7.9 Variable Rate Technology Risk Management

Investigators:

Carl Dillon, Department of Agricultural Economics, cdillon@uky.edu

Ron Fleming, Department of Agricultural Economics, rfleming@uky.edu

John Fulton, Department of Biosystems and Agricultural Engineering, jfulton@bae.uky.edu

Tom Mueller, Department of Agronomy, mueller@uky.edu

Scott Shearer, Department of Biosystems and Agricultural Engineering, shearer@bae.uky.edu

Tim Stombaugh, Department of Biosystems and Agricultural Engineering, tstomb@bae.uky.edu

Introduction:

Variable rate technology (VRT) has enabled agricultural producers to engage in site-specific fertility management (SSFM). SSFM is based on the premise that the quantity of fertilizer and lime that produces the maximum economic crop response varies spatially in a way that can be adequately predicted and managed (Sawyer, 1994; Pierce and Nowak, 1997; Mueller, 2001). A number of steps are involved with SSFM. For example, soil samples are collected, georeferenced and sent to a laboratory for analysis. The laboratory results are used to develop nutrient and prescription maps. Finally, VRTs are used for applying nutrients and lime site-specifically. Potentially there are errors involved with each step of the process including errors associated with georeferencing sample locations, global positioning system (GPS) measurements, soil sample analysis, soil interpolation procedures, fertilizer recommendations, and application errors. As these errors are controlled with improved procedures, the risks associated with applying incorrect, non-optimal nutrient levels decrease. Modeling the agronomic, economic, and risk consequences associated with this system of errors will not only improve our understanding of SSFM, but also will guide us in improving the weak links in the system.

Users of VRT need assistance in managing the risks they face from these multiple sources of error. An integrated research effort that assesses all of these components in a common economic model is needed. This
will permit the reflection of a holistic effort in developing production management strategies that maximize profit while considering these uncertainties.

Objectives:

The fundamental purpose of this research project is to assist crop producers by providing analytical procedures and information that will assist them in adjusting their decision-making processes to adequately reflect the uncertainty introduced in VRT from multiple sources of error. The procedures used here can be generalized to several production inputs (e.g., P and K). The specific objectives are to:

1) Quantify the degree of error introduced into VRT from the various sources (soil testing error, interpolation errors, application errors, GPS accuracy error),

2) Develop an economic risk management model using an empirical application that considers these sources of error to assist in making production management decisions, and

3) Use sensitivity analysis to ascertain how optimal management decisions change in response to reduction of the various sources of error to provide insights as to the most economically important errors.

Background:

Errors may be introduced by soil sampling procedures (i.e. sampling depth, core diameter, number and orientation of sub-samples in each composite sample), method of sampling (grid sampling or directed/zone sampling), and intensity of sampling (i.e. grid size, zone size). Errors associated with uncertainty of position (i.e. GPS errors), sample preparation, and laboratory analyses may be small compared to errors associated with prediction. The method used to generate spatial predictions at unsampled locations (e.g. nearest neighbor, inverse distance, and kriging) introduces error. Methods used to summarize spatial predictions with contours or application grids cells further degrade map quality. Errors are introduced when fertilizer recommendations are used to transform soil property maps into application map. This may occur because not all of the factors that contribute to an economic crop response are included in recommendation and because recommendations were
based on the hybrids, soils, and cropping practices used in their development. Hergert et al. (1997) provide additional explanations: the economic environment of crop production has changed substantially since the development of recommendations, soil variability has increased over time with management, and spatial variability is already compensated for in many whole field recommendations. VRT errors include errors related to GPS, heterogeneity of fertilizer composition, application overlaps and gaps (Fulton et al., 1999), topographic relief and the response lags when changing application rates. None of these errors are independent. Errors associated with map production will be magnified by application errors. Further, these errors may propagate non-additively. A model that explains how each source of error affects the economics of SSFM will allow research to be targeted at the most significant factors. Further, SSFM methods can be adjusted by producers to minimize these errors. Approaching SSM research in this way will require an interdisciplinary effort due to the complex nature of the problem.

A great deal of preliminary work has been done by University of Kentucky researchers to quantify errors associated with nutrient map errors, variable rate application, and GPS errors. Nutrient estimation procedural research has been led by Dr. Tom Mueller. Dr. Mueller and his colleagues collected soil samples on grids (100, 200, and 300 foot grids) for three fields in Kentucky (Mueller et al., 2000). These samples were analyzed for pH, buffer pH, P, and K. They found that even on very fine grids (i.e., 100 foot grid), prediction quality was only modest and it worsened substantially with decreasing sampling intensity. Since this work was published, the authors have found similar results on two other Kentucky fields. Further, this work produced similar results as work published from a Michigan study (Mueller et al., 2001). Dr. Mueller is looking at various methods such as incorporating secondary spatial data (i.e., sensor measurements) to reduce the errors associated with spatial prediction (Mueller and Pierce, 2003). His work in the area of soil electrical conductivity suggests that EC may be a useful tool for improving spatial estimates for depth of topsoil (Mueller et al., 2003), an important variable for variable-rate nitrogen management (Barnhisel et al., 1996).

Additional errors result from the inadequacies of application equipment to deliver the desired amount of nutrient(s) when considering spatial shifts in the desired amounts under VRT. It is believed that VRT can
spatially deliver the desirable amount of material; errors are inherent to this technology causing application errors. With VRT, more complexity is introduced with continuously changing application rates. Some of the more prevalent errors resulting from VRT are the existence of latency and distribution pattern shifts during rate changes causing deviations from the desired application rates. The concern is that these application errors could exceed acceptable levels. Research has indicated undesirable distribution pattern shifts from variable-rate broadcast spreaders when making rates changes (Fulton et al., 2001 and Olieslagers et al., 1997). Pattern shifts generate application errors since deviating from the desired pattern creates an uneven, non-uniform distribution. Fulton et al. (2001) also indicated that rate changes do not occur instantaneously again due to system latency thus adding to variable-rate application errors. Another aspect they identified was that the variable-rate system response was different when increasing the application rate compared to decreasing the application rate. Typically, the coefficient of variation (CV) varies from 5% to 10% for spinner spreader patterns under fixed application. However, this variation may be much higher with terrain irregularities (Parish, 1991) where CV’s in the upper 20’s to the lower 30’s were observed in some cases. Sogaard and Kierkegaard (1994) reported that CV’s of 15% to 20% are more typical of field tests. Most people find CV’s in the 15% to 20% range as acceptable but with the addition of distribution pattern shifts and system latency under variable-rate application, application errors could reach an unacceptable level causing poor agronomic and economic effects.

Both application and interpolation errors are further complicated by the error introduced in GPS accuracy as determined by Dr. Tim Stombaugh. The receivers used by practitioners have accuracy specifications ranging from 0.3 to 3 m; however, Stombaugh et al. (2002) showed that these numbers are not always truly indicative of the actual performance in an agricultural situation. GPS errors can become more pronounced under certain environmental conditions. Additionally, the computation algorithms used by some manufacturers tend to drift with time, which means that data collected at different times in the same area may not overlay perfectly. Thus, while most GPS manufacturers will provide accuracy specifications for their equipment, these numbers do not always reflect the true performance of the equipment in specific situations (Stombaugh et al., 2002).
Proper consideration of these errors in an economic production management model requires the use of risk management modeling. Risk management, although an important area of agricultural economics research, has not been extensively considered with respect to application in precision agriculture. The importance of risk management in agriculture decision-making has been well established (e.g. – Anderson, Dillon and Hardaker; Hardaker, Huirne and Anderson; Robison and Barry). However, risk management has not been examined extensively in the context of precision agriculture. Lowenberg-DeBoer (1999) outlined a number of risk factors faced by precision agriculture adopters and claimed that precision agriculture may also reduce risk. Research efforts by Carl Dillon have reflected the risk management implication of precision agriculture including Conservation Reserve Program (CRP) enrollment decisions, production versus nonproduction spatial decisions, initial testing of optimal management zone delineation modeling and variable rate germination date evaluation. Simple break-even decision criteria were exploited considering risk as well as profitability in the risk and returns tradeoffs in both CRP enrollment and the decision of whether or not to produce on less productive portions of the field (Stull et al. 2001, Stull et al. 2000, Powers et al. 2002). Research results from these studies indicate substantial influence on management decisions depending on the farmer’s attitude towards risk. An advanced nonlinear, mixed integer programming model was employed in evaluating the economic potential of innovative polymer coated seed in variable rate germination (Dillon, Mueller and Shearer, 2001; Dillon, Shearer and Mueller, 2001). The value of the coated seed technology was demonstrated to be markedly higher under variable rate seeding and for farmers wanting to use the seed to reduce production risk. Risk management was also reflected in an initial test of a nonlinear, mixed integer programming model procedure for optimal management zone delineation (Dillon, 2002). Risk played an important role in the optimal management strategies used, highlighting the need to develop an integrated, holistic economic risk management model that simultaneously considers the multiple sources of error in VRT.

Procedures:

The case study production decision model is formulated as a mathematical programming model wherein a producer attempts to maximize the risk adjusted net returns above specified costs (including all variable costs
and relevant fixed costs). Land charges, property taxes and returns to management and overhead labor will be excluded. The enterprises to be incorporated as decision variables in the model will depend on the availability of data but could include corn or soybeans. Constraints include land, suitable field days by week and crop rotation.

A quadratic programming model will be employed using an expected value-variance (E-V) framework to incorporate profit and risk considerations. Risks inherent from the multiple sources of VRT error are thereby included.

Data required include error distributions, yields, suitable field days, input requirements, commodity prices, input prices and land available. The distribution of errors from the various sources will be collected from prior literature including work done at the University of Kentucky. Statistical regression techniques will be used under the guidance of Ron Fleming to develop a nutrient level map that reflects the underlying cumulative error distribution of GPS inaccuracies, soil testing errors and nutrient estimation technique error. This will be coupled with application error in the development of yield data, completing the integration of multiple error sources.

Biophysical simulation (BPSM) or response functions will be used to estimate the underlying crop yield for a constant technology by altering production practices (nutrient level such as P and K and possibly other factors such as planting date). BPSM will also permit estimation of the days suitable for fieldwork. Input requirements and input prices will be taken from enterprise budgets as possible with Kentucky Agricultural Statistics Service and expert opinion supplementing this as needed. Land available and other supplemental data from Kentucky Cooperative Extension Service publications such as Kentucky Farm Business Management Program results will be used.

The sensitivity of the net returns and the chosen optimal nutrient management strategy to changes in the economic decision-making environment is investigated through alterations in the economic model. Systematic increases and decreases (e.g., 5, 10, 15%) of the errors will be included in the model and the new optimal solution determined. Similar systematic alterations in relevant components such as crop price and nutrient price could be examined as well.
**Expected Benefits:**

This research expressly addresses the purpose of providing Kentucky producers with insights regarding the consideration of errors in VRT. It will address several key questions. How can producers appropriately reflect errors in nutrient level estimation, application and GPS accuracy in nutrient prescription levels? How can a farmer adjust these decisions to reduce production risk given his or her attitude towards risk (e.g., low risk aversion versus high risk aversion)? Which of these errors (e.g. application or GPS accuracy) has the biggest economic impact? How are other management practices impacted by these errors (e.g. planting date decisions)? What impact does crop price or nutrient price have on the amount of fertilizer to use? Consequently, this research will provide insights into the establishment of practical, simple decision rules that may be used by producers using or considering VRT.

**Deliverables:**

Many deliverables are expected from this research. Model results should provide insights useful in the refinement of current and developing new recommendations on the economically optimal selection of production practices for greater profitability and reduced production risk. Refereed journal articles, popular articles, presentations, professional meetings and in-service training with county agents will be provided. Furthermore, communication of results through extension newsletters, extension publications and field days is envisioned.