Application of Precision Farming Strategies to Direct Seed Systems: 
The Cunningham Agronomy Farm

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Introduction

Precision farming (PF) has been defined as doing the right thing in the right place at the right time. PF strategies have largely emphasized high-tech applications such as global positioning systems (GPS), geographic information systems (GIS), variable rate technologies (VRT), yield monitoring, and the use of various environmental sensing technologies. After the excitement of looking at pretty maps wears off, a common conclusion is that we really do not understand what factors are contributing to the spatial and temporal variability of crop performance within a given field. If PF is to meet the potential and expectations of currently available and future technologies, we will need to: (1) diagnose and understand field-scale variability; (2) identify what variability is predictable and therefore potentially manageable; and (3) determine the economic and environmental value of applying precision farming strategies and technologies to manage variability. All of these steps need to be completed for PF strategies to be devised and for a PF system to be successfully implemented.

The motivation for managing field variability depends on our abilities to derive value (economic or environmental) from an increased understanding and ability to predict field variability (for example: crop yield and quality, soil nutrient deficiencies, changing soil depth, differences in weed or disease occurrence) and devise appropriate PF management strategies. Our abilities to diagnose and predict variability, however, are not the same for all field or farm related properties. Properties such as soil test levels of phosphorus, soil pH and soil organic matter tend to change fairly slowly over time and variability is largely expressed as spatial patterns across a field that do not change significantly from year-to-year. In contrast, some properties, such as grain yield, percent protein and soil nitrate levels, can change not only across a field but from year-to-year. This last situation, where a property varies both spatially and temporally, is the most difficult to diagnose and predict, and consequently, the more difficult situation in which to apply PF strategies.

In 1999, the Washington State University (WSU) Cunningham Agronomy Farm (CAF) was initiated to develop principles and strategies that reduce risk, increase profits and improve environmental quality of agricultural systems. Two over-arching areas of research are thought to be fundamental for achieving this goal: (1) the development of continuous direct-seed cropping systems; and (2) the development of precision farming strategies. One could speculate that the successful development of direct-seed systems is at least partially dependent on applying PF strategies. I suggest this idea based on the general observation that direct-seed systems tend to increase the diversity and variability of the cropping system (soil properties, pests, rotations, crop performance), as compared to tillage-based systems. Managing variability in low disturbance systems may therefore be of greater importance than in high disturbance systems and perhaps key to realizing benefits from greater efficiency of input use, decreases in costs and reductions in adverse environmental impact. My objectives in this presentation are to: (1) describe our research approach for developing sound PF management strategies; and (2) present our current progress on diagnosing and predicting field variability and the potential for generating value from PF practices.

Research Approach

The success of cropping systems research at the CAF is dependent on how well we can integrate good farming practices with good research. We use field-scale equipment and relatively large field areas for treatments. All crops are seeded with a one pass system using a direct-seed drill. Fertilizer is either applied with the drill during seeding or broadcast at strategic times during the year. During the first year of operations, we established 369 geo-referenced sample locations in a grid pattern across 92 acres of the CAF. Sampling points were located using a global positioning system (GPS). The ability to know the geographic position of these points and return to them for repeated sampling allows us to characterize the spatial and temporal variability of any property of interest (for
example: soils, weeds, disease and crop yield, quality). Hard red spring wheat (HRSW) was grown the first year and spring barley the second. During this time the site was flown to obtain aerial photos and further characterized for soil properties, weed seed bank, soil-borne disease, electromagnetic induction (apparent soil conductivity), topography (using a survey-grade GPS), and crop grain yield and protein. The detailed elevation measurements from the GPS were used to derive terrain attributes (for example: slope, aspect, curvature, catchment area) and aid characterization of variations in the physical environment. A weather station and additional sensors were positioned in strategic locations to collect data required for crop modeling. We hypothesize that the terrain and crop modeling can be combined and used in meaningful ways to diagnose and predict variability leading to advances in decision support systems.

Endless Variability

The complex landscapes and soils of the Palouse area seem like the perfect place to apply PF technologies. However, our lack of understanding of the tremendous variability created by this environment has hindered our capabilities to use PF strategies. Field-scale complexity is shown in the variability of grain yield and protein of HRSW grown at the CAF in 1999.

Grain yield for the 92-acre field ranged from 15 to 78 bu/ac for “WB926R” hard red spring wheat while grain protein ranged from 11 to 18%. In 2000, spring barley (Baronesse) yield and protein also varied considerably ranging from 2300 to 6200 lbs/ac for yield and from 6 to 16% for protein. We concluded that: (1) almost as much variability in grain yield and protein exists in one field as there is throughout the whole dryland region; (2) large within-field differences occur in economic return; and (3) there is substantial variation in potential risk of environmental degradation of soil, air and water quality. One promising aspect of these two years of data is that there appears to be similar patterns across the field for both grain yield and protein. If the variability in crop performance is, in part, dependent on fixed (temporally stable) landscape and soil properties, this would increase prediction capabilities and we could proceed to create management zones where farming practices could be tailored to better optimize returns and reduce environmental risk. To progress toward this goal we are experimenting with rapid diagnostic tools that could be readily used by growers, and slower sample-based measurements of soil and crop properties that, although not often practical for growers to collect or use, can aid interpretation of variations in crop performance (Figure 1).

One rapid diagnostic tool that we have used is a survey grade GPS that measures latitude, longitude and elevation. A digital elevation model (DEM) and associated terrain attributes can be derived from these data. Terrain attributes such as slope, aspect, curvature and catchment area are relatively fixed values for a particular field and would only need to be measured once. Unfortunately, current low-end GPS instruments are not accurate enough to provide meaningful elevation data and a more expensive (accurate) GPS is needed to obtain meaningful results.
Another rapid “sensor” instrument that we are using is an electromagnetic induction meter which measures apparent electrical conductivity (EC$_a$). The GPS and EC$_a$ data can be collected simultaneously with a four wheeler and data-dense maps created with available software. Our first approach is to use these potentially readily obtainable data in an attempt to predict spatial variation in yield and protein. Additionally, although yield data are collected at the geo-referenced sampling points, we also run a yield monitor in the combine. A yield monitor is one of the best measures of field variability currently available to growers.

**Defining Management Zones: First Approximations**

**Use of Terrain Attributes and Electromagnetic Induction**

Terrain attributes were derived from a DEM using ArcGIS software. Aspect, percent slope, various measures of surface curvature and wetness index were calculated from the DEM. Electromagnetic induction data were collected using a Geonics EM-38. This instrument measures EC$_a$, which is influenced by soil texture, water content, salt content and temperature. We have collected EC$_a$ data in the spring prior to planting and again after harvest during 2000, 2001, 2002 and 2003. The reasoning behind using EMI is to evaluate its usefulness for predicting soil available water and for detecting field areas where potentially root- and water-restrictive subsurface clay layers exist in a given field.

Multivariate clustering techniques were used with the terrain attributes and EC$_a$ data to initially “group” similar data together into clusters. The result of these analyses was to create zones entirely based on information that could be readily obtained with a GPS and EM-38. The next step is to evaluate if these zones can explain variations in other properties of interest such as crop performance (yield, protein, economic return), soil organic matter, available water and nitrogen use efficiency. These results and our analyses to date will be presented at the conference.

**Concept of Suitability Zones**

Often the success of growers in applying direct seed or precision agricultural technologies depends on a number of factors that change from region to region, field to field and within locations on a given field. These differences in realizing management objectives gives rise to a concept I will call agroecologic suitability. Conceptually, if the combination of grower practices, market forces, government programs and ecological (environmental) constraints come together to meet given criteria necessary for the farms continuing survival and improved quality of life, the agroecologic suitability is high. Furthermore, given the spatial and temporal variability of socioeconomic and environmental drivers, locations within a field are going to be more or less suited to achieving overall goals under a uniform set of cultural practices. Consequently, an agroecologic suitability zone can be defined as an area that has a similar potential to meet socioeconomic and ecological objectives under a given set of practices. For example, certain areas within a field may or may not be suited for producing direct-seed hard red spring wheat (HRSW) depending on site-specific economic (profits due to grain quantity and quality, input costs, markets, etc.) and environmental (air, water and soil quality, biological degradation) performance. Another way of looking at the concept of agroecologic suitability is to define it as the degree to which a set of agronomic practices, combined together at a given location, achieve socioeconomic and ecological objectives. Agroecologic suitability zones can be defined within fields for combinations of practices (crops and crop rotations, pest, nutrient and residue management) that evaluate site-specific system performance and aid the development of PF strategies and viable direct-seed systems. In fact, the blending of direct-seed and PF strategies may well lead to increased overall agroecologic suitability at the field and farm scale. Presented at the conference will be an example with HRSW, where yield, protein, variable costs, returns, and nitrogen use efficiency are used to assess agroecologic suitability zones.