On-Farm Digital Solutions and their Associated Value to North American Farmers

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A paper from the Proceedings of the

14th International Conference on Precision Agriculture

June 24 – June 27, 2018

Montreal, Quebec, Canada

Abstract. *Digital tools and data collection have become standard in a wide variety of present day agricultural operations. An array of digital tools, such as high resolution operational mapping, remote sensing, and farm management software offer solutions to many of the problems in modern agriculture. These technologies and services can, if implemented correctly, provide both immediate and long term agronomic value. A growing number of producers in Ohio and around North America question the proper method of initiating and/or advancing their investment in digital agriculture technologies and services due to multiple associated challenges. Sometimes, technology providers boast unachievable benefits while field-scale savings can make the perceived return on investment unclear. This has led to a void between producers and technology providers that continues to grow as technology advances.*

An attempt was made to close this void through utilizing a myriad of available technologies to document data that can be collected through commercial technologies by farmers. This project followed the data collection process for a single field, and specifically for a single corn plant in order to understand the type and total amount of data being collected. A total of 18.5 GB of data was collected that included 2,476 individual files. These files were then categorized and ranked according to ease of adoption, added value, amount of generated data, and various other categories. The highest rankings in these categories signify the types of technologies found most valuable to the production of this corn plant. Key data layers used by the famer during the 2017 growing season were as-planted, yield, imagery, seeding Rx and weather. Post-harvest analyses provided a means to separate data layers or files that provided value and ROI to the farmer. While impractical in commercial application, this platform served as a means to encourage adoption of these technologies and a determination of the many ways that data can be collected, analyzed, and acted upon in the current state of digital agriculture.

Keywords. *data, technology, world record, return on investment, value, adoption, digital.*

Introduction

Agricultural data use has exponentially increased with the adoption of innovative digital tools and services over the last decade. While the industrial transition to digital agriculture is in full effect, uncertainty exists at the farm level regarding the implementation of on-farm digital tools and services. This barrier to adoption is one that is not easily broken. Many of these tools and services are known to have value, but due to the variability of scale and management practices the actual added value is not constant across producers. Additionally, the cost of digital tools and services are continuously increasing as they grow in complexity. The current state of slim margins in the agricultural industry make it difficult to invest in these technologies unless a clear return on investment is observable. These technologies are becoming more difficult to adopt from a producer's perspective, and easy-to-implement solutions need to be delivered into the hands of the producers (Fulton, Brooke, & Virk, 2013).

On-farm technology adoption and output of associated data can be overwhelming in some respects to producers. However, a recent study showed that across the United States, 73.5% of all farmers were engaged in some type of precision farming technology use (Zhou et al., 2017). Certain technologies have been proven valuable, such as autosteer (D'Antoni, Mishra, & Joo, 2012), while the holistic picture of on-farm technology adoption can be vague. Sometimes, technology providers boast unachievable benefits while field-scale savings can make the perceived return on investment unclear. While most agricultural producers are aware of the benefits of technology adoption, these barriers make it difficult to initially invest in tools and services that are overpriced for the value they provide. Diekmann and Batte (2010), described a need for more educational and extension material related to precision farming technologies in Ohio and identified challenges in adoption of these technologies. Additionally, Coble et al., (2018) identified a need for educational material and trainings on how to evaluate these technologies from an economic perspective, something infrequently investigated.

An array of digital tools are available on the market today such as high resolution operational mapping, remote sensing, and farm management software, offer solutions to many of the problems in modern agriculture. This has led to a void between producers and technology providers that continues to grow as technology advances. In order to close this void, producers need to be informed about the technology and data layers that are most useful to an operation and how to use them. In order to learn from the information generated by these technologies, a decision process has been identified to understand how to learn from these data layers. Three steps to making a data-based decision include (1) collecting data - observations, or records of what has happened, (2) information - created from data by putting it into agronomic context, (3) knowledge - learnings generated from the analysis of actionable information. Until known information can be acted upon, it will remain information and be unable to influence productivity levels for the current crop.

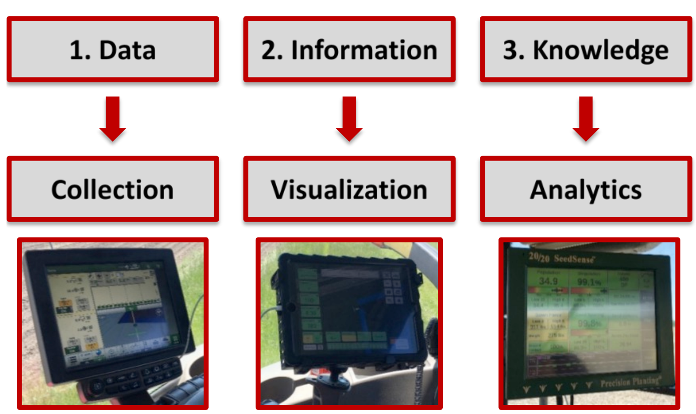

Figure 1: Acting upon data is only enabled by the collection, visualization, and analytics that are performed on that data. Depicted are examples of each category including collection of positional data, visualization of as-planted data, and analytics of a sensor signal produced by automated downforce control.

Methods

This project followed the data collection process for a single field, and specifically for a single corn plant in order to understand the type and total amount of data being collected. In order to reflect actual production situations, the technologies and data sources selected for this study are all commercially available tools and services that can be implemented in a commercial-scale operation.

The selected field was located at the Molly Caren Agricultural Center (MCAC) in London, Ohio. This farm is fully independent, and can only invest in these tools and services as their current production budgets will allow. The specific corn plant was selected at random from an area of high productivity within the field (see zones, Figure 2). All tools and services utilized in this study were provided either by MCAC or by the Food, Agricultural and Biological Engineering Department at The Ohio State University.

Figure 2: The world record field was delineated into distinct management zones that were classified as having either low, medium, or high productivity levels.

After all of the data was collected for the year, the layers were compiled and ranked according to various value. Each layer's value was assigned by a select group of agronomists, consultants, and extension agents who were asked to evaluate each type of layer independently.

Digital Strategy

In an effort to better understand the benefits associated with these digital tools and services, attempts were made to define the strategies that should be used by producers when considering on-farm adoption. To test all available tools, a data timeline was generated throughout the growing season (Figure 3). For each occurrence, data was recorded and analyzed for any associated benefits to the producer. All of these digital tools and services in this study were currently commercially available and able to purchased or subscribed to by the producer.

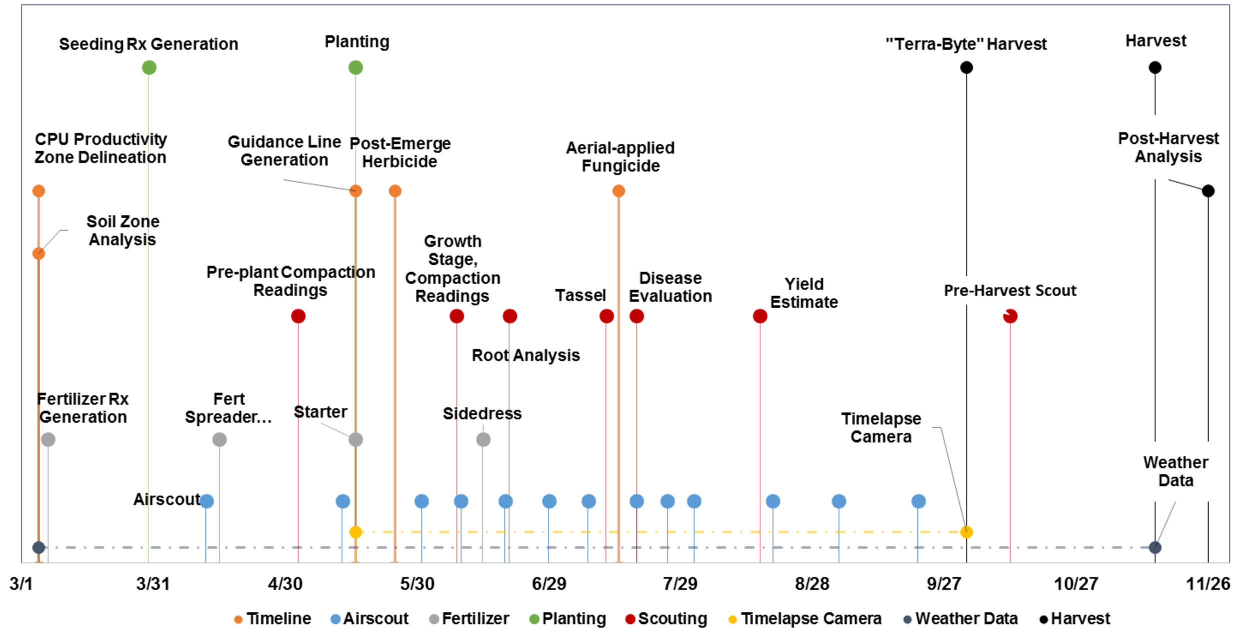

Figure 3: Growing season events where data was collected in the 2017 cropping year.

The following digital tools and services were used for data acquisition and processing in the world record project: Climate FieldView, Box, Ohio State PLOTS App, SMS Advanced, FieldView Drive, My JohnDeere, Precision Planting 20/20 Monitor, Trimble Ag Software, FieldView Plus Software, AirScout Aerial Imagery, GIS, WeatherOp, Excel, Precision Planting POGO, JD Link, and John Blue Blockage Monitor. In order to portray the data layers used throughout the growing season, the Figure 4 graphic was generated. Notice that weather data, and delineated zones were used through the majority of the season, while other data layers were found useful at certain points during the growing season. Consistently, it was the data layer that most closely predicted future growing conditions that was found to be useful in our digital strategy.

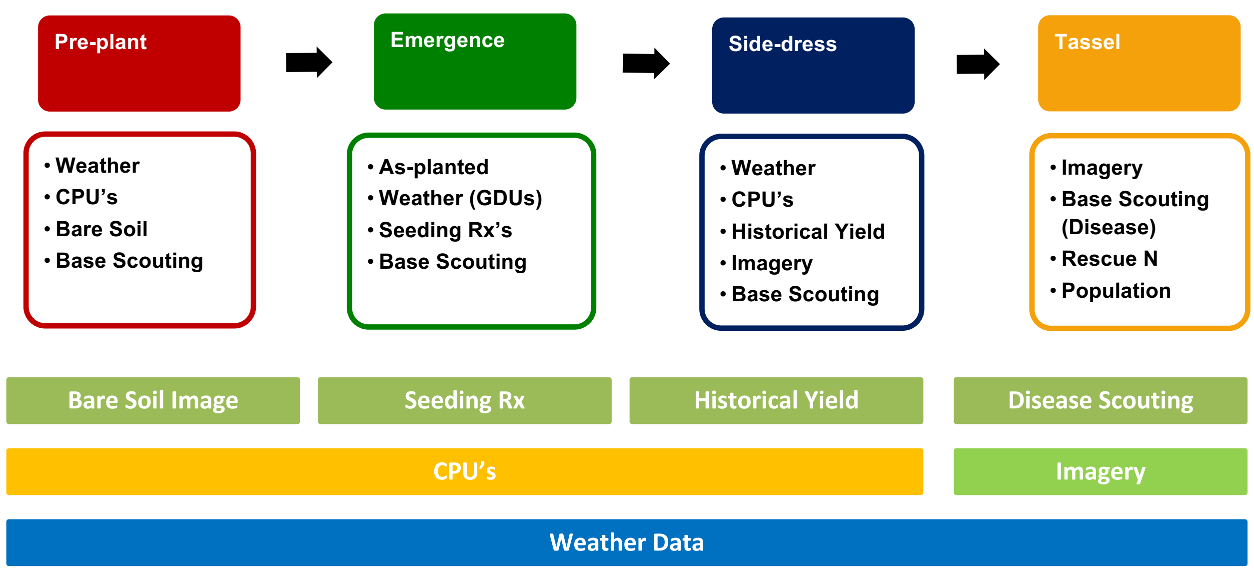

Figure 4: Data Collection Timeline for the 2017 crop year. The lower region of the graphic depicts the data layers that are used during that time of growing season.

Results

A total of 18.5 GB of data was collected that included 2,476 individual files (Figure 5). These files were then categorized and ranked according to ease of adoption, added value, amount of generated data, and various other categories. The highest rankings in these categories signify the types of technologies found most valuable to the production of this corn plant. Key data layers used by the farmer during the 2017 growing season were found to be as-planted, yield, imagery, seeding Rx and weather data. Post-harvest analyses provided a means to separate data layers or files that provided value and ROI to the farmer. While impractical in commercial application, this platform served as a means to encourage adoption of these technologies and a determination of the many ways that data can be collected, analyzed, and acted upon in the current state of digital agriculture.

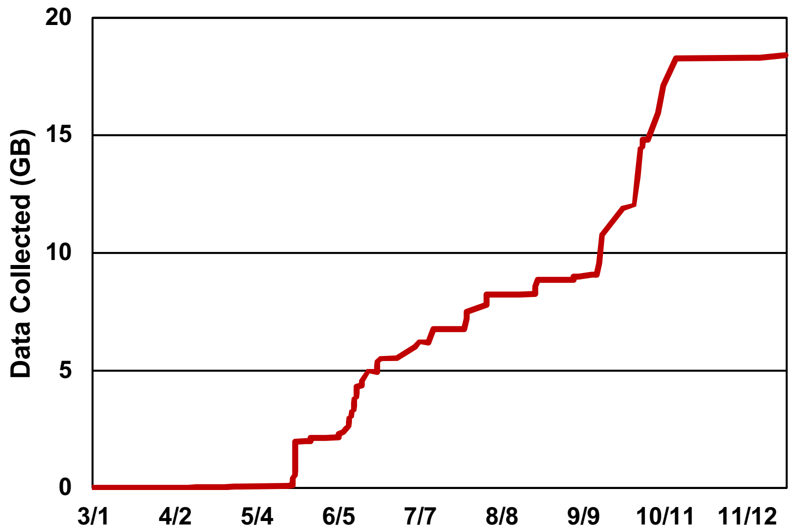

Figure 5: Data collection timeline for Terra. Data collection accelerated throughout the growing season, accumulating a total of 18.5 Gb at the time of harvest.

Ranking

Post-harvest rankings were generated for the various data layers utilized throughout the growing season. The rankings of these data layers are displayed below in Table 1. These rankings were conducted for three different categories: current value, potential value, and ease of adoption. We defined the current value of these digital tools and services to be value immediately added to the operation upon implementation of the tool/service. Potential value of a tool or service is the foreseen value if that tool is used at its maximum capacity by taking into account advances in the tool/service. Ease of adoption is an arbitrary ranking assigned to each layer describing how easy it is for someone with an average amount of technological experience to adopt this tool.

All of the data layers utilized in this project were delineated into distinct tiers based on these rankings. Tier 1 data layers were defined as those that are believed to have a concrete return and that are in the producer's best interest to invest in every year. Tier 2 data layers were defined as those that are helpful to production, but in a downturn market the producer may deem these layers as disposable. Tier 3 data layers are not listed in this document and were classified as information that may provide some insights into production, but that the producer would probably not invest in on an annual basis.

Interestingly, the cooperator in this study was already utilizing all of the tools and services that were ranked as being in the first tier. The top three data layers for current value were: as-planted data (4.7), soil sampling data (4.7), and yield data (4.0). For potential value, all of these layers were ranked at the top of the chart with very bullish projections for use of these technologies in the future. Ease of adoption was the most variable category, with rankings from 1.3 to 5. The most easily adopted forms of these data layers are base scouting and soil sampling data.

Table 1: Top tier data layers as collected and ranked by a team of producers, consultants, precision ag experts, and university extension personnel.

Tier 1

Data Layer	Current Value	Potential Value	Ease of Adoption
As-planted Data	4.7	5	2.3
Soil Sampling Data	4.7	5	4.7
Yield Data	4	5	3.7
Aerial Imagery	3.3	5	3
Base Scouting	4	5	5
Seeding Rx	3.7	5	2

Tier 2

Data Layer	Current Value	Potential Value	Ease of Adoption
CPU Zones	3.7	5	1.3
Weather Data	3.3	5	5
Historical Yield Data	4	5	3
As-applied Fertilizer	3	5	2.3
Scouting Plus	2.5	4	3.3

Case Studies:

For the 2017 cropping year, three case studies were analyzed in order to determine the value added by adopting a specific tool or service. The tools selected for the case studies were (1) variable-rate fertilizer application, (2) as-planted data, (3) aerial imagery.

1. Variable-Rate Fertilizer Application

These spread rates are based on 2 year crop removal values, and are representative of the producer's current practices. Prices used in these calculations were identical to the available price at the nearest fertilizer distributer (MAP - $410/ton, Potash - $285/ton). Spread charges for each application scenario were also sourced from the local cooperative, and are comparable with a $5.00 charge per acre for straight rate applications and a $5.50 charge per acre for variable-rate applications.

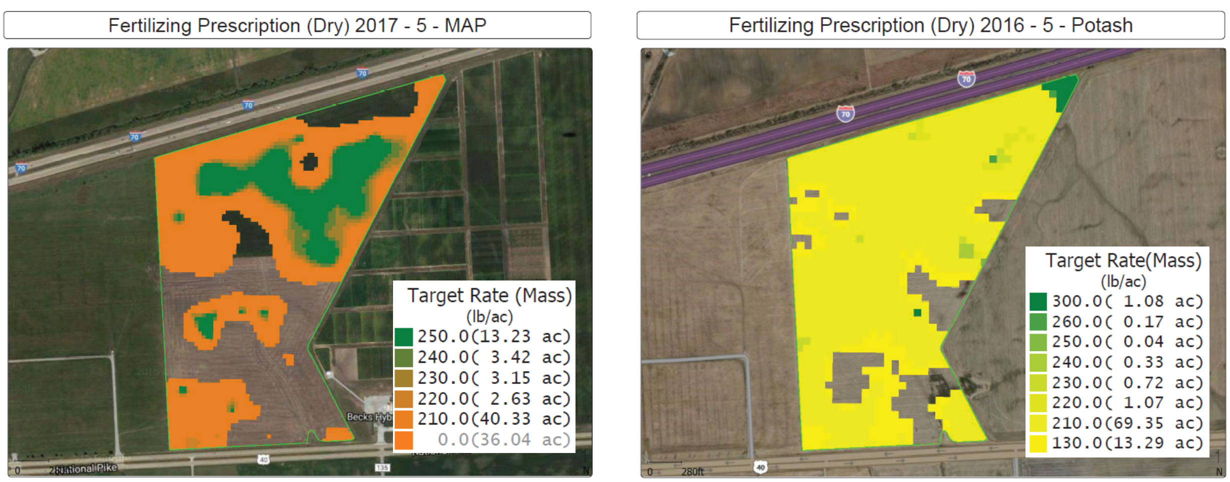

Figure 6: Fertilizer application prescriptions for both MAP and Potash applications. Note the savings in low rate and no rate regions of the field.

Table 2: Costs and benefit analysis for implementation of variable-rate spreading on the world record field.

Costs	Straight Rate	Variable Rate
MAP	$4,223 (210 lb/ac)	$2,788 (140 lb/ac)
Potash	$2,936 (210 lbs/ac)	$2,765 (199 lbs/ac)
Spread Charge	$489 ($5/ac)	$537 ($5.5/ac)
Total	$7,648	$6,090

Total application charges for the straight rate scenario totaled $7,648 charge for this 100 acre field, a $76.5 per acre expense. Comparatively, the variable-rate application totaled $6,090, a $60.9 per acre expense. Essentially, by electing to apply the phosphorous and potash fertilizers at a straight-rate the producer would have over-applied and overspent in a significant portion of the field. In fact, the producer did apply this field using a variable-rate and calculated a total savings of $1,558, or ***$15.95*** per acre.

2. Variable-rate Seeding

The second case study highlighted the implementation of variable-rate seeding and the collection of associated as-planted data.

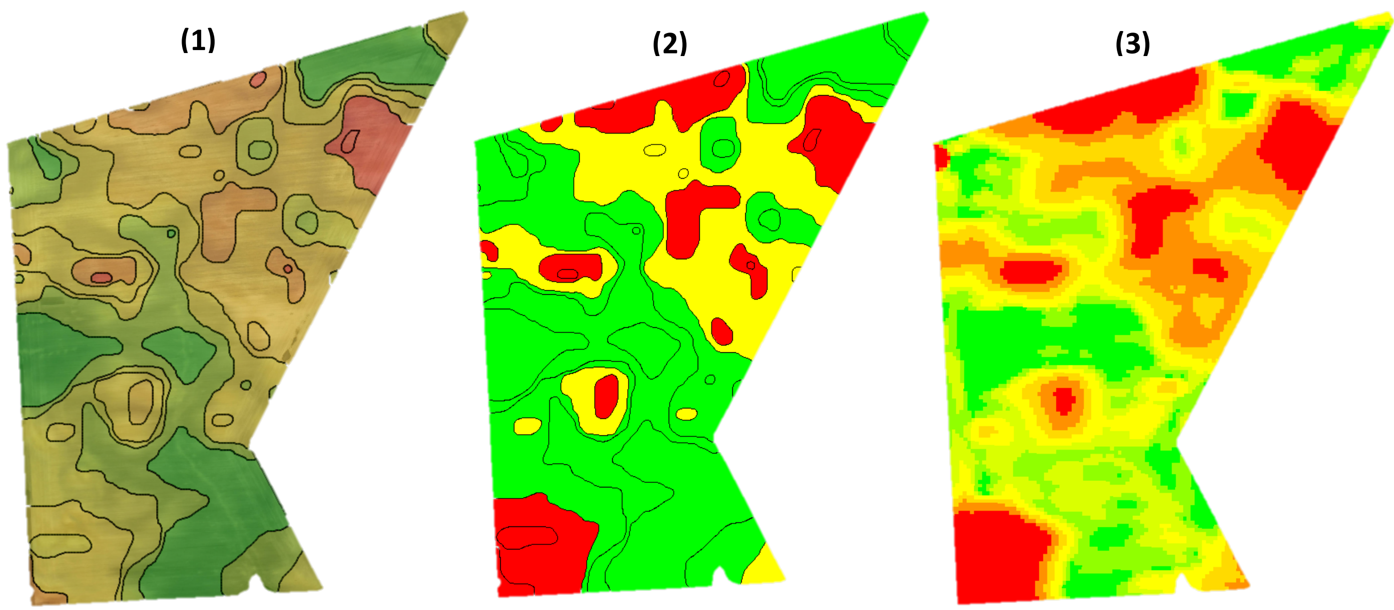

Figure 7: Execution of the variable-rate seeding operation for the world record field: (1) delineation, (2) prescription, and (3) execution.

This field was delineated into zones of high, medium, and low productivity, these zones were assigned seeding rates of 32,000, 34,000, and 36,000 seeds per acre, respectively. Previous research both on farm and from university experts have revealed a 10 bushel per acre advantage for the implementation of variable-rate seeding, and this advantage was used to calculate a cost-benefit analysis.

The increase in seeding costs from raising population levels corresponded to a $5.50 per acre expense, seeding prescription generation costs from the producer's third party consultant totaled $1.10 per acre. The 10 bushel per acre benefit associated with implementation of variable-rate seeding along with current $3.60 per bushel corn prices were used in the calculation of a final savings. These practices resulted in a ***$29.40*** per acre benefit to the producer, a substantial benefit for this particular grower. Additionally, the as-planted data collected through the execution of this prescription was used throughout the season for scouting and input verification purposes.

3. Aerial Imagery

The final digital technology case study analyzed for this field was aerial imagery. Aerial images were captured at ten various times throughout the growing season using a fixed wing aircraft. These images were delivered more frequently during the June, July, and August months when crops were approaching critical growth stages. These images were evaluated upon delivery and serve as a “directive scouting” tool in this application.

This season, the image taken on July 26th revealed some deficiencies in the northeast corner of the field. Upon investigation, it was revealed that Grey Leaf Spot Disease pressure was beginning to develop in the crop. In response to this knowledge, the producer applied 10 oz/ac of Headline AMP plus adjuvants by helicopter and the disease pressure was relieved.

A nearby field with similar productivity levels also had Grey Leaf Spot Disease pressure, but fungicide was not applied in order to compare the effect of the fungicide application. This field produced on average 18 bushels per acre less than the world record field. Growing conditions and field practices were identical for both fields, so much of this discrepancy can be attributed to the lack of fungicide application. This 18 bushel benefit (@ $3.60/bushel) was used to run a cost-benefit analysis for the fungicide application ($36.00/acre), and it was determined that the total benefit of application was ***$28.80*** per acre.

While the imagery itself did not detect the disease, it did allow the producer to be aware of the stresses within the field. This type of directive scouting can provide benefits to producers for identification and analysis of any crop stress.

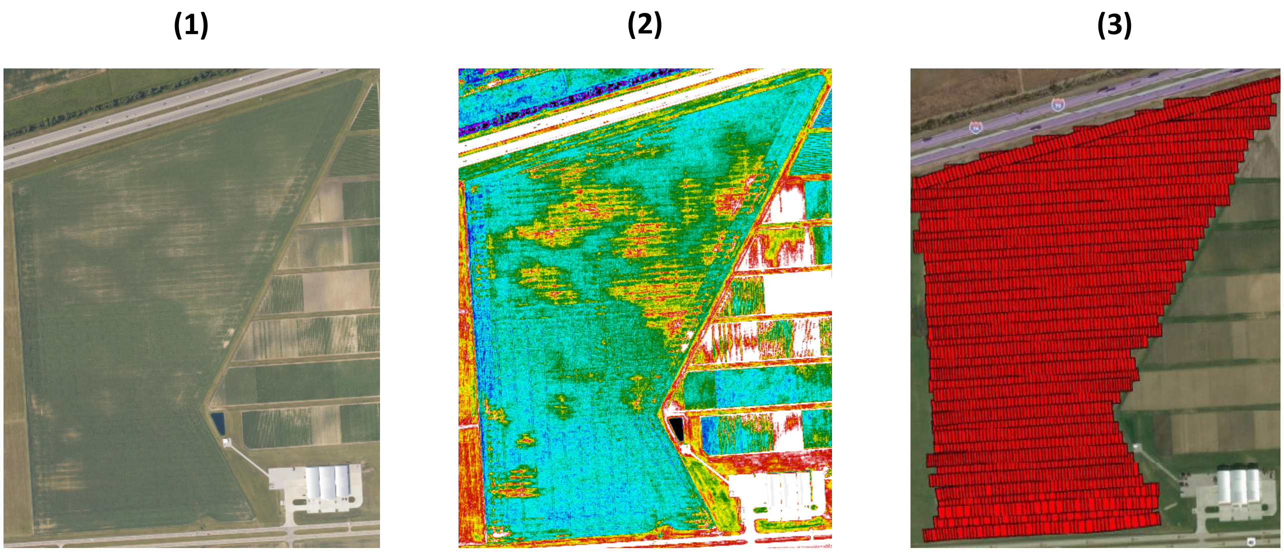

Figure 8: Implementation of aerial imagery on the world record field starting with (1) image collection, (2) image analysis, and (3) responsive action.

Digital Strategy

Producers throughout North America, and specifically in the state of Ohio have trouble understanding where to start regarding the adoption of on-farm technologies. There is a need for implementation of an on-farm digital strategy to ensure efficient utilization of these digital tools and services. In this study, two strategic recommendations for those growers attempting to adopt some level of digital technologies in future growing seasons were defined. These are the “Doer” and “Dreamer” strategies; meant to be undertaken in succession and used in conjunction with each other as levels of adoption increase.

The first strategic method for adoption approaches these technologies from the "Doer Perspective", which is defined as adoption of "*short-term, concrete solutions that provide an immediate return.*" Data layers that were identified as capable of providing this short-term benefit are: zone delineation, high definition soil sampling, variable-rate phosphorous and potash application, and variable-rate lime application. These technologies are fairly easily adopted and provide the biggest impact per dollar spent on adoption.

The second strategic method for adoption utilizes the "Dreamer Perspective", which is defined as adoption of "*Long-term, data-based solutions that provide value through storage and analytics.*" Goals, rather than specific data layers, were identified as capable of providing long-term benefits through adoption. These goals are: data recording for every field operation, learnings gleaned from specific management zones, ability to make in-season crop management decisions, and organized data storage for future analytics. These goals, if adopted, will be useful in ensuring maximum efficiency is reached for each specific digital tool and service that is adopted.

Generally, from this experiment, the individuals involved determined that appropriate digital strategies should utilize savings from reduction in low productivity areas and reinvest that savings into pushing the higher productivity areas into higher levels of yield.

Conclusion

This study reveals that there is a tremendous level of untapped value in digital tools and services when properly applied to serve producers' needs. The record amount of data collection for a single plant exposed the vast selection of digital tools and services that are available to producers in the United States. These tools and their associated data layers were found to hold significant value for the producer. The data layers holding the most value if adopted immediately on the farm were: (1) as-planted data, (2) soil sampling data, and (3) yield data. All data layers described in Table 1 were found to have significant current value, and were ranked extremely high for future value when those layers are utilized to their fullest potential. Three case studies extracted from this exercise showed that value can be attributed to each data-based decision on the farm. Finally, digital strategy analysis from multiple sources revealed that a multi-faceted approach, which considers immediate and long-term value should be used when adopting digital agriculture technologies.

Acknowledgements

The authors of this paper would like to recognize farm manager Nate Douridas of the Molly Caren Agricultural Center for his help with data collection, processing, and analysis throughout the year, as well as his insightful perspective into the realities of on-farm technology adoption.

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