PERFORMANCE OF ICEMM-COTTON SIMULATION MODEL IN A PRECISION AGRICULTURE STUDY

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Abstract

Precision farming revolves around the use of information-based technologies. The prescriptive nature of precision farming requires immense data to be effective. From the biological standpoint, most of this information is currently obtained from plant mappings and scouting reports. These means of information gathering are time consuming and expensive. Crop simulation models and plant mappings can provide most of these vital biological data. The first year results of adapting the ICEMM-cotton simulation model to a precision farming study at the King Ranch in Kingsville, TX, show promising use of the model. A 100-acre field divided into 20 blocks was used for the study. Agronomic practices, daily weather data and soil physical and chemical properties (collected at the start of the planting season) were used as inputs to the model. The dates of occurrences of developmental events were predicted within 2 days of actual occurrences. The final plant height and node numbers were close to the observed values in the 20 blocks. Although the overall average yield data approximated the actual yield, individual block yield comparisons were inconsistent, partly due to erroneous soil hydrologic parameters.

Introduction

Fifteen years ago, the aim was to develop computer programs to assist users– producers, consultants, researchers, etc.--in the management of their crops. With the availability of information-based technologies such as Geographic Information System (GIS), Geographic Positioning System (GPS), and variable rate implements, precision farming is becoming a reality. However, most of the biological data necessary for management decision making are still obtained by plant mappings and scouting reports. Mechanistic and dynamic crop models can provide this information on a daily or weekly basis or as often as the user desires. One such crop model is the ICEMM cotton simulation model.

ICEMM Cotton Model

The Integrated Crop Ecosystem Management Model (ICEMM) is based on the 1988 version of GOSSYM. It has been improved and extensively validated as well as calibrated by Landivar (1991) for the Coastal Bend areas of TX. It simulates the physiological and soil processes. As a mechanistic and dynamic model it requires for its inputs:

1. Daily weather–temperature, rainfall, radiation and wind
2. Initial soil fertility status
3. Soil physical properties–bulk density, hydraulic conductivity, and moisture retention characteristics
4. Cultural inputs–row spacing, cultivar, plant density, fertilizer and plant growth regulators applications, etc.

It provides the user with a daily status report on a number of plant parameters, such as: plant height; node, square, green boll and open boll counts, nitrogen, water and carbohydrate stresses, etc. At the end of a full season run, it creates a summary table on date of maturity, plant height, yield, and for each designated developmental events, the number of nodes, squares, green bolls and open bolls.

Precision Agriculture Study in South Texas

This project is being conducted at the King Ranch, Kingsville, TX. Two adjacent 100 acre area fields under sorghum/cotton rotation have been chosen for the study to isolate the sources of in-field cotton production variability that can be identified, measured and used profitably in management decisions. Both fields have been georeferenced using a differential GPS. Each field has been subdivided into 20 5-acre area blocks. Figure 1 shows the field layout of the cotton field used in this study.

Precision agriculture requires a database to characterize the soil and plant growth. Soil sampling using systematic grid sampling was done in January 30, 1997 for each of the soil horizons of the Mercedes clay (fine, smectitic, hyperthermic Udorthentic Pellusterts), Raymondville clay loam (fine, mixed, hyperthermic Vertic Calciustolls) and Victoria clay (fine, montmorillonitic, hyperthermic Udic Pellusterts). These samples were analyzed for bulk density, hydraulic conductivity and moisture retention characteristics. Results of these laboratory analyses were used to develop the soil hydrology input files of ICEMM.

Soil samples were also taken at 15, 46 and 76 cm depths for soil nutritional analyses. These are for organic matter content, P, K, Mg, Ca, pH, SO_4, Zn, Mn, Fe, Cu and B.

Plant mappings were done at 25, 45, 63, 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 which were applied on June 3 and 18, 1997.

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At harvest, yield was estimated by hand sampling and yield monitor. In all the plant parameters data collection, transect sampling was used on the 32 blocks.

Discussion

ICEMM is continuously being improved to include the latest knowledge on cotton growth and development. For example, the soil routines (Boone, et. al., 1995) of the 95 release of GOSSYM/COMAX have been incorporated in ICEMM. This revised version of ICEMM is used in this first year study.

Figures 2 and 3 are the yield maps of the observed and the simulated yields. Although the maps showed that ICEMM estimation of the yield was fairly close for about 50 percent of the area, it is interesting to note that the model can predict the yield variation. The actual yield in the 100-acre field ranged from 392 to 749 lb/ac with an average of 518 lb/ac. The simulated yield varied from 342 to 966 lb/ac with a mean of 549 lb/ac. The average yield values differ by 6%, which is an acceptable margin.

Typical examples of blocks that ICEMM had performed well and poorly are shown in Figures 4 and 5. The node estimates differed by 1 to 2 nodes for both blocks, which is the same as the average node difference of 1.5 nodes between actual and predicted node count.

The plant height predictions were greatly off on Block 54, which also overestimated the yield by almost 65%. On the other hand, height predictions on Block 55 were fairly close. Moreover, the yield estimate differed by -19 lb/ac on an actual yield of 749 lb/ac.

The close node count estimation illustrates the robustness of the model in predicting developmental events. The model predicted the occurrences of the phenological events within 2 days of the actual occurrences. Although plant height estimations were off by 6 in. on the average, this problem is likely because of the lack of accountability of the PIX applications by ICEMM.

A major data input of the model is the soil hydrology files. There were some problems with the laboratory analysis of the hydraulic conductivities, which for Victoria clay ranged from 1 to 12 cm/day. The laboratory results have values that are in the hundreds of cm/day. Although some of the hydraulic data that were used in the model had been adjusted by using the average of the nearest surrounding sample points, still they were inadequate. These erroneous data files are the likely explanations for the differences in the yield map.

The final plant height, node and boll count did not have an effect on the observed yield variations in the 100-acre study site (Figs. 6, 7 and 8). The weather patterns and the cultural practices were practically the same with the exception of the PIX applications.

Considering all of the above factors, what can possibly be the source of yield variations? It appears that the soil nutritional status could have a likely influence on them. Figure 9 shows the plot of the Magnesium (Mg) content of the field at 15 cm depth and the yield by blocks. Note that the points fall on top of one another. Among all the soil elements analyzed, only soil Mg content seemed to be related to yield.

Conclusion

The revised ICEMM model performed favorably in its first year of testing. The predicted node count and yield values are within reasonable range. ICEMM's estimates of the occurrences of phenological events are within 2 days of the actual events. Soil Mg content at 15 cm depth seemed to influence the observed yield variations in the study site.

To fully evaluate the performance of ICEMM , adequate soil samples need to be taken to correct the problems in the soil hydrology input files. Consequently, a better sampling strategy needs to be explored and developed for both the soil physical and chemical properties evaluation.

References

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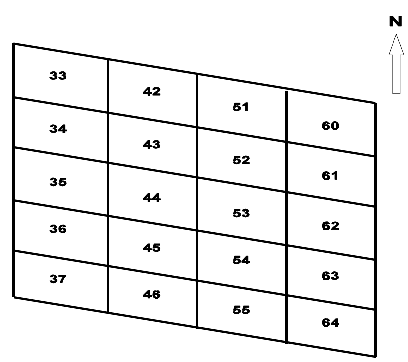


Figure 1. Field layout of the cotton field at the King Ranch, Kingsville, TX.

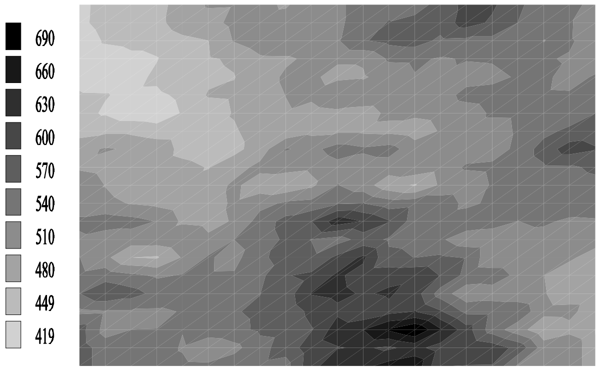


Figure 2. 1997 Actual cotton yield map (King Ranch, Kingsville, TX).

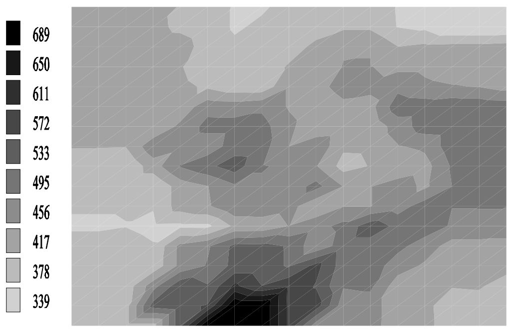


Figure 3. 1997 Simulated cotton yield map (King Ranch, Kingsville, TX).

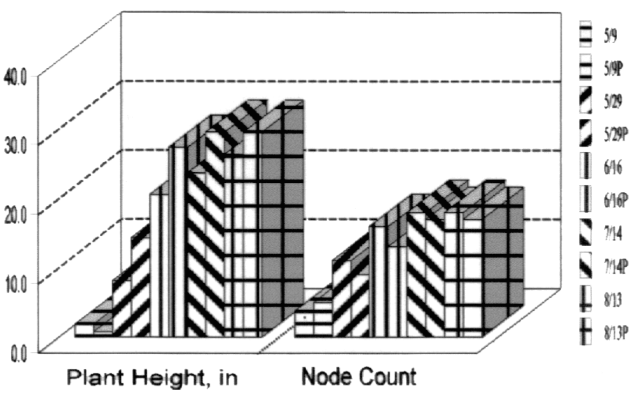
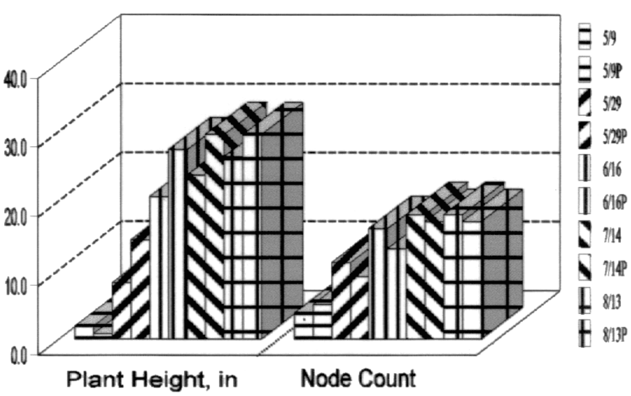


Figure 4. Actual vs. predicted plant height and node count in Block 54.



Note: P after a number = Predicted value

Figure 5.Actual vs. predicted plant height and node count in Block 55.

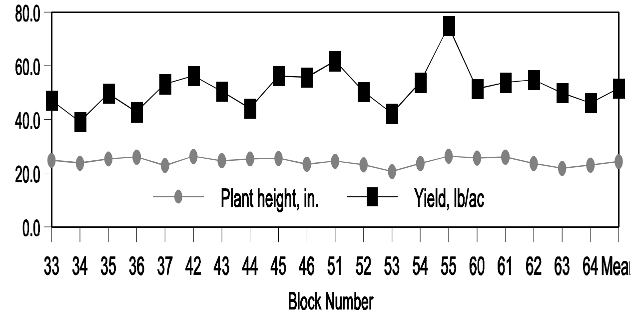


Figure 6. Plant height (in) and yield (x10 lb/ac) by blocks at harvest.

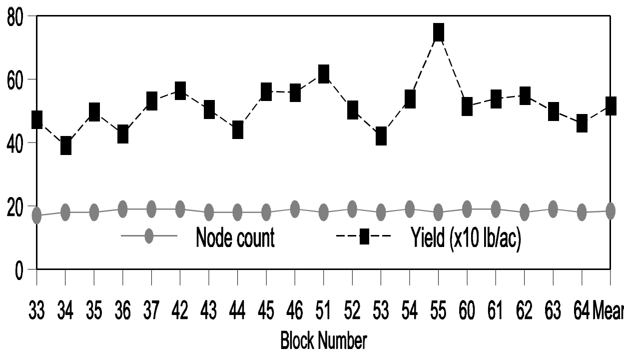


Figure 7. Final Node count and yield (x10 lb/ac) by blocks at harvest.

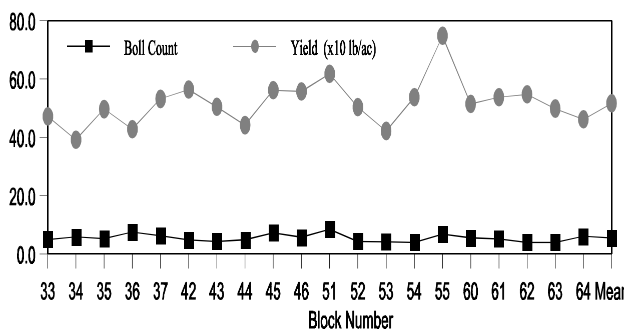


Figure 8. Boll count vs. yield (x10 lb/ac) by blocks at harvest.

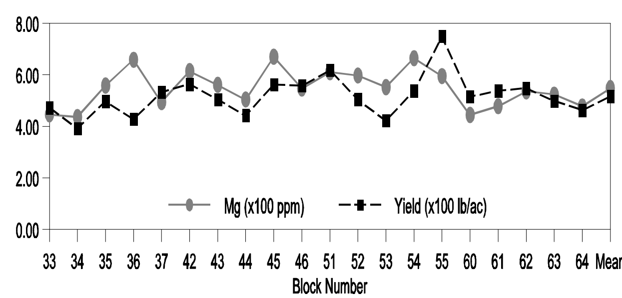


Figure 9. Plot of Mg content (ppm) vs. yield (x100 lb.ac).