EVALUATING SOIL PROPERTY INFORMATION ON A LANDSCAPE

Cristine Morgan, Christine Molling, John Norman and Birl Lowery[1]

Introduction

Agricultural models such as the Precision Agricultural Landscape Modeling System (PALMS) are designed to facilitate producers' management strategies in a precision agriculture environment (Molling et al., 2001). Maps, such as soil water content, grain moisture, and effects of compaction on yield, can supplement management decisions and increase the profit margin in production agriculture. Presuming that precision landscape models will be used by farm managers, we can identify four categories of information that will be needed: weather, landscape, plant, and management. Of these four categories, weather, plant, and management change on a continuous basis, anywhere from hours (weather), to days (management, such as planting, tillage, harvest), to seasons (hybrids). This information needs to be collected on a continuous basis - fortunately not an excessively costly or time-consuming process in most situations. Landscape information, on the other hand, can be very costly and time-consuming to collect. Landscape data, such as topography and soil hydraulic properties, are essentially fixed (except in cases of severe erosion or compaction) and can be collected once.

In this paper we explore some methods for obtaining landscape information, and study the utility of the various accuracy levels of the data obtained. We evaluate the utility of the landscape information by comparing the yield result of PALMS with three landscape information scenarios as input.

Materials and Methods

A 4.4-acre field located on the University of Wisconsin Arlington Research Station (Columbia Co.) was used in this study. The field landscape included a closed depression and slopes generally 1%. The two soil-mapping units in the field included the Plano silt loam and the Ringwood silt loam. The Plano silt loam was the dominant soil mapping unit found in the field, located thought out the majority of the field except the northeast corner. It was described as a moderately well drained soil with high available water capacity and fertility. The Ringwood soil loam, a more eroded soil, was located in the northeast corner. It was described as well-drained with medium available-water capacity and high fertility. The field was managed in a cropping rotation of corn (*Zea mays* L.) and soybeans *(Glycine max* (L.) Merr.). For years that corn was planted (1999 and 2000), the row spacing was 30 inches and the corn was harvested for grain with a combine equipped with a yield monitor.

Three different soil mapping strategies were created to evaluate which measurable attributes were most important for improving the utility of landscape models (Fig. 1).

[1] C. Morgan, J. Norman, and B. Lowery, Department of Soil Science, C. Molling, Space Science and Engineering Center, Univ. Wisconsin-Madison.

Each of the three strategies was created to simulate increasing knowledge of the field and an increase in effort to obtain the knowledge. The first strategy assumed a basic knowledge of the field obtained without making any direct or indirect measurements of the soil or landscape. The USDA soil survey and USGS topographic map were the two sources of information used to describe the landscape for the model for Strategy 1. The second strategy added to the basic information acquired from the USDA soil survey by using yield maps from the producer (Morgan, 2000) and surveying the field for accurate elevation data (< 2 in. vertical precision) with a differential GPS. Strategy 3 used the information from Strategies 1 and 2, plus a survey of electrical conductivity (Morgan, 2000, Morgan et al., 2000), a penetrometer survey (Rooney et al., 2001), and 10-20 soil cores to correlate the instrument surveys to soil properties such as a horizon location, depth, and texture.

The three-dimensional soil landscape maps created by each of the three strategies were used to initialize the soil requirements for PALMS. Each soil landscape map was run for the 1999 and 2000 growing seasons using a 15-foot spatial grid size. The resulting yield maps from each PALMS simulation were compared to the yield monitor data using the root mean squared error (RMSE).

Results and Discussion

The growing seasons of 1999 and 2000 were very different from each other with respect to rainfall. The 1999 growing season had average rainfall quantities and intensities for the region - soil moisture was at field capacity in the spring and at planting, and adequate rain fell throughout the season to prevent severe drought stress. The spring of 2000 on the other hand was very wet, with some corn seedlings drowning in the closed basin area of the field.

The results of the PALMS simulations for 1999 and the yield monitor data are shown in Figure 2. Water availability became a yield-limiting factor for some locations in the field for 1999. Because the 2C and E horizons were considered root limiting horizons, the location and depth of these two horizons became influential in determining yields. Yield from Strategy 1 was fairly uniform within each soil type. In the Ringwood soil (NE corner) yield was slightly lower, where the silt loam layer was shallower. The yield varied more in Strategy 2 because realistic topography caused runoff, making the soil-stored available water vary more across the field (Fig. 2C). The glacial till (2C) horizon was mapped shallower on the hilltop in Strategy 3 compared to Strategy 2. As a result, the yields on the hilltop for Strategy 3 are lower than Strategy 2. In the remaining areas of the field, the 2C horizon was mapped shallower in Strategy 2 compared to Strategy 3 resulting in a lower average yield for Strategy 2 in the entire field (Fig. 2). According to the RMSE calculations, Strategy 2 was closest to actual yield measurements in 1999. However, Strategy 2 did not have the yield variability of the measured yield. The yield patterns of Strategy 3 more closely resembled the yield monitor data.

The high rainfall intensity present in the 2000 season demonstrates the importance of having accurate elevation data in addition to soil information (Fig. 3.). Similar to 1999,

mapping Strategy 1 was uniform across the field, within soil mapping units. Once elevation was included in the soil landscape map (Strategy 2), much less water was available for crop growth in the higher slope regions and on the hilltop (Fig. 3C). Strategy 3 added the compact E horizon in the basin, causing crop drowning from ponding water. The spatial variance of yield for Strategy 3 was much higher than Strategies 1 and 2, and Strategy 3 seemed to come the closest to properly representing the spatial distribution of yield.

All of the modeled yield results differ from yield monitor measurements by more than the acceptable error (10-20 Bu ac^{-1}). The PALMS crop growth and yield model has not been calibrated for any particular field and the crop growth model is quite generic. Nonetheless, rigorous testing has been implemented to ensure the quality of the PALMS soil water and runoff routines. We believe that predicting yield is not the primary utility for precision landscape models. Models of this type will be used for other management decisions such as timing for planting and grain dry down. Currently, the important aspect of the PALMS yield results is the spatial variation and distribution of yield over the landscape of the field. If the yield for Strategy 3 in 1999 were multiplied by a constant so that it had the same average as observed yield, the RMSE between the two would be 12 Bu ac^{-1}, an acceptable result for a yield model. Hence the fact that the yield portion of PALMS is not calibrated does not hinder the usefulness in determining the important soil properties - their spatial distribution and affect on yield across the landscape.

Summary

We have shown that USDA soil maps and USGS topography information are insufficient input for a precision landscape model. This does not mean that this type of information is useless; the information from the USDA soil maps was used as a basis for soil information with augmentation from other soil mapping technologies. Accurate elevation information was imperative in situations where runoff of rainfall affected the yield; in both years (average and wet) the depth of the root-limiting horizon was also necessary.

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