc in the spring as his method of soil preparation prior to planting.

"Then, about 6-8 years ago, we decided we needed to go in a different direction with no-till. We weren't getting the yields we wanted and we needed to reduce soil erosion to protect our fields and waterways," Jeff says.

While the Lakes grow mainly cash crops — roughly 60% corn, 40% soybeans — they're implementing alfalfa into their operation to support a growing 30-head herd of Angus beef cattle.

"We have about 50-60 acres of hay for forage. We're slowly ramping up the Angus herd, selling the meats locally," Jeff says.

In a Sandbox

With about 500 of their acres under irrigation, the Lakes were looking at improving the organic matter levels and cation exchange capacity in their sandy soils.

Both Jeff and Jake estimate that they have dozens of distinct soil types — including sandy loams such as Plainfield, Hubbard and Chetek — that can vary even under just one pivot. "With the Hay River being so close to our fields, we just have tons of variations, but we like the way our overall soil health is coming along," Jake says.

In one particular field, for example, its soil organic matter level of 2.4% is a marked improvement compared to 6-7 years ago, when the same field was below 2%. Some fields are still in the 1% range.

Although they initially saw a slight yield drag in their first transition to no-till corn, corn and soybeans rota-

OPTIMIZING SEEDING. Jeff Lake (left) and his son, Jake, no-till 1,500 acres of sandy soils in northwestern Wisconsin. The Lakes use EFC Systems' Profit Zone Manager tool to help them optimize variable-rate corn seeding rates between 18,000 and 32,000 with their 16-row Case IH 1200 Early Riser planter.

tions, the Lakes quickly adopted a cover crop strategy to help build soil tilth and retain much-needed moisture.

In this northern region, red clover and annual ryegrass need to be interseeded into corn early to help the plants establish growth before colder weather arrives. "We interseeded at pre-tassel and when the corn leaves started turning yellow. We're going to try at about V8 stage," Jeff notes.

Interseeding has been both by helicopter and using the Lake's Case IH 3310 high-boy fertilizer spreader during the last urea application. They've also tried cereal rye and wheat in previous years.

"On our farm we've noticed higher yields, which we attribute to better knowledge of our soil health, cover crops and spoon feeding our crops nutrients throughout the season with multiple passes," Jeff says.

"The high-boy spreader is the big thing that has helped our farm's nutrient management program. We've watched our corn grow bigger and we have fewer nutrients winding up in the water."

Average yields before no-till were about 150 bushels per acre for corn. 2017 was a good year, Jeff says, with an average of 185 bushels across the whole farm. Soybeans used to hover around 35 bushels per acre and those are now pushing 45-50 bushels.

Filling a Prescription

Jake has demonstrated an affinity for technology and is Jeff's go-to person for analyzing yield maps and determining field prescriptions.

"We recently started working with prescriptions, looking at our fertility, soil types and yield data," Jake says. "We can now put a dollar value on every acre as far as seeding and split applications of fertilizer."

With their 16-row Case IH 1200 Early Riser corn planter, they'll apply at-plant nutrients both in furrow and in a 2-by-2-inch configuration. In 2018, they were using 10-15-2.6 formulation, along with 6½ pounds of sulfur and ¼ pounds of zinc at about 15-17 gallons per acre.

This is followed with two in-season fertilizer applications, with 150 pounds per acre of ammonium sulfate (AMS) and 150 pounds per acre of urea sidedressed at V6 and 150 pounds per acre of urea applied at V10. Nitrogen (N) for corn nets out to approximately 0.8 pounds per bushel, Jeff says.

A Demco 1,000-gallon, pull-type sprayer and Case IH 3310 high-boy fertilizer spreader are used to apply the liquid and dry fertilizer. For soybeans, the Lakes prefer to sidedress AMS post-emergence.

"Our soils are typically high in phosphorous around here. It's just locked up in the sand so we don't really add too much phosphorous. We do add N and potash and we're trying to come up with a cocktail of micronutrients," Jeff says.

"We can now put a dollar value on every acre as far as seeding and split applications of fertilizer…" *— Jake Lake*

Soil samples are taken every 2-3 years on the entire farm in 5-acre grids. The tests have revealed a need for sulfur, zinc and manganese, while boron and copper levels are sufficient.

"As something different, we are applying high-calcium lime from municipal water treatment facilities because our magnesium levels are high so we're looking for more of a calcium source," Jeff says.

The lime is broadcast with a manure spreader. A limited amount of manure is also available from the cattle, which is applied to the Lake's sandiest soils.

Variable-Rate = $

Planting several varieties of corn from DeKalb, Pioneer, Channel and Rob-See-Co, Jeff variable-rates his populations to match the available yield map data. They vary their rates from 18,000-32,000 seeds per acre on 30-inch rows.

With the efficiencies gained using no-till by eliminating tillage passes, Jeff says he can plant at a slower speed and reduce errors. Their Early Riser planter is equipped with individual row shutoffs.

"We now have it in our minds that the seed savings are there," Jeff says. "It just doesn't make sense to put down 30,000 seeds in a sandier area. By putting down, say, 22,000 instead we might be getting fewer ears, but they're bigger ears that don't fall through the combine."

Jeff uses a flex-ear hybrid to maximize growth potential. He estimates that in 2017 alone he saved $12,000 in seed corn costs.

Their Hiniker air drill doesn't have precision technology, so soybeans are no-tilled at 133,000 seeds per acre in 15-inch rows. "We don't know if the payout is there yet in beans to switch to variable-rate," Jeff says.

The Lake's seeding rate and nutrient management evaluations have been made possible, in part, because they joined a unique partnership that formed in 2016 through the Hay River Watershed.

Agronomic planning was offered using EFC Systems' AgSolver Profit Zone Manager software to identify underperforming acres, with the goal improving land usage and potentially providing wildlife habitat.

The software can put actual dollar values on any areas of mapped land, which aids in identifying marginal acres on farms in the watershed. This enables alternative uses of land while increasing farmers' bottom lines, improving soil health and water quality and benefiting wildlife.

Jeff says Scott Stipetich of Pheasants Forever got involved through his watershed district and talked to him about how the practice of precision agriculture could identify places they might not even want to plant — places that weren't providing any return, or even a negative return.

Ask the Right Questions When Evaluating New Precision Technologies

By Ray Asebedo

Ag professionals are nearly overwhelmed by the amount of precision technologies available. New developments in precision and connective technologies are turning the farm into a digital storm of data.

There are soil moisture sensors, satellite imagery, drones, autonomous tractors and artificial intelligence (AI) like Siri that will all supposedly increase profit per-acre. These claims have become commonplace in broad acre crop production.

Even though I have a Ph.D. in Soil Fertility and have been researching precision technologies for the past decade, even I can become overwhelmed by the array of advancements. So, I go back to my Midwestern roots and keep it simple by asking the right questions to determine if a new technology proves itself trustworthy and has potential to make more money for the farm:

1. Does the technology address or impact more than one pillar of agronomic management: planting, fertility, protection and harvest?
2. What is the perceived level of impact on profit per-acre by adopting the technology?
3. Are there any proven results to verify the profitability of the new technology?
4. What is the DNA of the company who created the technology? Do any of the executives and/or product team have an ag background?
5. Do I need a Ph.D. in order to use the technology?

These types of questions have served many ag professionals in the sea of products and services. Consider the implementation of auto-steer which was one of the first revolutionary precision technologies that has now become a standardized technology. Auto-steer helped ensure equally spaced planting to help optimize plant population and use of land area.

Auto-steer impacted planting, fertility, protection and harvest, thus having a high perceived value for improving profit per-acre. Universities were quick to conduct applied on-farm research to show yield benefits, input reductions and operational efficiency improvements.

> **"Are there proven results to verify profitability of a new technology? Make a company earn your trust..."**

Real-world results verified that auto-steer would be profitable. Initial companies that developed and marketed systems were deeply entrenched in ag and GNSS technology.

Let's consider the recent buzz over using drones for improving agronomic analysis. Drones were made out as the next big thing, and were supposed to increase farm profitability by unimaginable levels.

I saw multiple ways for drones to improve farm profitability in nutrient management. However, rather than jumping on the train saying drones will save the world, I asked my questions.

Drones have the capability to impact planting by assessing germination, fertility through nitrogen (N) management, and crop protection by disease and pest detection. Therefore, the perceived level for improving profit per acre is high.

However, there has been limited verification to prove the profitability of drones in any of these areas. Universities, companies and other third parties are continuously testing drone technology and are discovering more development is needed in order to get drones to improve farm management and profitability.

At the start of the drone "bubble" in ag, there were many startup companies that flooded the ag market, and very few of them had personnel with ag backgrounds. As a result, a lot of false promises were made on what drone technology was capable of simply because the companies didn't have the knowledge base required.

Asking the right questions revealed that drones have the possibility to improve items like N recommendations, but algorithms or easy to use software can make this a challenge.

With anything new, there is always the hope that it could help your farmers be more profitable. Amidst this excitement, it is critical to ask the right questions, and make any precision technology and the company selling it earn your trust.

Any new technology should be easy to understand and have your confidence that it will improve farm profitability. All it takes is asking the right questions.

Dr. Ray Asebedo completed his B.S. degree in agronomy and obtained his Ph.D. in soil fertility in 2015 from Kansas State University. He has taught courses in precision agriculture and his research focuses on the development of agronomic algorithms to drive the artificial intelligence of ground and aerial autonomous vehicles (GAVs, UAVs).

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