USES OF SIMULATION MODELS IN PRECISION COTTON FARMING

J. A. Landivar
Texas A&M University
Agricultural Research and Extension Center
Corpus Christi, TX

Abstract

Successful uses of precision farming technology depend on our ability to readily assess field variability and to relate the information to optimum management action. Current techniques used to assess field variability (soil sampling, plant mapping, and scouting) are tedious, slow and expensive. Simulation models can play an important role in the development of geo-referenced soil and/or plant databases for use in precision cotton farming. A crop simulation model running on real time can readily provide this information at a fraction of the cost of sampling. Initial performance evaluation of the ICEMM-cotton simulation model to a precision farming study at the King Ranch, in Kingsville, Texas shows promising uses of the models for this purpose. Actual yield in a 100-acre field ranged from 442 to 884 kg/ha with an average of 585 kg/ha. The simulated yield varied from 385 to 1089 kg/ha with a mean of 619 kg/ha. The average yield values differ by 6%. Blocks where ICEMM failed to simulate yield often showed an under estimation of vegetative growth. Slow vegetative growth in the model is often related to a failure to simulate the time course of soil water potential. Our experience on the use of ICEMM to generate geo-reference databases for precision farming applications indicated the following; (1) mechanistic, process level models are required to simulate plant growth and yield in response to inputs reflecting differences between adjacent blocks or management units. ICEMM is such a model; however, improvements and enhancements to the various subroutines are needed to improve the accuracy of the simulations, and (2) improved soil sampling techniques and laboratory analysis are needed to capture and quantify field variability in physical and chemical soil properties.

Introduction

Precision farming offers an opportunity for improving the economic and environmental sustainability of agriculture. It revolves around the use of information-based technologies. The biological information link between the crops and these technologies are obtained from soil sampling, plant mapping and scouting reports. However, these activities are time consuming and expensive. Because of the dynamics of soil and crop processes, biological field information needs to be obtained several times during the season. Successful use of precision farming techniques depends on our ability to readily assess field variability and relate the information to optimum rate of application. A crop simulation model running on real time can readily provide this information at a fraction of the cost of sampling. Initial performance evaluation of the ICEMM-cotton simulation model to a precision farming study at the King Ranch, in Kingsville, Texas shows promising use of the model.

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Discussion

ICEMM Cotton Simulation Model

The Integrated Crop Ecosystem Management Model (ICEMM) is based on the 1998 version of GOSSYM. It has been improved and extensively validated for the Coastal Bend Region of Texas. ICEMM is a dynamic simulator of physiological and soil processes. Inputs required to run the model are: 1) daily weather (temperatures, rainfall, radiation and wind), 2) initial soil fertility (nitrate, ammonia and organic matter content by layers), 3) soil physical properties (bulk density, hydraulic conductivity and moisture retention characteristics), and 4) cultural inputs (cultivar, planting density, planting date, and irrigation and chemical applications). The model takes these inputs and simulates the main processes in the soil-plant environment. Some of the processes simulated are: water and nitrogen uptake and redistribution, organic matter and ammonia transformations, root growth in response to chemical and physical impedance, carbon assimilation and distribution to growing organs, phenological events and the initiation and growth of organs. It provides the user with a daily status report on a number of soil and plant parameters such as soil water content, nitrogen levels and distribution, plant height; node, square, green boll and open boll counts, nitrogen, water and carbohydrate stresses, etc. At the end of the season run, it provides an estimate of lint yield.

Precision Agriculture Study in South Texas

Two adjacent 100 acre fields were selected for the study (Figure 1). The fields were located at the King Ranch, Kingsville, Texas. Soil samples using systematic grid sampling were performed on January 30, 1997. More sampling to complement the existing data was taken on January 21, 1998. Three distinct soil series were identified in both the 100 acre fields; these were Mercedes clay, Raymondville clay loam and Victoria clay. These samples were analyzed for bulk density, hydraulic conductivity, and soil texture and moisture retention characteristics. Results of these analyses were used to develop the soil hydrology input files of ICEMM. Soil samples for soil nutrient analyses were also taken at 15, 46 and 76 cm. depths. These included organic matter content, N, P, K, Mg Ca, SO_4, Zn, Mn, Fe Cu and pH.

Plant mapping was performed at 25, 45, 63 and 91 and 121 days after planting. These data were used to validate the model. The plant height data were necessary for the estimation of Pix applications that were applied on June 3 and 18, 1997. At harvest, yield was estimated by hand harvesting 27.4 ft. of row sections in a dense grid pattern. Weather data was collected by a network of weather stations located at each corner of the 100 acre fields.

Simulation Results

Figure 2 shows the yield maps of the observed and simulated yields for the east 100-acre block. Although the maps showed that ICEMM estimation of the yield was fairly close for about 50% of the area, the actual yield in the 100-acre field ranged from 442 to 884 kg/ha with an average of 585 kg/ha. The simulated yield varied from 385 to 1089 kg/ha with a mean of 619 kg/ha. The average yield values differ by 6%. Blocks where ICEMM failed to simulate yield often showed an under estimation of vegetative growth. Lack of vegetative growth in the model is often related to a failure to simulate the time course of soil water potential. This state variable is strongly affected by water retention characteristics of the soil. These blocks were mainly located on the upper-left corner of the east block and were associated with a shallow layer of soil made up of a coarse, calcium-rich material (caliche layer). The water retention characteristics input data for these blocks indicated low water retention characteristics. However, plants in the field displayed a vigorous vegetative development and produced higher yields than the simulated plants. This failure of the model to simulate the observed growth pattern of plants in the field led us to review the accuracy our input database and the logic in the model used to estimate soil water dynamics. As a result, more soil samples were obtained on January 21, 1998 to complement our existing soil database.

Conclusions

Successful uses of precision farming technology depend on our ability to readily assess field variability and to relate the information to optimum management action. Current techniques used to assess field variability (soil sampling, plant mapping, and scouting) are tedious, slow and expensive. Simulation models can play an important role in the development of geo-referenced soil and/or plant databases. Simulation models such as ICEMM can provide daily information on plant height, number of mainstem nodes, square, green bolls, mature bolls and many other state variables at a fraction of the cost of conventional techniques. Extensive use of simulation models in precision farming depends on the ability of the model to simulate plant growth and yield in response to a gradient of soil characteristics encountered in the field. This requires a model containing enough mechanistic details to respond to those differences. To complement this objective, we must devise soil sampling methods and laboratory analysis capable of capturing and quantifying those differences.

Our experience on the use of ICEMM to generate geo-reference databases for precision farming applications indicated the following:

1. Mechanistic, process level models are required to simulate plant growth and yield in response to inputs reflecting differences between adjacent blocks or management units. ICEMM is such a model; however, improvements and enhancements to the various subroutines are needed to improve the accuracy of the simulations.
2. Improved soil sampling techniques and laboratory analysis are needed to capture and quantify field variability in physical and chemical soil properties.

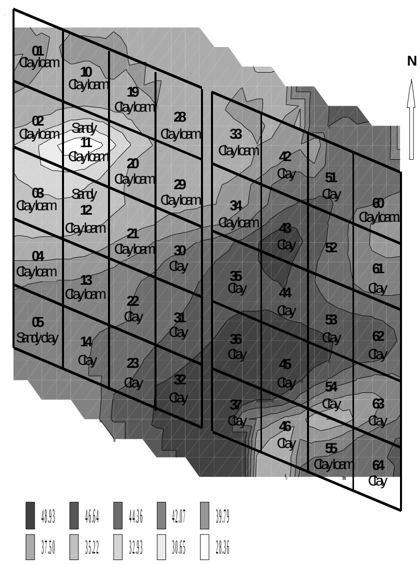

Figure 1. Field layout of the precision farming study site at the King Ranch, Kingsville, TX showing the block numbering and the soil texture at 15 cm depth.

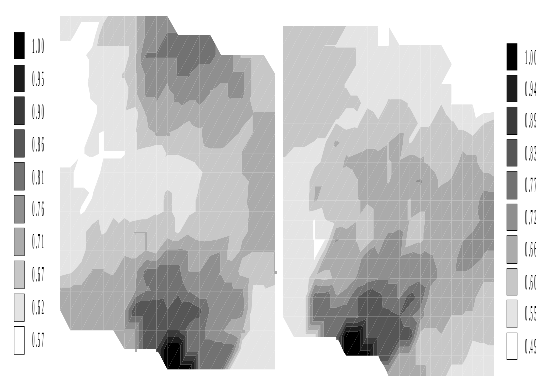

Figure 2. 1997 Actual (Yield/692 kg/ha) and simulated (Yield/774 kg/ha) cotton yield at the King Ranch, Kingsville, TX.