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John E. Sawyer  
GROWMARK, Inc., jesawyer@iastate.edu

Ron Milby  
GROWMARK, Inc.

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REALITIES OF PROVIDING SITE-SPECIFIC SERVICES TO CUSTOMERS

John E. Sawyer
Manager, Agronomy Services
Crops/Seed Division
GROWMARK®, Inc.

Ron Milby
Precision Farming System Integrator
Crops/Seed Division
GROWMARK®, Inc.

Introduction

Site-specific agriculture has the potential to improve management of crop production inputs and efficiency of use. Improved technologies should be applied when a need is identified and implementation is feasible. Currently, technology costs and our capacity to reliably delineate or map properties affecting crop production does not always allow maximum benefit to be derived from site-specific services. This will likely improve as the costs for certain technologies decrease and there is a better understanding about variability management. Today a whole range of "new technologies" are often thrown together as the site-specific approach. These include GPS, GIS, yield monitoring, grid soil sampling, variable rate application, remote sensing, and more. One must understand each of these, and determine if, when, and where there is a fit for each. In other words, there should be a clear understanding of the benefit for each possible segment of the site-specific approach, and the relationship each has to potential improvement in the crop production system. All may not be useful. Not all areas of crop production may benefit from a site-specific approach. This must be considered as site-specific services are delivered to the farmer. Soil sampling and yield monitoring, combined with variable lime and fertilizer application, are today the most prominent components of site-specific services. Our discussion of site-specific agriculture will focus on these topics (much of the following information was taken from Sawyer, 1994a).

Concept of Variable Rate Application

Variable rate application makes sense because it is known that factors affecting crop production are not uniform within fields. The premise is that uniform application does not maximize input efficiency or field profitability because it does not accurately account for spatial variances in these factors. Variable application, then, potentially can accurately account for spatial variances within-fields, and improve field profitability by optimizing input efficiency (that is, eliminate over and under application that can occur when a uniform rate is applied across a whole field). Success in this requires an accurate map of within-field variation. Optimum success would be to map all variation exactly as it occurs in each field. This, however, is not economically feasible for soil testing because costs escalate rapidly as sample intensity increases. Something less than ideal (while not greatly sacrificing potential benefit) must be acceptable to both the
supplier of precision farming and the farmer. It may be economically feasible for yield mapping because of the large number of data points collected during the harvesting process.

Two items determine the potential increase in field profitability when variable application is compared to uniform application. One is savings from reduced overapplication. The other is improved yield (more than offsetting the costs of increased product use required to increase the yield). Profitability from variable application is then, in theory, different for each field because the variability and level of factors affecting crop production is likely different in each field. Enhancing yield is more important for improving profitability than is input cost saving.

What does this imply. Results will not be the same for every farmer or every field. Potential economic return from site-specific management will depend on soil test levels, yield, and past management. If a farmer is managing inputs for highest possible productivity or managing based on lowest soil tests in a field, yield improvement is not likely and any enhanced profitability will come from input savings (Schmitt and Fairchild, 1991). In some situations this may look very good, but much of the savings would likely have come from use of currently accepted best management systems (such as soil testing and field recommendations) and not just because of a site-specific approach.

Theoretical Crop Response To Variable Fertilizer Application

One main objective of variable fertilizer application is to increase crop yield. As stated previously, this is also important to enhance field profitability from variable fertilization (Wollenhaupt and Buchholz, 1992). Potential yield increase from variable fertilization depends upon the extent of field area in different soil test categories (zone A, B, or C in Fig. 1) and crop response to soil and applied nutrients. Remember, greatest crop response to applied nutrients occurs when soil tests are deficient (low end of zone A in Fig. 1). Odds of yield increase are small when soil tests are optimum (zone B in Fig. 1) or above (zone C in Fig. 1). Site-specific nutrient management may be more suitable for recommendation systems that manage in the responsive soil test range than systems that build up to a non-responsive range.

For yield improvement from variable application compared to a uniform rate, areas in the field must be underfertilized from uniform application. The extent of underfertilization, both the amount of field area and the disparity between uniform and optimum rates, determines the level of potential total field production increase with variable application. It is the combination of significant field area with a low or very low soil test plus a uniform fertilizer rate based on a high soil test average (uniform rate A in Fig. 2) that can result in substantial increased production when variable rate is implemented (a field uniform rate of zero and sizable low testing area would provide the greatest opportunity for yield increase with variable application). Also, enhancement of profitability and efficiency with variable input can occur if there is field area where uniform application overfertilizes and thus is either an unneeded input, results in yield reduction, or is a potential environmental risk (uniform rate B in Fig. 2). Soil test mapping should then probably identify both deficient and excessive soil test areas.
Figure 1. Generalized crop yield response curve indicating relative yield and expected positive response to an applied nutrient (A = highly likely, B = marginal, C = highly unlikely).

Figure 2. Expected crop yield increase from fertilizer application at different soil test levels, with identified example field uniform rate (dashed lines A and B) and optimum rates (dotted lines) at each test level (adapted from Tisdale et al., 1993).
In theory the above should give ideal results. However, the real field situation is not nearly so straightforward. Theoretical work by Jensen and Pesek (1962b) showed that non-uniform spatial N fertilizer application (spread pattern) to uniform soil resulted in calculated yield loss only at low soil test levels (Fig. 3). The maximum rate of the simulated nonuniform distribution pattern had to be quite large (> 50% of the optimum rate) before significant yield loss occurred. This implies that exact fertilization rates are not always required and that determination of the exact rate to optimize yield is hard to predict. It is influenced by many factors, including soil test level, soil supply potential, previous nutrient application, application method, environment, cropping system, and soil characteristics such as rooting depth and subsoil chemical properties. Ideally rates are based on curves similar to the example in Fig. 4, but in reality these predictions are not always reflected as exactly in field situations. For major improvement over uniform management, variable fertilization rates must be closer to economic optimums than uniform application. This requires specific and sensitive methods for determining variable fertilization needs within-fields, perhaps more specific than current recommendation systems.

Field Research Results With Variable Fertilization

As stated previously, economic return to variable application is dependent upon the specific field. This is born out in the field experimentation completed to date. A classic example is the work by Buchholz (1991) where he used a theoretical fertility index equation (Fisher, 1974) to determine yield response to soil test P and K levels and variable P and K fertilizer application. He concluded that economic improvement is dependent upon the field, the variation in soil test P and K within the field, the predicted yield response to uniform (field average) and variable fertilization, and the costs of variable fertilization. In the fields studied, economic improvement varied from large to small, depending upon the characteristics of each field.

The major identified problem to date is the high sampling costs incurred to map soil test variability. Several studies have shown yield improvement and input savings, but overall economic return was less than a uniform system because of mapping costs not being offset by either sufficient yield increase or input savings. Field research continues today. This work will help clarify needed site-specific management services.

Soil Testing

A major portion of site-specific management revolves around soil testing. With the availability of variable rate fertilizer and limestone application equipment, heightened interest is present for mapping soil test variations within-fields. Mapping soil test variability is not new. The University of Illinois, for example, published a circular in 1929 outlining practices to intensively (23 surface samples per 40-acre field) soil sample fields for soil pH mapping and variable limestone application. Since other presentations and reports at this conference are specifically addressing systematic soil sampling and spatial test variation, we will not discuss sampling procedures in detail. Suffice it to say that the grid point sampling approach is currently receiving most attention as the sampling protocol for site-specific practices. A large question is the number of samples required to acceptably map soil test variation (within economic justification).
Figure 3. Relative crop yield response (yield increase = $\Delta Y_2$ and yield decrease = $\Delta Y_1$) and to misallocation of applied input ($\Delta X$) (Jensen and Pesek, 1962a).

Figure 4. Influence of soil test P level on the fertilizer P rate required for maximum yield (Tisdale et al., 1993).
Reliable soil tests and accurate variation maps are prerequisite for site-specific management. Soil tests must be calibrated to expected crop response, show stability and repeatability over time, and change as expected with excess or deficit input application. Variance from these qualities deters from potential benefits and expectations of site-specific management. One must recognize limitations of current soil test procedures, and be willing to accept the effect of those limitations on the potential of site-specific management. It won't be perfect.

As mentioned previously, grid point sampling is receiving the most attention as a superior sampling protocol for site-specific practices. Following is some information from Sawyer (1994b) that discusses the value of grid sampling.

Benefits From Grid Sampling

• Ability to map major soil fertility features within fields.
• Ability to produce site-specific application maps, for either manual or automated applications.
• Increased confidence of central tendency values (mean and median) and lowered sample averaging across low and high test areas.
• Although not an immediate benefit to farmers, generates a geographic soil test database that can be analyzed to help make many decisions; such as future nutrient application needs, nutrient problem areas, potential environmental problems, potential for variable application, and enhanced knowledge about soil properties, such as buffering capacities (when tied to nutrient application databases).
• Ability to re-sample the same locations in fields (especially with the availability of positioning systems such as CPS). This enables long term monitoring of management practice effects on soil test levels.
• Tie harvest nutrient removals (with the capabilities of grain yield mapping) to immobile nutrient replacement and soil test changes over time.

Problems That Detract From Grid Sampling

• Sampling scale and inability to map all variation features within fields.
• Inherent laboratory analysis errors. These occur in all laboratories and cannot be eliminated, although every effort is usually taken to keep them as small as possible.
• Soil tests with less than ideal calibration to expected crop response.
• Repeatability between samplings. Although point sampling (cores taken within a small radius of grid intersection points) reduces variability in cores composited into a sample, sample collection usually is the largest source of variation. This occurs as a result of time of year, depth, fertilizer bands, uneven manure application, previous crop, residue distribution, and vertical nutrient stratification. Problems with analysis stability over time vary with different analyses. Some, like pH, are more stable than others, like available potassium. Grid point sampling, utilizing positioning systems, greatly improves repeatability, although only within the constraints listed above.
• The real world. Soil sampling does not take place in a test tube. Soils are dynamic systems and the sample only represents one time frame.
Suggestions For Providing Economical Grid Soil Sampling

- Follow research derived guidelines for sampling intensity. Several examples are presented at this conference. Recommendations change over time, and with the advent of computer controlled application equipment, recent grid size recommendations have intensified to accommodate capabilities of computer processing and application equipment.
- Be flexible and consider modifying grid sampling protocols when improved sampling techniques are identified, especially those with the potential to reduce the total number of samples required per field or ability to target intense sampling in fields or areas of fields identified as potential candidates for variable application (in essence using existing information to guide future intense sampling).
- Be flexible, and reduce future sampling intensity when fields are identified as non-candidates for variable applications.
- Soil test only for those characteristics needed to determine input needs and rates. With some recommendation systems, these might include only pH, buffer pH, and available P and K.
- Frequently test only for those characteristics that change rapidly or change because of farmer management.
- Infrequently measure those characteristics that do not change rapidly, are not used in the recommendation process, or are not needed on a site-specific basis.
- Provide maps that can be generated from soil test databases in future years, thus eliminating the costly map building process. Provide maps that are compatible with other systems, such as yield monitoring and variable applicators.
- Offer the ability (through modeling) to evaluate the need for variable application on an individual field basis and be willing to alter future sampling protocols to enhance delineation of important test areas in fields.
- Spread sampling and mapping costs over multiple input needs.

Yield Variability

Many published studies show that crop yields vary within fields. Some examples include Karlen et al. (1990), Carr et al. (1991), Colvin (1993), Miller et al. (1993), Franzen and Peck (1993), Vetsch et al. (1993), and Wibawa et al. (1993). This subject will be covered in detail elsewhere at this conference. Yield variation is not surprising and is commonly observed by farmers. Yield variation can be due to many factors or combination of factors, including nutrient availability, available soil moisture, drainage, rooting depth, landscape position, pest pressure, and competition. Delineation of the exact cause will probably be difficult in many instances. Differences may be due to one factor, or it may be due to multiple factors. Cause and effect relationships will not be readily apparent.

Of great interest is the use of yield maps for prediction of variable fertilizer need, such as N requirements for corn, and for postharvest assessment of crop removal of immobile nutrients. This postharvest assessment may hold the greatest promise for long-term variable fertilizer application. In fact, for successful management of variable soil test levels, crop nutrient removal may be required, otherwise soil test variation may increase rather than decrease.
Summary

Site-specific management has the potential to improve crop input management and field profitability. Should site-specific management be implemented on every production field or is it the best management system for all farmers? As is the case for many management practices, no definitive answer exists. Likely it depends – on the expectation of crop response to inputs, the value of the crop, the characteristics of the variability affecting crop production, and the capacity to measure, map, and manage variability.

There is no predetermined guarantee that site-specific management will be economical for all farmers. As for all production practices and systems, including site-specific management, an assessment of each field or geographic region is needed to ensure greatest chance for profitable implementation. The greatest benefit from site-specific management is the heightened awareness of the crop management practices available today, and the critical field evaluation and management it requires. For site-specific management systems to be fully implemented within production agriculture, a major change must occur in how agribusiness and farmers view and manage crop production inputs – a change from the predominant practice of uniform input application and adjusting input needs only between fields.

References


