MOVING PRECISION AGRICULTURE TO A NEW DIMENSION
The ARS/CSU Precision Farming Project at Wiggins, Colorado

Kim L. Fleming, Dwayne G. Westfall,
Colorado State University, Fort Collins, Colorado
and Dale F. Heermann
USDA-ARS, Fort Collins, Colorado

ABSTRACT

As more producers become aware of precision farming technology they are asking how it can improve productivity and profitability. There is a vast array of claims, beliefs, and testimony, yet little quantitative data to answer this question. Multi-disciplinary field scale research is needed in precision farming to answer the questions of productivity and profitability. The Agricultural Research Service and Colorado State University have begun a multi-disciplinary research program that focuses on developing a clearer scientific understanding of the causes of yield variability. We intend to develop decision support systems for site specific management. A team of 15 scientists covering the areas of soil fertility, crop production, weed science, entomology, plant pathology, system engineering, remote sensing, GIS, irrigation engineering, agricultural economics and statistics has started a project to develop a better understanding of precision agriculture in Colorado. They are collecting and analyzing data from 2 center pivot irrigated fields. Cooperating farmers manage all the crop production operations and provide yield maps of the corn grown on the fields (175 and 130 ac.). The important variables for crop production have been sampled at several different intervals. Both fields have been sampled at a grid spacing of 250 feet. More intensive sampling has been done by various disciplines in smaller areas at a variety of scales down to 50 feet. Concurrent work, in cooperation with industry, is developing center pivot and linear move irrigation systems to apply variable site specific rates of chemicals and water. We will discuss the project and the various data layers being collected.

INTRODUCTION

Precision farming is a management system based on variability that occur in farmers fields. Although farmers have been aware that fields have variability, conventional management has generally been uniform within fields. Precision farming seeks to match production inputs with potential production and profit. This, in theory has the potential of providing economic and environmental benefits due to reduced waste of inputs. For example, fertilizer and herbicides would be applied only where needed, avoiding applying too much or too little on specific sites.

This new opportunity for replacing uniform application is derived from recent technological advances. These include: (i) improved microcomputer capabilities, (ii) global positioning systems (GPS) for field navigation (Larsen et al., 1994; Petersen, 1991), and (iii) variable rate fertilizer and pesticide application equipment (Larsen and Robert, 1991).

Crop producers in Colorado are beginning to adopt precision farming technology, with DGPS yield monitors and variable rate fertilization two of the most common applications. As more

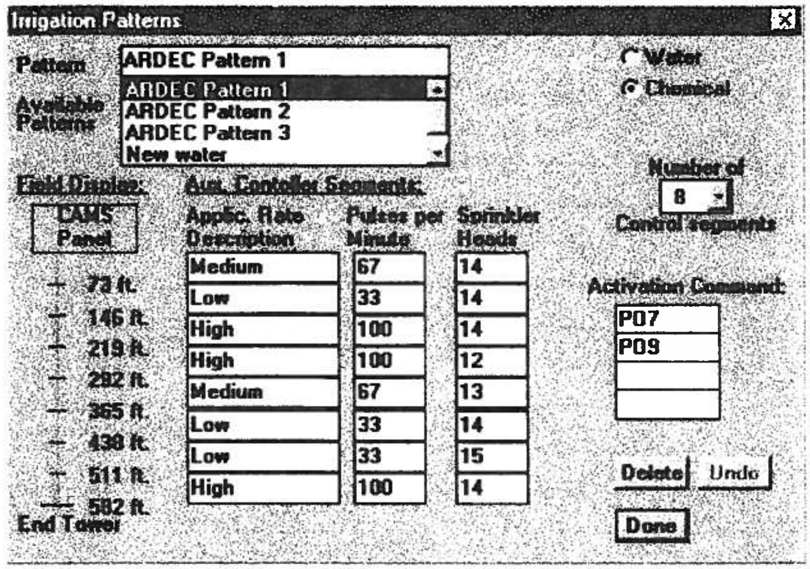

Figure 2. Setup for variable chemical application.

producers become aware of this technology they are asking how precision farming can improve my productivity and profitability. There is a vast array of claims, beliefs, and testimony, yet little quantitative data exists to answer the basic questions (Nowak, 1997).

Multi-disciplinary field scale research is needed in precision farming. Colorado State University and the Agricultural Research Service Water Management Unit (ARSWMU) in Fort Collins have assembled a multi-disciplinary team to assess the technical and economic feasibility of precision farming. This project involves fifteen scientist, two farmers, three extension specialist, and four graduate students working on two center pivot irrigated fields near Wiggins, Colorado.

Our initial goal, before precision farming treatments are applied is to complete two years of intensive and coordinated data collection and analysis. With these data we can begin to identify and quantify the factors contributing to yield variability under sprinkler irrigated conditions. In addition, through intensive data collection we will develop and evaluate various aspects of precision farming sampling methods and strategies, along with analysis techniques. Ultimately we hope to develop models to predict the effect of spatial variability on the profitability of precision farming. The levels of spatial variability within a field is in itself variable, thus increased production and savings in input cost from site specific management should also vary. We then hope to incorporate those models into a decision support system we feel is essential in moving precision farming from the early adopter phase into the mainstream farming community.

DISCUSSION

Farm Management and Operation

Both center pivot irrigated fields were in sugar beets in 1996 and will be in continuous corn throughout the study. Pivot 6 (175 acres) is operated by Larry Rothe while pivot 39 (130 acres) is operated by Bob Geisick. They are responsible for all management decisions and farming operations on the fields.

Topography

The Natural Resource Conservation Service assisted in topomapping both sites in March. Two methods were used, a laser level to determine elevation along with GPS to generate position and Total Station which determines xyz data.

Soil Fertility

Dwayne Westfall, CSU completed our initial spring soil sampling in April 1997. A 250 foot coarse grid was sampled over the entire field at both locations. In addition a 500 x 1000 foot area of maximum variability within each field was identified. Within these areas soils were sampled on a 50 foot fine grid. Sample locations within the grids were randomly selected . The surface 0-8 inches was analyzed for NO_3N , NH_4N, P, K, Zn, pH, organic matter, and texture. Subsoil samples from 1 to 2, 2 to 3, and 3 to 4 foot increments were analyzed for NO_3N and NH_4N.

Conductivity Mapping

Newell Kitchen (USDA,ARS, Columbia, Missouri) mapped conductivity at both sites using a electromagnetic induction (EM) ground conductivity sensor. Originally developed for geophysical surveying applications, EM sensing uses electromagnetic energy to measure the apparent conductivity of earthen materials. This method has been used to measure the apparent conductivity of saline and sodic soils, map thickness of clays, measure soil water content, and for groundwater research. Factors that influence variation in EM response include the volumetric water content, the types and amounts of ions in the soil solution and clays present.

We found a wide range of conductivity readings with systematic rises and dips across the fields. We plan to ground truth the data working with NRCS personnel. This should prove to be a valuable layer in assessing and correlating variability at our sites.

Weed Sampling

Phil Westra, CSU and Lori Wiles, ARSWMU collected weed seed and seedling data. In May they collected soil cores for weed seed bank assessment at the center of the coarse grid locations established for soil sampling. In addition three 500 by 500 foot star shaped locations were sampled each containing 150 samples. In early June and September weed species counts were taken at the same locations weed seed bank samples were collected. Weed seed sampling was repeated in November after corn harvest. The weed seed soil cores were also analyzed for nematodes and corn rootworm eggs.

Insect Monitoring

Frank Peairs, CSU feels we have set a world record for the number of insect traps in one field. European Corn Borer, Western Bean Cutworm, and Western Corn Rootworm populations were monitored throughout the growing season. Pivot 39 had 189 locations with pheromone traps at all coarse grid locations plus an additional 101 randomly selected locations. One hundred seventy eight locations were monitored on pivot 6, again at all course grid locations plus an additional 53 random locations. Populations were determined on weekly basis from mid June through mid September.

GPS

A GPS base station has been established in the area which will continuously broadcast the differential correction using an Ashtech Super C/A 12 (C/A code + carrier phase) receiver. The radio used to broadcast the differential correction is a FreeWave spread spectrum transceiver. A computer will be located at the base station site to store raw data for post processing to improve position accuracy, if desired.

Four control points (benchmarks) have been established outside each of the two fields for georeferencing aerial photography. These points can also be used to evaluate the accuracy of GPS receivers.

Remote Sensing

Walter Bausch, ARSWMU is heading up the remote sensing work for the project. He has equipped a high boy sprayer with multi-spectral remote sensing tools. A boom-mounted instrument platform carries two Exotech four-band radiometers 30 feet above the soil surface. One measures the irradiance while the other one measures target radiance, the down-looking radiometer is pointed perpendicular to the crop surface (nadir view). Radiant energy is measured in the green, red, and infrared wave bands. These wavebands are the same as on the Landsat Thematic Mapper as well as what will be in the upcoming commercial satellites operated by Resource 21, SpaceImaging, and EarthWatch. The instrument platform also carries an IR transducer to measure surface temperature which also has a nadir view. A GPS antenna is mounted directly above the down-looking radiometer to determine the approximate position.

A side-mounted arm near the tractor carries a IR transducer (6° below the horizontal), an aspirated relative humidity/air temperature sensor, and a 15° Exotech radiometer (15° below the horizontal). These are located at 0.3 m, 0.8 m, and 1 m, respectively, above the crop surface. The IR transducer and Exotech radiometer look perpendicular to the crop rows.

A data point is collected and stored every 2 s. Traveling 4 mph, the distance between centers is approximately 12 ft. Fifteen transects were run thru each field with the high boy to measure canopy reflectance, each covering 40 rows. Measurements were taken each week from V6 through R5 growth stages. In addition population, leaf area, and chlorophyll measurements were taken at 46 course grid locations corresponding with the transects within each field.

Color 35 mm aerial photographs of each field were taken each week from V6 through R4 growth stages. In mid July TASC an east coast based imaging company flew the fields with a Kodak digital infrared imaging system. This data was correlated with Walter's ground based data.

Sorptivity and Hydraulic Conductivity Measurements

To begin to assess the spatial variability in soil infiltration and drainage properties Gerald Buchleiter and Roger Smith, ARSWMU, took sorptitvity readings using three and 3/4 inch rings. The coarse grid at both pivots was measured in April, plus an additional 140 locations in the fine grid on pivot 6 and 80 locations in the fine grid on pivot 39.Soil samples were taken for moisture and bulk density measurements at 10 % of the locations.

In late April through early May one hundred 12 inch single ring infiltrometer readings were taken in the fine grid on pivot 6. The rings were initially saturated before the infiltrometer measurements were taken to determine saturated hydraulic conductivity. Soil samples were taken at each location down to three feet to determine bulk density and 1/3 bar field capacity.

Irrigation Monitoring

Dale Herrmann and Harold Duke, ARSWMU, are exploring the spatial variability in center pivot water application. They performed sprinkler uniformity tests at various locations in the field. The data will be used to correct irrigation models for wind and validate spatial water applications models. Pump tests were also performed at many locations in both fields, flow, power consumption, and pressure were measured at the pivot point. They found variability in water application within both pivots.

Each pivot was equipped with a Valley CAMS panel with phone links to the ARSWMU in Fort Collins. Scientists could monitor the pivots position from Fort Collins and plan field activities accordingly.

Weather Data
Weather stations are located at each pivot. In addition six tipping bucket rain gauges are installed around the pivots. The project is also coordinating with CSU-CHILL National Radar Facility to track raindrop and hail size and intensity.

Yield Mapping
Both fields were yield mapped during the 1997 harvests. Pivot 6 was harvested with a Case IH 1460 Axial Flow combine, while a 1680 Axial Flow was used at pivot 39. Both were equipped with Micro-Trak yield monitors with Ashtech GPS equipment and a base station for differential correction discussed earlier.

SUMMARY

A multi-disciplinary team from CSU and the ARSWMU are accessing the technical and economic feasibility of precision farming. Baseline data was collected and analyzed on two center pivot irrigated fields near Wiggins, Colorado in 1997. In 1998 all data collection will be repeated with the same parameters being measured at the same locations to monitor shifts in parameters with time. Precision farming treatments will be explored in years 3 thru 5 to maximize yields and economic return, while maintaining the resource base. From this project the team ultimately hopes to develop models to predict the effect of spatial variability on the profitability of precision farming and incorporate those models into a decision support system.

REFERENCES

Larsen, W.E. and P.C. Robert. 1991. Farming by soil. In "Soil management for sustainability" (R. Lai and F.J. Pierce, eds.), pp. 103-111. Soil Water Conserv. Soc., Ankeny, IA

Larsen, W.E., D.A. Tyler, and G.A. Nielsen. 1994. Precision navigation with GPS. In "Computers and Electronics in Agriculture" Elsevier Science Publishers. Vol 11, pp.85-95. Amsterdam.

Nowak, P. 1997. The "War of the Eyeballs" and the "Battle of Unrealistic Expectations". INNOVATOR Online at http://www.agriclture.com

Petersen, C. 1991. Precision GPS navigation for improving agricultural productivity. GPS World 2(1), 38-44.