Agriculturalists' Use of Precision Agriculture Technology and Reliance on Mobile Devices

Terry Griffin (twgiffin@ksu.edu) – K-State Department of Agricultural Economics
October 2020

Abstract

As with many businesses over the last 20 years, operating a crop or livestock farm has become highly dependent on computers. And given the nature of agricultural work, farms have become especially reliant on mobile electronic devices. A farming enterprise involves a complex ecosystem of people and information, including the farms themselves, their supply chains, government advisors, and multiple sources of data needed to understand and manage farm conditions. Mobile devices play a key role for each of the players in this system, and the importance of mobile devices is only increasing as precision agriculture becomes the order of the day for 21st-century farmers.

What is precision agriculture?

Precision agriculture—often described as "information technology applied to agriculture"— is a core element of the modern farming ecosystem and involves a wide variety of technologies. Traditionally, "precision agriculture" described the use of satellite-based navigation systems (like GPS), or of basic electronic sensors to measure things like crop yield or the moisture of the soil. Those technologies create an important foundation for precision agriculture and have been widely adopted (Schimmelpfennig, 2016). But advances in modern computing have led to a rapid expansion in the kinds of technologies available to hone agricultural practices. Farm equipment like tractors and combines can now be steered automatically, ensuring that none of the equipment's passes through the field are wasted and that no segment of field goes unfarmed. Another suite of technologies, known collectively as "variable rate technology" (or "VRT"), allows for on-the-go application of seeds or fertilizer at different rates across a field to improve output and use fewer resources.

More cutting edge technologies empower farmers and their advisors to collect huge amounts of highly targeted data about production, and to control devices that manage the use of their resources—from water, to seeds, to fertilizer, to feed for livestock—with greater precision than ever before. Smart cameras are automatically identifying diseased plants; mobile sensors are monitoring the vital signs of dairy cows; remote-controlled drones are measuring the health of crops, and even herding cattle, all from above. Whatever the angle, the unique practical benefits of mobile technology have facilitated the rapid growth and integration of all these improvements into farmers' lives.

Why are precision agriculture technologies so important?

Precision agriculture technologies have driven dramatic increases in productivity and efficiency. From 1990 to 2018, the amount of land required to grow a given amount of corn or soybeans fell by 33% (Newton, 2020). Dairy farmers are producing 60 percent more milk from 30 percent fewer cows than in 1967 (Salfer, 2019). Farmers can thank precision agriculture technologies for a significant share of these gains. And experts view these technologies as necessary to ensure that these improvements do not plateau as land, fuel, and other farming inputs become more scarce.

The unique challenges of farming as a business further explain why precision agriculture technology has become so valuable. Farms operate on slim margins. U.S. corn farmers, to take one example, have an average profit of only $85 per acre after overhead expenses (Nowakowski, 2018). The pressure on profits in recent years has been particularly intense: in the years since 2014, corn has sold for an average of $3-4 a bushel, down from $6-$7 per bushel in 2013 (USDA NASS, 2020). The median annual farming income from 2015 to 2019 was negative (Todd and Whitt, 2020).

Particularly in times of reduced sale prices and expensive inputs, viability for a farmer in any given year depends on maximizing his resources and optimizing how those resources interact with the environment. That relationship is precarious. Corn, for instance, must be planted over a three-to-four week period once per year. If seeds are planted too early, the soil may be too cool for the seed to emerge; too late, and there is not enough time for the seed to develop into harvestable corn. On top of that, only a fraction of this already narrow month-long window is actually suitable for fieldwork. Adding to this complexity is that most farms producing corn also produce other crops such as soybeans, grain sorghum, and wheat; each crop competes for equipment and labor resources during key bottleneck times. Real-time data about environmental factors like temperature and moisture, as well as the ability to carefully track the use of resources like seeds, fertilizer, and water—not just in the moment, but year-to-year—becomes critical to maximizing output and, in turn, the chances of economic success (Griffin et al., 2018).

The economic benefits of using precision technologies are substantial. For example, farmers with access to maps of the yield of specific areas of their fields and the quality of their soil can expect a boost in technical efficiency of up to 7.2%, according to the results of USDA's Agricultural Resource Management Survey (ARMS) (McFadden, 2017). Yield monitors with VRT were associated with a 4% reduction in fertilizer costs (Schimmelpfennig, 2018). Farmers using automated guidance could increase their farm size from 3000 acres to 3335 acres while using the same equipment and still complete their farming operations in a timely manner, thus reducing fixed per-acre equipment expenses (Griffin et al., 2005).

But precision agriculture is not just important to farmers' economic success. Adoption of these technologies is increasingly viewed as essential to keep agricultural production apace with the growing needs of the global population and to preserve our environment in the process. As recent reporting explained: "The United Nations estimates that the world's growers will have to produce 70 percent more food using just 5 percent more land by 2050." Technology "is seen as the force that will get them there." Precision agriculture results in "fewer losses of fertilizer and pesticides to the environment, reduced water consumption, and reduced greenhouse gas emissions." Studies over the past decade have estimated that precision agriculture technologies have resulted in a 25% reduction in fuel expenditures and up to a 90% reduction in the use of pesticides. Adopters of soil testing with VRT had 33% higher nitrogen productivity than non-adopters on below-average soils (Khanna, 2001).

What role do mobile devices play in precision agriculture?

The development of some of the technologies just discussed started before the advent of modern smartphones or tablets. But given the huge flexibility and ever-increasing capabilities provided by smartphones and tablets, these mobile devices have increasingly taken a lead role in facilitating precision agriculture. Many crop farmers, for example, navigate their equipment using a tablet mounted in the cab of their tractor or combine. Tablets are frequently used to control drones that survey the fields. Smartphones alert dairy farmers of changes in the vital signs of their herd. Several example narratives describing how various players in the agriculture sector use mobile devices in precision agriculture are set forth in more detail in the Appendix.

In fact, smartphones and tablets are increasingly becoming not just a way, but the way that farmers engage in precision agriculture practices. One 2019 survey of over 2,000 corn, soybean, specialty crop, and livestock farmers found that 9 in 10 farmers used smartphones in the field (United Soybean, 2019). Most of the surveyed farmers used tablets (56%) or laptops (66%) in addition to their smartphones. In another recent survey conducted at the American Farm Bureau Federation's 2020 Annual Convention, 86.5% of attendees described mobile electronic devices or other connected technologies with apps as "essential" to their farming activities (American Farm Bureau Federation, 2020).

As in other sectors, mobile apps increasingly supply key avenues to accessing the innovations in precision agriculture. The number of useful mobile apps geared toward farmers has skyrocketed over the last decade (Arnall, 2018). Even by 2018, 70 percent of farmers had downloaded agricultural apps to their mobile devices (Farm Journal, 2018), and increased utilization of mobile apps by farmers in the subsequent two years is likely to mirror their explosive growth in society as a whole over the same period.

Apps are being developed by both the public and private sectors. Land-grant universities, through their extension specialists, develop and deploy apps to stakeholders like farmers, crop consultants, and crop scouts. The USDA, agricultural service providers, input retailers, and equipment manufacturers also develop mobile apps to help their customers.

These apps generally fall into two broad categories: standalone apps and apps that support precision agriculture systems that use external devices. Standalone apps include things like weather trackers, commodity-price checkers, and smart camera software that can identify plants and weeds in real time. They also include apps—many developed by universities—that provide interactive electronic versions of what previously would have been large instructional guides or handbooks—covering key issues like pest identification,[1] wheat variety selection,[2] grain-drill calibration,[3] and field scouting.[4] Still other apps tap into the availability of "big data" on farms by allowing farmers, for example, to analyze the historical yield of their land at a highly granular level, which helps them efficiently allocate inputs like seed and fertilizer during growing season.

Apps that support precision agriculture systems include controllers for drones, monitors for field and livestock sensors, and tools to prescribe the amount of fertilizer to apply or pesticide to spray. Many of these system-based apps are provided by the equipment manufacturer—John Deere, for instance, offers a suite of popular iOS and Android apps, including one that allows farmers to monitor and diagnose problems with their machines from afar.[5] CASE IH, another leading equipment manufacturer, offers apps that connect farmers with equipment dealers and facilitate machine repairs.[6]

Beyond precision agriculture per se, farmers and other agriculturalists use mobile devices for a host of important everyday tasks—from finding directions, to shopping for inputs or replacement equipment parts, to

[1] DASNR, 2019. OSU Turfgrass Pocket Guide. https://play.google.com/store/apps/details?id=edu.okstate.dasnr.turfgrassguide

[2] Oklahoma State University 2019. Wheat Variety Selection. https://apps.apple.com/us/app/wheat-variety-selection/id1489180273?ls=1

[3] DASNR, 2016. Grain Drill Calibration Calculator. https://play.google.com/store/apps/details?id=edu.okstate.dasnr.calibration

[4] Purdue. Purdue University Mobile Apps. https://ag.purdue.edu/agry/dtc/Pages/MobileApps.aspx

[5] https://www.deere.com/en/technology-products/precision-ag-technology/data-management/jdlink/

[6] https://www.caseih.com/northamerica/en-us/service/resources/apps

networking with colleagues and experts and accessing repair manuals or checking the weather. A recent Pew survey showed that 1 out of 5 rural Americans accessed the internet only using a smartphone (i.e., they did not have a high-speed internet connection at home), which is a higher rate of smartphone-exclusivity than either urban or suburban Americans (Anderson, 2019). Nearly 90% of farmers used mobile devices to send or receive text messages (Farm Journal, 2018). In terms of social media, Farm Journal reported that 58% and 14% of farmers used Facebook and Twitter, respectively, on their mobile devices, with half of respondents checking these social media platforms at least once a day.

What does the future hold for precision agriculture?

As seen in the wide range of cutting-edge farming technologies, there is no shortage of innovation in precision agriculture. Indeed, the precision agriculture industry is booming: the market was worth an estimated $4.7 billion in 2019 and is anticipated to grow at some 13% per year until 2027 (Grand View Research, 2020).

The pressing question for the future of agriculture is how to ensure widespread use of precision agriculture technologies that help produce more food with fewer resources.

On one hand, rural demographic data suggests that precision agriculture will only become more prevalent. By 2041, one third of farm operators are expected to be from the Millennial generation—a generation that data show to be very swift technology adopters (Griffin et al. 2019). One recent study found Millennials 83% and 77% more likely to use automated guidance and yield monitors, respectively, than their Baby Boomer counterparts, and that Millennial farmers were also 121% more likely to adopt variable rate applications of fertilizer sooner after they became available (Ofori et al., 2020).

But hurdles still stand in the way of universal adoption of precision agriculture technologies. For one thing, modern precision agriculture—from basic soil monitors to cutting-edge big-data aggregation—depends on fast, reliable internet (Griffin et al., 2016). Even as of 2019, nearly 60% of surveyed U.S. farmers and ranchers said they did not have adequate internet connectivity to run their business (United Soybean, 2019). A significantly larger share of rural Americans (24%) than urban and suburban Americans (13% and 9%) say that high-speed internet is "a major problem" in their community (Anderson, 2018). Another survey found that 65% of agricultural producers declined to adopt certain technologies because of their cost, suggesting that, to break through production plateaus in the future, low-priced technologies will be key (Erickson et al., 2017). And it is not just the experimental, frontier uses of technology that may stand out of reach.

Insufficient wireless broadband connectivity leads to potential economic losses. Existing data transfer systems are time-consuming and inefficient, impairing farmers' ability to share production and other data with trusted partners (Coble et al., 2018). Agriculturalists would benefit from improved systems of wirelessly transferring data in real-time (Coble et al. 2018). At least some farmers are actively using telematics to track farm equipment in near real time via wireless cellular connectivity (Griffin et al., 2016). Limited wireless broadband connectivity in crop production areas has restricted the perceived benefits of precision agriculture and big data (Griffin et al., 2016).

Recognizing the need for increased adoption of these technologies, several federal agencies in recent years have made clear that ensuring their broad-based availability is a top priority. The 2018 Farm Bill, for example, created the FCC Task Force for Reviewing the Connectivity and Technology Needs of Precision Agriculture, and instructed it to "promote effective policy and regulatory solutions that encourage the adoption of broadband Internet access service on farms and ranches and promote precision agriculture." Given the intense economic pressures facing farmers, and the predicted rapid expansion of our food-production needs in the coming decades, governments are recognizing the need for close coordination and the devotion of significant public resources to the development and adoption of precision agriculture technology.

Appendix: Examples of Uses of Mobile Precision Agriculture Technology

A Day in the Life of a Farmer

This year, the family farmer controls 4,800 acres and will plant half corn and half soybeans, plus some wheat after corn in the winter. The farmer and his unpaid family members operate most farm equipment themselves, and—in contrast to those who run larger nearby farms—hire paid laborers only at the busiest times like planting and harvest. Modern precision agriculture technology is critical to this farmer's operation: he cannot remain competitive and productive without it.

A day leading up to planting

Temperatures are rising compared to just a few weeks earlier as the farmer counts down the number of days until spring planting season begins. He kicks the ground to loosen the soil, then leans down to pick up a handful to ribbon between his thumb and forefinger to feel the temperature. Then he pulls his smartphone from his pocket to check current soil temperature on a website that displays a regional "meso-net" of weather stations providing frequent, localized updates (A meso-net is a network of automated weather and environmental monitoring stations designed to observe mesoscale meteorological phenomena).
The most recent data indicate that the soil is 48 degrees at 2 inches; the farmer is waiting for the 7-day average soil temperature to hit 50 degrees before planting corn seed into the ground. He has been checking meso-net stations on his smartphone each afternoon to see that day's warmth and the progression of the average temperature.

A day during planting season

The weather finally decided to cooperate. The farmer had been monitoring the soil temperature daily, and it finally reached the desired level. It rained hard in recent weeks, and the farmer—using wireless in-soil monitors that he checks frequently with his smartphone—couldn't do any field work because the soil was too wet. Weekly text messages from the USDA National Agriculture Statistic Service ("NASS") confirmed that the number of days suitable for fieldwork over the past two weeks was well below average. About once a week, the farmer also has been checking current fieldwork conditions against long term expectations from an interactive land grant university website on his tablet. These data confirm that it is the right time to plant. The farmer ordered his corn seed on the seed manufacturer's mobile app after consulting with university specialists, crop consultants, and seed salespeople back in the fall, and has now loaded up his planter with seed that was just delivered. The tractor engine cranks, and the farmer hooks it up to the planter to transport the seed to the first field of the season to be planted. As the planter unfolds into its operating configuration, the farmer eagerly takes a photo then posts it to Twitter for his 1000 or so followers to view, hoping to attract the attention of landowners who he knows follow him on Twitter and who may be potential landlords in the future.

The planter looks ready to begin placing seed into the soil, but just as the farmer is about to begin, he realizes something is wrong. Rather than trying to describe what he's seeing on the complex screen, the farmer takes a photograph and texts it to his local equipment dealer's support group. A few minutes later, the farmer gets a phone call from the equipment dealer to discuss the setup procedure on the in-cab planter monitor. The equipment dealer can "see" and take control of the farmer's monitor via a modular telematics gateway. The equipment dealer support specialist applies the correct settings to the planter monitor via telematics remote connection capability. The updated settings fix the issue, saving the farmer time and enabling him to move forward and line up the first pass through the field. The farmer sits back and allows the automated guidance technology—which he sets up and tracks using an internet-connected touchscreen device in the cab—to make parallel passes through the field.

Inside the cab, the farmer frequently scans several in-cab mobile devices that help control and monitor the planting process. One of them controls seed singulation, ensuring that the planter drops only one seed at a time and that the limited space for corn in the field is used efficiently. Another device measures as-applied seeding rates—helping the farmer calibrate the total number of seeds planted per foot of land to maximize output without wasting seeds. Yet another device shows the farmer coverage maps, where the planter has already placed seeds in the soil. This helps to prevent doubling up of seeds in odd shaped fields, saving the farmer money and making it easier for more than one planter to work the same field.
As the farmer has been planting, another planter tractor, operated by his hired laborer, has been making passes though fields elsewhere on his land. The farmer peers at a tablet to determine how the other planter tractor is progressing before returning to check if he has any messages on his smartphone. One of three alerts is a calendar reminder of an upcoming weed identification webinar offered by the farmer's local land grant university. The planting operation is going well so far; the farmer calculates that if his luck holds, he may be able to catch a couple more episodes of the new Netflix series in between turning the tractor around at ends of the field.

The farmer checks his mobile device again to see how the other planter is progressing. With modern telematics and wireless cellular connectivity, the farmer can monitor several parameters in real time, including speed (and acres planted per hour), engine temperature, fuel level, and seed capacity. The farmer finds viewing this information has been especially important in managing multiple pieces of farm equipment. Based on fuel levels of both tractors planting, the farmer sends a diesel "nurse truck" to the other field to refuel the tractor driven by his hired laborer.

A day during in-season

The farmer's smartphone buzzes, indicating a new text message. He sees that his crop consultant, who is out checking the farmer's fields, has found a patch of unidentified weeds in the farmer's newly rented 160-acre tract. Although the field was previously farmed by a well-respected operation, the farmer had lingering concerns about the weed control and fertility programs. The farmer was happy to have hired the crop consultant, especially given all the unknown factors attendant to a new tract of land. The crop consultant had a good grasp of modern agricultural technology—including cutting-edge analytics and strong communications technology—that would benefit the farmer.

The consultant tells the farmer that he sent the images of the weeds to a university county agent—a local official who provides unbiased agricultural information and serves as an important link to university researchers. In a matter of minutes, the county agent sends a reply positively identifying the weed, along with approved herbicide recommendations to control it and regulatory information about the use of that herbicide. Although having to eradicate these unexpected weeds isn't the best news, since this herbicide was not on his original crop planning budget, the farmer is grateful to find out what the weed infestation is and what herbicides can control the outbreak. The farmer goes to the local cooperative app on his smartphone and orders the herbicide.

Later that day, the farmer transports his self-propelled sprayer to the tract of farmland infested with weeds and climbs into the cab. As the farmer finishes inputting spray settings into the digital spray monitor inside the cab, the retail sales agronomist arrives with herbicide from the cooperative. The crop consultant has already performed the calculations on his mobile device for the amount of herbicide and surfactant to include in the tank mix, and the farmer quickly loads the correct amount onboard the sprayer.

The crop consultant maps the infestation of weeds using an unmanned aerial vehicle (a “UAV,” commonly known as a drone), the GPS on his smartphone, and a specialized precision agriculture mapping app. The farmer thus has access to a customized map showing where herbicide is needed and not needed. In addition to the map, the consultant records a bird’s-eye video of the weedy spots from the UAV by controlling it with his smartphone. To avoid overapplication of the herbicide, the farmer will not be applying herbicide where weed infestations have not occurred within the field. As the farmer drives the sprayer parallel to the planter passes made several weeks earlier, the sprayer sprays predetermined areas of the field using a system that automatically controls sections of the “boom” (the arm of the sprayer that administers the herbicide). This automated boom control system has been especially useful to avoid wasting herbicide in areas where crops were not planted in the grass waterway meandering through the field. It is satisfying to see each section of the spray boom turning on and off consistent with the customized map, and to see this all displayed in real-time on the tablet mounted in its bracket within reach of the spray operator. Using the same touchscreen, the farmer can individually monitor each of the 72 nozzles across the spray boom to determine if they are performing as expected. Switching the display to rear-facing cameras, the farmer verifies the boom is spraying at desired height above the crop canopy before switching back to monitor remaining herbicide mix remaining in the spray tank.

The farmer checks a pair of apps on his smartphone one more time: one reports real-time moisture sensors inserted three feet deep in the soil. These moisture sensors indicate subsurface moisture is approaching critically low levels—the farmer will need to irrigate his crops if it does not rain this week. The other app provides a three-day weather forecast that the farmer will use to decide how to allocate hired labor to start irrigating. An alert indicates that weather conditions have changed such that the herbicide could drift to a neighbor’s field, so the farmer shuts down the sprayer to avoid damaging another farmer’s crop. Hopefully, weather conditions will be in his favor to continue spraying tomorrow.

A day of irrigation

The rain did not fall, so the farmer opts to irrigate several fields based on subsurface moisture sensor readings that he views on his smartphone. The center pivot irrigation system looks almost like a giant dinosaur skeleton on wheels as it revolves around the water well applying about one-quarter inch of water from its sprinklers. Based on aerial imagery viewed from a mobile device, the farmer notices that some sprinklers are not releasing as much water as others, so he decides to take a closer look. Using a UAV similar to the one his consultant used to map weeds, the farmer watches real-time video on his smartphone as the UAV hovers near the sprinkler. Rather than walking across the field and climbing 15 feet on top of the irrigator, he can see on his smartphone which sprinkler nozzle is malfunctioning and is able to determine which parts he needs to buy before making repairs. As the UAV returns to the edge of the field, the farmer is already placing orders on his tablet for replacement parts. Then an alert comes across his smartphone. On the other side of the county, a thunderstorm has popped up and dropped an inch of rain; the alert from his app reports that the precipitation is enough to warrant shutting down the field's irrigation system. Relieved to be able to protect the crops and save water, the farmer taps on his tablet screen, stopping irrigation water from being pumped and applied to his field.

A day during harvest season

One of the most exciting days on the farm is the first day of harvest. The combine harvester has many of the same types of touchscreen displays as the planter tractor and sprayer. One mobile device is wirelessly connected to the telematics system and displays a map of agronomic data, such as crop yield in real time. In addition to yield, the sensors on the combine record moisture and sometimes protein content. As the farmer monitors video of the combine bin nearly full with grain, the farmer checks a mobile app on another mobile device that informs him of conditions at each of his grain storage bins, including grain moisture and remaining capacity. He then checks the moisture content of the load that he just unloaded into a grain cart that has synchronized with the combine to match its speed. The front portion of the grain cart is filling up before the back half, so the farmer taps the screen a few times to nudge the grain cart tractor to move forward 5 feet. The farmer texts a semitruck driver with information on which grain storage bin to unload this grain, once the grain cart unloads into the semitruck. This choice is intended to optimize moisture content to reduce overall drying costs. The farmer can also see where the semitrucks are on the screen to assure that grain is being transported to the planned locations.

Information on grain moisture is also automatically populated into the farmer's planning app. Some landowners take a portion of the production and marketing risk by leasing farmland based on a percentage of the harvest rather than asking for a set cash amount. The app allocates the percentage of grain and some input expenses to be split with landowners under this crop-share agreement.

Once the field has been harvested and the collected data transferred from the combine harvester to the cloud, the farmer views a map of his field on his tablet showing crop yield and quality metrics by area. He zooms into a low-yielding portion of the field and then taps that location to set a flagged pin that is sent to his consultant so that they can target it for soil fertility tests.

This particular field was the location of an on-farm experiment in collaboration with the local seed dealer and county agent; six hybrids of corn seed were planted in field-length strips so that side-by-side comparisons can allow relative rankings by yield. Dragging his finger over the screen, resizing rectangular areas of interest, the app quickly updates average yield by corn hybrid for just the selected area. The farmer draws several more rectangles from his knowledge of the field's soils and different areas of prior productivity to see how each hybrid ranks, as he forms an opinion on what hybrids to order for the following season. The sooner he orders, the better the early order discount will be. With a few more finger taps on the screen, he shares the results with his seed salespeople, as well as the number of acres committed to each of the three best hybrids from the experiment.

A day of planning

The farmer has devoted a cold winter's day to conducting some necessary planning for the months of farming ahead. One crucial step is to secure an operating loan for the upcoming season. The farmer's bank prefers electronically generated financial statements rather than paper statements and a shoebox of records; plus, it's easier to be on the same page when the spreadsheets are simultaneously accessible on both of their tablets. One of the big decisions for next year involves deciding how many acres of each crop to produce—a decision he makes based on university researchers' agronomic and economic projections of yield and crop prices for the upcoming year. To prepare for his meeting with the banker, the farmer uses his tablet to pull up model enterprise budgets provided by the local agricultural university, and then cross-references the quantities and costs of seed, fertilizer, herbicides, and diesel fuel he had preordered using suppliers' respective apps to populate the budget spreadsheet. With a tap of his finger on the tablet, the spreadsheet generates a monthly cash flow statement that will serve as a talking point when he goes to set up a line of operating credit with the bank.

And now that the costs of producing a crop have been calculated, the farmer has more confidence locking in advance contracts to sell the upcoming year's production. The farmer navigates to a commodity trading website where he browses the charts for corn, soybean, and wheat contracts to sell 10% of his expected production for delivery a few months after harvest.

The farmer also recently hired a new worker who will be operating one of the planter tractors next spring. The farmer provides a tablet to each worker that controls some of the equipment functions, such as the seeding rates on planters, and also provides other information about repair and maintenance. The farmer downloads user manuals and repair manuals for each of the tractors, planters, sprayers etc. from the manufacturers, so that these will be preloaded onto the tablet for the worker to access. Specialized apps have been installed that synchronize task information so that every farm worker has up-to-the-minute knowledge of what fields have been planted, sprayed, and harvested. Although unpaid family members have tablets that allow them to see the cost of inputs, this tablet assigned to the new employee has permissions set to see only per-acre usage rates (as opposed to the cost) of each product. Prerecorded webinars on equipment maintenance and safe operation have also been added for viewing.

Using the same app, portions of the crop planning tool's analysis have been shared with input suppliers, such as seed dealers; equipment dealers; and retail cooperatives that provide fertilizer, crop protection chemicals, and a range of custom services, so that the supplier knows when and where each of the respective inputs needs to be delivered. Since the farm acreage is spread out across the county, it makes sense to have products delivered strategically.

A Day in the Life of an Equipment Dealer Support Specialist (during planting season)

The support specialist's smartphone rings; a farmer customer wants to discuss the error message appearing on his planter tractor that prevents the planter from operating. Using the modular telematics gateway on a tablet, the support specialist views what the farmer sees on the in-cab planter monitor. Now that the support specialist can "see" the screen, he can take control of the farmer's monitor via the modular telematics gateway. The equipment dealer support specialist is able to apply the correct settings to the planter monitor via the remote connection capability.

A Day in the Life of an Extension Agent (during growing season)

Sitting with a tablet on a weekly Zoom meeting with peers from other counties and the local university to discuss photographs and recent observations of farm issues each member made in their respective geography, a direct message comes across Twitter from a crop consultant with an image of a plant seedling, asking for a positive identification to determine if modified weed control is necessary. The county agent remembers a time before digital cameras and electronic media when farmers would have to bring in weed specimens for identification. Modern technology has reduced transaction costs and time lags substantially. The plant seedling looks familiar, but the county agent submits the photo to a specialized app for a second opinion. The app rapidly compares the photo to others in its broad database of weeds and confirms its identity. The county agent responds back to the crop consultant and the specific farmer from whose field the weed was collected. The county agent turns back to the Zoom meeting.

A Day in the Life of a Crop Consultant (during growing season)

It's a warm sunny day as the crop consultant walks through the growing corn planted a few weeks earlier. The crop consultant is thankful for the dozen or so farmers who have hired her to scout fields and make recommendations. Most of the farmers for whom she consults want her to scout the fields to evaluate if weed control practices have been effective and to give advice on whether follow-up herbicide or fungicide applications are needed to control emerging pests or plant diseases. Her smartphone is one of her most valued tools; not only for voice and text communications but for taking photographs and videos of crops, weeds, insects, and possible pathogen infestations on growing crops. She has made use of a UAV to assist in mapping weeds and crop progress; seeing areas of anomalies in real time on her smartphone allows her to use her time efficiently by intensively scouting targeted areas in the field rather than walking random patterns.

A Day in the Life of a Retail Sales Agronomist (during growing season)

The retail sales agronomist works at a farm cooperative providing sales assistance to farmers. The sales agronomist receives an alert on his smartphone that one of his customers has made an order for herbicide that was not part of his original plan for this year. The sales agronomist selects the herbicide from the warehouse and loads ten 2.5-gallon jugs plus some surfactant into the bed of his work truck, then drives off to deliver to the farmer. Using the same app that alerted him of the herbicide order, the sales agronomist follows the turn-by-turn directions to the field where the farmer requested delivery of the herbicide.

Crop farmers aren't the only agriculturalists who use precision agriculture…

Although many well-known precision agriculture technologies were developed with crop farming in mind, other agriculturalists are increasingly reaping the benefits of mobile technology. Dairy and hog farmers, for example, increasingly rely on smartphone-controlled systems to calibrate the amount—and the content—of the feed delivered to their herds. These farmers also use "smart collars" to track the amount their animals are eating and drinking, which can facilitate early detection of health problems. And they are using GPS-enabled sensors to track the location of cattle grazing across large fields, allowing farmers to save on time and resources previously devoted to in-person tracking. In terms of health monitoring, one recent study even found that veterinarians using a smartphone-based ECG device could measure animals' heartrates and cardiac rhythm with accuracy comparable to a bulky and expensive standalone ECG system. As with crop farming, livestock farming is changing dramatically, thanks to mobile technology's capacity to transform complex, onerous and/or costly tasks and systems into much more streamlined and accessible information and activities for ordinary farmers and ranchers.

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