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The Evolving Nature of Precision Ag: Forwards towards the 2040s

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Last Monday's *farmdoc daily* article reviewed the path of precision agriculture over the last three decades (Sonka). It was the first of three articles. Today's article speculates about the future path of technologies and their effects. The third article in this set, The Confluence of Societal Interests and Precision Ag, is set for next Monday.

That practical philosopher, Yogi Berra, has been quoted as saying, "It's difficult to make predictions, particularly about the future" (Laidler). He is, of course, correct and the observations offered here shouldn't be assessed as predictions. A better term might be speculations, based upon the path of precision agriculture to date, societal needs, and an incomplete assessment of relevant technologies currently in late-stage development or early-stage commercialization. Implementation of those technologies, if successful, is likely to have significant impact on how decisions in the ag sector are made.

The article will identify specific technologies and products. These are not recommendations, instead their inclusion is to provide tangible examples. Finally, last week's article identified technology applications existing today that weren't widely known (or known at all) in the early 2000s. There will be technology applications in the 2040s that we're not aware of today.

Introduction

The ending observation of last week's article highlighted the growing recognition of the role of data and decision making in precision ag. This was contrasted with the observation that the early days of precision ag tended to emphasize the novelty of "shiny toys". This article's initial segments concentrate on data, but "shiny toys will be included".

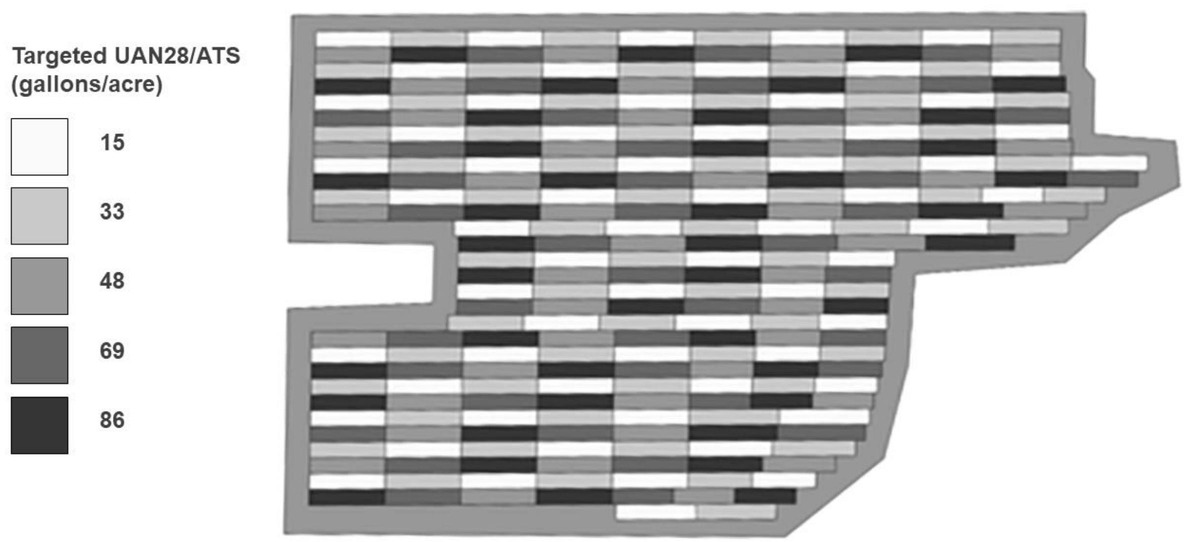
Data Intensive Farm Management

Farmers always used information to help them make better decisions. I recall an Illinois farmer describing how, decades ago, he assessed the performance of differing corn varieties. The process involved painting numbers on telephone poles, planting different varieties in the spaces between those poles, and then, while harvesting, comparing how much corn was in the combine bin. When precision ag came along, quantitative data became available to link levels of fertilization and yields. With reasonable accuracy, less fertilizer could be applied to those areas of the field thought to have lower productivity.

While useful correlations, that process didn't really address the "how much" question. How much less or how much more fertilizer should be applied to the areas thought to have lower or higher productivity? With private sector collaboration, a USDA-supported project, Data Intensive Farm Management (DIFM) is developing the capabilities to allow farmers to explore the "how much" question based upon data from field trials conducted on their own farm.

Figure 1 depicts the layout of a field trial conducted on an actual farmer's field where five levels of nitrogen application were compared. Each level of nitrogen is shown by its own shaded block. The pattern illustrates how the different nitrogen levels are tested throughout the field, with each small block being an experimental plot. The results directly respond to the "how much" question. Importantly, the associated field operations (input applications and harvesting) can be done with the farmer's existing equipment and processes.

Figure 1. Example of a Field Trial Layout



ILLINOIS Source: Data Intensive Farm Management program farmdocDAILY

More information about this innovation is available from the DIFM program (https://difm.farm). This includes a freely available cloud-based cyber-infrastructure ("platform"). This tool can be used to design on-farm precision experiments, to transfer the design files to machinery, to upload as-applied yield and other kinds of data, and to store, manage, process and analyze that data. The end result is a report of the economic implications for each trial. This process is similar to the Total Quality Management revolution that led to major improvements in manufacturing performance in the 1990s (Hendricks and Singhal).

It's not likely that an individual farmer would conduct such trials every year and on every field. However, as a young professor (decades ago), I got to interact with a group of swine producers who were striving to understand new technologies and approaches. They routinely met to share their experiences with the new tools entering the industry. Further they compared quantitative performance outcomes among themselves and their advisors. A similar approach, fueled by the DIFM method and possibly organized by ag retailers and/or Extension, would seem to be an extremely effective means to advance learning.

Seeing Over the Corn

In last week's article, we observed that remote sensing was an emerging technology, although the preferred method of acquiring data wasn't clear. As illustrated in Figure 2, drones and other means such as satellites, airplanes, and robots can be used for data acquisition, with differing strengths and weaknesses.

Figure 2. A Drone in Operation over I-FARM: Farm of the Future

The use of remote sensing in agriculture is not new. World War II technologies led to use of airplane-based photography to map cropland features in the 1950s and satellites started to be employed for similar uses in the 1970s (Nellis, et.al). While interesting, the resulting information lacked precision for many agricultural production decisions. I recall chatting with a farmer who was experimenting with aerial mapping about a decade ago. He mentioned that when areas of abundant vegetation were noted it was worth checking because it was either a really good stand of corn or of weeds.

Major advances in analytic methods have materially enhanced the specificity and results available from remote sensing. Anticipating crop yields during the growing season is one area where improvement has led to meaningful results. For example, integrating satellite data generated from a diverse spectral range has shown considerable success to rival traditional, more expensive methods of estimating yields over large-scale geographies (Guan, et.al.)

Obtaining data is one interesting use of remote sensing. Other applications will be addressed in next week's article.

Who's Holding the Steering Wheel (or the App)

The survey results reported in last week's article documented the massive increase in farmers use of guidance/autosteer technology. Evidently farmers were willing to "give up the steering wheel" even when they were in the cab. The future offers the potential for farm vehicles operating without a person being physically present on the machine. (Given the relatively controlled farm field setting, it is not hard to imagine several machines being controlled by one person using a controller or app on the cell phone. A next step would be those machines operating without a person in the field watching them.

Predicted benefits include enhanced productivity, efficiency and sustainability (Nokia, Nolen). Imagine, could the future farmer's last task before going to bed be to use his cell phone to check yields and see if the combine operating in the field was OK? While a bit "out there", thirty years ago the robotic milking machine seemed to many of us to be just as far "out there". They are now commonly used.

Much of the focus of current attention regarding autonomous farm equipment is focused on impacts on field practices. An interesting extension is to consider potential effects on farm equipment design. A constant trend throughout my lifetime has been that next year's tractor would be bigger and more powerful than last year's. One constraint throughout that time was the need for a person to physically be on the machine. If that constraint is relaxed and the machine can operate day and night, would it make sense for a smaller machine to be preferred?

Finally, farmer safety may be an additional important benefit. While not emphasized here, a recent webinar addressed this topic in detail (*farmdoc* Webinar).

Generative Artificial Intelligence

An innovation that has dominated the media, and the financial markets recently is Generative AI. A simplified description of generative AI is that it is an artificial intelligence tool that can create **new** content based on analysis of patterns in existing data. For example, one could employ generative AI to entirely create an article exploring the future evolution of precision ag. (But I didn't!)

Before we reach conclusions regarding generative AI, it might be useful to note two things:

1. Generative AI is relatively new and our understanding of its impacts will be revealed over time and

2. Throughout history, the impact of innovations has been shown to follow a predicable pattern. That pattern is known as the Hype Cycle (Gartner). The Hype Cycle describes the typical steps a new technology follows from its introduction to market success:

    - A period of **overestimated expectations** as to the technology's potential impact,

    - Followed by **disillusionment** because those overestimated expectations aren't achieved immediately, and

    - Typically, after a few years, recognition that the technology does have **positive impact**—sometimes exceeding the overestimated expectations.

Generative AI was positioned at the Peak of Inflated Expectations in the 2023 hype cycle analysis (Gartner). Appreciating the tendency for irrational exuberance, it is important to consider Generative AI as a potential tool within precision ag.

- One such role as an embedded element within farm equipment. Most of us don't understand the technicalities associated with GPS navigation in our car but it's a tool we use. It is very likely that the capabilities of tomorrow's farm equipment will be improved by generative AI that the farmer never sees.

- The second role links to data analysis. Talking with today's farmer who is a successful user of precision ag tools, one is very likely to hear a comment such as, "DATA!!!, I'm drowning in data!" (Lin).

Discerning management insights from the reams of digital information currently available presents daunting challenges. Practices such as DIFM and data gathered from remote sensing are going to exacerbate the drowning in data phenomenon. Generative AI hopefully will be a key analytical tool to address that challenge.

In farming, tools that effectively employ generative AI could be beneficial, whether directly used by the individual farmer or in creating advisor recommendations. One potential benefit is the ability to interact with data and information resources in a more natural, human-like fashion. For example, for years it has been easy to be frustrated with search engine results that deliver hundreds of thousands of hits, but then require the user to sort through them to find useful responses. While not perfect, current generative AI platforms enable asking questions in a natural fashion and provide specific responses. That example may be a useful analogy, when applied to data from farm fields. Hopefully, tools employing generative AI will enable farmers to unlock insights about improved farm practices that today are hidden in a myriad of spreadsheets and reports. Interestingly, just last week, Bayer announced an initiative to sell agriculturally specific generative AI tools as a new product in the agricultural industry (Bousquette).

Use of generative AI throughout society is likely to experience many bumps in the road. Societal acceptance is already an issue of debate. Privacy breaches at the individual and international levels are surfacing. Such instances of misuse likely will proliferate. These may lead to societal limitations on the extent and manner in which generative AI can be used, including in agriculture.

Ubiquitous Connectivity

Underlying the perspectives discussed here is the expectation that rural connectivity will be much improved by the 2040s. Several federal programs have been initiated in recent years with the stated goal of improving rural connectivity. However, progress to date hasn't shown significant results (Ferrechio).

A 2024 announcement does indicate a differing path to achieving the rural connectivity goal (Tita and Maidenberg). That announcement described a deal to link Space'Xs Starlink service to John Deere farm equipment. The goal is to provide ubiquitous connectivity, without which the benefits of the technological innovations noted in this article will not reach their full potential. Starlink's more than 5,000 satellites provide a powerful platform to extend across rural America. Hopefully, competitors, such as Intelsat and others, will emerge to provide additional service opportunities in rural America.

Wrapping Up

In this article a diverse set of future agricultural applications has been used as examples of enhanced decision-making methods that could be routinely employed by the 2040s. An underlying purpose for describing those examples was to illustrate capabilities that are currently emerging. These capabilities would undergird the practices employed in a future precision agriculture:

- Ubiquitous connectivity to empower rural areas.
- Autonomous farm vehicles of large and small size.
- Massively expanded remote sensing networks integrating multiple means of data collection.
- Analytics which will employ concepts we've become introduced to in the last decade such as Big Data, Cloud Storage, and Traditional and Generative AI.
- The Data Intensive Farm Management concept, which could allow farmers and agribusiness managers to profoundly improve performance, similar to the past effect of Total Quality Management and similar concepts in manufacturing.

While individually intriguing, it is the combined effect and application of these technologies that will drive performance. Farmers and managers who lead in integrating them on the farm are likely to earn the early adopter benefits.

In this, and last Monday's article, the focus was predominately constrained to the boundaries of the farm. Next Monday's contribution will consider how technology may allow agriculture to more effectively respond to societal interests that extend beyond the farm gate.

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