THE CHALLENGES OF PRECISION AGRICULTURE: IS BIG DATA THE ANSWER?*

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*Selected Paper prepared for presentation at the Southern Agricultural Economics Association (SAEA) Annual Meeting, San Antonio, Texas, February 6-9, 2015.

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Precision farming utilizes information technology to add exactness to the quantity, quality, timing and location in the application and utilization of inputs in agricultural production. Though having tremendous potential, after two decades of work pertaining to precision agriculture, our abilities to capitalize on this technology have fallen far short of expectations. This manuscript frames the discussion concerning the challenges and opportunities of precision farming identifying critical knowledge gaps that must be addressed before precision agriculture technologies will be more widely embraced.

A review of the agronomic, pest management, economics and management literature provides the foundation for this discussion, helps identify knowledge gaps and outline some of the progressions in technologies needed for the industry to better capitalize on the potential advantages offered by precision agriculture.

Introduction

Precision agriculture is not new. Discussions of possible improvements from application of precision agriculture techniques have been widespread for more than two decades. Despite many years of progress, gains thought possible from widespread adoption of precision agriculture remain elusive. Recently, a number of firms have entered the precision agriculture arena with the goal of applying "big data" techniques in an attempt to improve returns derived from precision agriculture techniques. The goal of this manuscript is to identify some of the key factors that have inhibited or discouraged more widespread adoption of precision agriculture techniques and to provide guidance with respect to future research, which could make precision agriculture techniques more profitable and, hence, lead to wider adoption.

Evolution of Precision Agriculture

A wide variety of precision agriculture technologies have evolved over the last two decades. Periodic surveys of agricultural retailers conducted since the late 1990s provide insight into various technologies adoption rates (Erickson and Widmar, 2015). A foundation for much of precision agriculture is more detailed analysis of soil fertility requiring enhanced soil sampling techniques that use GPS to record exact sample locations. This technology has been available for a many years and, by the late 1990s, approximately 33 to 45 percent of retailers provided customers GPS based soil sampling. Adoption of this technology continued to grow over the next two decades and, in 2015, two-thirds of retailers provided this service. Interestingly, this implies that one-third of retailers still did not offer GPS based soil sampling in 2015.

Yield monitors have been widely available for combines since the early 1990s and are another foundation of precision agriculture. Erickson and Widmar's survey data indicates that from the late 1990s through the mid-2000s approximately 18 to 30 percent of agricultural retailers provided yield monitor data analysis to their customers. Over the last 10 years the percentage of retailers providing this service to customers increased, but only to 51 percent in 2015. Although it's not clear from survey responses whether or not farmers are receiving yield monitor analysis services from other firms or input providers, it is curious that half the retailer survey respondents have chosen not to provide this service to their customers.

One of the potential benefits of precision agriculture is to, ostensibly, only apply nutrients where they are most profitable based on soil test results and, perhaps, analysis of yield data. Doing this requires the ability to apply nutrients at rates that vary in lieu of applying nutrients at a uniform rate across an entire field. Agricultural retailers willingness or ability to provide variable rate application of various of fertilizer has grown over time, but follows an adoption path similar to that of GPS based soil sampling. In the late 1990s Erickson and Widmar indicate that approximately one-third of respondents to their agricultural retailer surveys provided single nutrient variable rate fertilizer application to their customers. By 2015, 69 percent of retailers were offering variable rate application of a single nutrient to their customers. But this still implies that approximately 30 percent of retailers still did not provide variable rate application services to their customers in 2015, presumably continuing to offer only uniform application rates across an entire field.

Challenges Limiting Adoption

Agricultural retailer surveys indicated that adoption of key precision agriculture techniques increased significantly since the 1990s. However, given that some of the key building block technologies, such as GPS based soil sampling, have been available for over twenty years, it is surprising that usage is not even more ubiquitous. Why have key components of precision agriculture not been adopted more widely?

The inherent appeal of precision crop agriculture is embedded in the idea that managing crop production on a small scale, certainly smaller than individual field scale, will lead to increases in total production, reductions in input usage, or both production increases and input usage reductions. For this to be true, it implies that crop production functions change as you move across a field. Importantly, it also implies that the decision maker knows when the crop production functions change, thereby entering a new management zone, has detailed knowledge of the crop production function for each management zone, and has the ability to optimize input usage for each management zone. Once optimum input levels for each management zone have been identified, precision application equipment must be used to apply the inputs specified by the optimization routine. All this sounds simple, but in practice, of course, it is not so simple.

The key factor discouraging more widespread adoption of precision agriculture technology is profitability or, more precisely, failure to demonstrate that application of precision agriculture technology improves farm profitability. Given that the premise of precision agricultural crop production technology is so simple, namely apply the "right" quantity of crop inputs in the right location at the right time, what's the problem(s)?

There are a multitude of challenges facing a farm operator interested in using precision agriculture techniques to improve profitability. First, the crop production function needs to be identified with respect to key crop inputs. Although this sounds straightforward, in practice it is not easy. Camberato provides an interesting summary of the evolution of nitrogen rate recommendations in Indiana. Initial nitrogen rate recommendations were somewhat subjective and, over time, oriented towards providing adequate nitrogen based upon yield goals. Subsequent research led to the conclusion that basing nitrogen application rate recommendations on yield goals was not reliable. Although the current approach to nitrogen rate recommendations in Indiana is research based and derived from a model of corn production, it's also clear that current modeling techniques do not provide the precision required to vary optimal rate recommendations as an applicator travels across a field. Similar problems exist with respect to identifying optimal applications of other important nutrients. Thus, the first problem to be addressed is more detailed knowledge of crop production functions with respect to usage of key nutrients including, but not necessarily limited to, nitrogen, phosphorous, and potassium.

The second challenge facing a crop farm operator is identifying the appropriate size management zone to use when making decisions regarding input usage. Historically, farmers tended to manage at the field level, effectively treating an entire field as though it was an optimal management zone. In some cases this evolved into breaking a field down into several management zones, sometimes based upon soil type changes within the field. Research into identifying optimal management zones has been limited, but does not currently offer broad-based conclusions farmers can rely upon. For example, Scharf, et al examined eight different fields and concluded that in half the fields nitrogen management zones of greater than 1 hectare were best, but in the other four fields smaller nitrogen management zones were needed.

Closely related to the management zone issue is the need to identify the optimal size zone for soil sampling. Mallarino and Wittry examined this issue and, similar, to the nitrogen management zone researchers, found that they could not identify a single soil sampling zone recommendation that was best in all fields and across nutrients. They did observe that variability across sample zones tended to be larger for phosphorous and potassium than for soil ph or organic matter, implying that optimal soil sample size zone might vary depending on the nutrient or soil characteristic of most interest.

Initial attempts at identifying optimal management zones and soil sampling zones are often based in part on soil survey maps. But not all soil maps are created equal. Most soil survey maps are classified as order 2 maps, with a scale of 1:24,000. Slater indicates that order 1 maps were typically produced by soil scientists combining observations from aerial photography with on the ground soil observations reliant upon soil bores covering 10 to as much as 5 acres. The minimum size delineation for an order 2 maps is 5.7 acres and hence relying on order 2 maps to identify a management or soil sampling zones is limited by this level of granularity. Order 1 soil maps are much less common, but are prepared at a much smaller scale ranging from 1:2,500 or 1:10,000 and can be used at the one acre or less level (Slater). Frazen et al examined the usefulness of Order 1 vs. Order 1 soil maps when identifying nitrogen management zones and concluded that Order 2 maps were rarely helpful whereas Order 1 maps were much more useful.

Results from researchers examining optimal management and soil testing zones indicate that work providing clarity with respect to sizing both soil testing zones and management zones is needed to make precision agriculture techniques more profitable. Additionally, higher quality soil maps with resolutions equivalent to what's provided by Order 1 maps are needed in much of the U.S.

Moving Forward

Bullock and Bullock argued one and a half decades ago that the availability of precision agriculture technology makes information more valuable and that to make separate management recommendations for small areas of fields, much more information is needed about relationships among crop yields, input application rates, soil characteristics and weather. That's still true today. Although there has been an evolution of research in this arena, it's clear that much more is needed. The cost of precision agriculture equipment has declined in many cases and, combined with very positive returns in much of crop agriculture from 2007 through 2013 that encouraged investment in precision agriculture technologies, farmers have far more opportunities to apply precision agriculture techniques than in the past. But to push precision agriculture closer to its potential will require a concerted effort on the part of researchers to provide the data and analysis needed to fully take advantage of this technology and more clearly demonstrate the profit potential of precision agriculture.

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