COSSMO: A COMBINATION CROP GROWTH AND WATER MANAGEMENT MODELING SYSTEM

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INTRODUCTION

Controlled-drainage/subirrigation (CDSI) is a management scheme by which the water table below the crop root zone is managed (by adding or removing water) to provide an optimum soil water environment. Since crop growth is affected by water management strategies, a method is needed to predict the crop response to these various strategies. Improper management can lead to plant injury by allowing either too much or too little water to reach the plant's roots, thereby reducing yields. The water management model DRAINMOD (Skaggs, 1978) was developed as a design and management tool for use with CDSI systems in humid regions. A limiting aspect of DRAINMOD is the inability to simulate crop growth directly.

In order to determine the potential benefits of managing soil water conditions with a CDSI system, a method for evaluating the effects of various irrigation strategies on crop growth is needed. Many efforts have been made to enable DRAINMOD to simulate crop growth (Sabbagh et al., 1991; Brink, 1986; Evans, 1991). This presentation describes an attempt to add crop growth capabilities to DRAINMOD by developing an "expert simulation system", COSSMO (COmbined Subirrigated Soybean MOdel), to link DRAINMOD with the crop growth model SOYGRO. This presentation also indicates the results of validating the COSSMO system with soil, weather data, and observed yields from studies in North Carolina. Simulation results from COSSMO are also compared to simulation results from SOYGRO stand-alone.

METHODS

The two models, DRAINMOD 3.4 and SOYGRO 5.4, simulate water table management and soybean crop growth, respectively. The SOYGRO model was modified to accept upward water movement from a water table from DRAINMOD and to account for crop stress from possible root flooding. The DRAINMOD model was enhanced to accept evapotranspiration and effective rooting depths from SOYGRO and to incorporate a feedback control loop (Perry et al., 1990). An expert system, COSSMO, was developed to obtain various model input from the user, execute the two models in an iterative fashion, and provide output information to the user. The two models were able to share data by the use of data swap files. Perry et al. (1990) described the development and code verification in detail. However, no validation was performed.

In order to validate the modeling system, sixty-five sets of field data from the Tidewater Research Station near Plymouth, North Carolina were obtained. For each year, variety, and study combination, actual field drainage system parameters were used in the COSSMO simulations (Table 1). Four soybean varieties (Bragg, Davis, Forrest, and Ransom) grown in the North Carolina studies were used in the validation simulations. A Portsmouth fine sandy loam soil (fine sandy over sandy or sandy - skeletal, mixed, thermic Typic Umbraquult) was used in all simulations. Complete soil properties measured at the Tidewater station were reported by Gilliam et al. (1978) and Skaggs (1978). The reader is referred to Evans et al. (1991) for detailed information on the field and system characteristics

Rainfall and temperature data were obtained from weather records collected by a weather station at the site. Solar radiation was not available for the Tidewater station, therefore monthly mean daily insolation values were obtained (de Jong, 1973) and converted to solar radiation values.

Once the necessary data files were generated, COSSMO simulations were run using a row spacing of 91.4 cm (36 inches) and a plant spacing of 7.6 cm (3 inches). The SOYGRO model was executed stand-alone using the same soil, weather, and variety information.

RESULTS AND DISCUSSION

A predetermined "allowable" range of error of 670 kg/ha (10 bu/ac) overprediction to 340 kg/ha (5 bu/ac) underprediction was assumed to gauge resulting predicted yields. This range is based on a ±340 kg/ha (5 bu/ac) allowable range (17 % of maximum yield). The additional

Table 1. Studies Used in Validation.

Year	Varieties	Drainage Systems Spacing (m)	Type
OVT Test			
1967	B	41.8	PT
1968	B, D	38.9	C
1969	B, D	96.0	C
1970	B	32.0	C/P
1971	B	26.2	C
1972	B, D, F, R	17.8	C/P
1973	B, D, F, R	73.0	PT
1974	D, F, R,	73.0	PT
1976	D, F, R	36.5	PT
1977	B, D, F	36.5	PT
1978	B, D, F	36.5	PT
1979	B, D, F	73.0	PT
1980	B, D, F	36.5	PT
1981	B, D, F	73.0	PT
1986	B, D, F	17.8	C/P
1988	F	22.9	PT
1989	F	22.9	PT
1989L	R	73.0	PT
1990	F, R	26.2	C
1990L	F, R	73.0	PT
WTM Test			
1989L	R (20,30,41,51 cm water table)	23.0	PT
1990	R (15,30,45,60,75 cm water table)	23.0	PT
1990L	R (15,20.45.60,75 cm water table)	23.0	PT

B = Bragg F = Forrest C = Clay Tile
D = Davis R = Ransom PT = Plastic Tubing
C/P = Clay and Plastic

+340 kg/ha allowing for overprediction was based on the assumption that the model would overpredict in most cases, because yield limiting factors (such as weed and insect pest effects) are not accounted for in the simulations.

Figures 1 and 2 represent the COSSMO and SOYGRO results from simulating a study with Forrest and Ransom varieties. Bragg and Davis varieties were also simulated. Forty-four of the 65 COSSMO predicted yields (68%) were within the "allowable" range while only 16 SOYGRO predicted yields (25%) fell within this range. The mean difference between COSSMO predicted and observed yields for all data sets was +340 kg/ha (+5 bu/ac) with a sample standard deviation of 590 kg/ha (9 bu/ac). The mean difference between SOYGRO predicted and observed yields for all data sets was -689 kg/ha (-10.2 bu/ac) with a sample standard deviation of 1170 kg/ha (17.5 bu/ac).

For these simulations, COSSMO appears to predict yields more reliably than does SOYGRO alone. Thus, the combination of DRAINMOD and SOYGRO apparently reflects the soil-water interactions during water table management (conventional drainage, controlled-drainage, or subirrigation) more accurately than SOYGRO alone does. Perry et al. (1990) notes that the SOYGRO water balance model is limited to rainfall and sprinkler irrigation and does not account for upward flux from a water table. By adding a rudimentary upward flux function to SOYGRO and using water table and upward flux values from DRAINMOD, SOYGRO could account for these water table effects.

SUMMARY

A modeling system, COSSMO, was developed that combined a crop growth model (SOYGRO 5.4) and a water management model (DRAINMOD 3.4) via an expert system. The user is prompted for input values needed to carry out the simulation using the two models which are executed in an iterative fashion. DRAINMOD was modified to accept input values from SOYGRO, which was modified to accept inputs from DRAINMOD. The system was validated using soil, weather, and crop data from Plymouth, North Carolina. Sixty-five sets of field data were used to compare observed yields to predicted yields from COSSMO and SOYGRO (stand-alone). Sixty-eight percent of COSSMO predicted yields were within the "allowable" range (670 kg/ha (10 bu/ac) overprediction to 340 kg/ha (5 bu/ac) underprediction) while only 25% of SOYGRO predicted yields fell within the range. The difference between COSSMO predicted yields and observed yields (mean of +340 kg/ha (+5 bu/ac), sample standard deviation of 590 kg/ha (9 bu/ac))

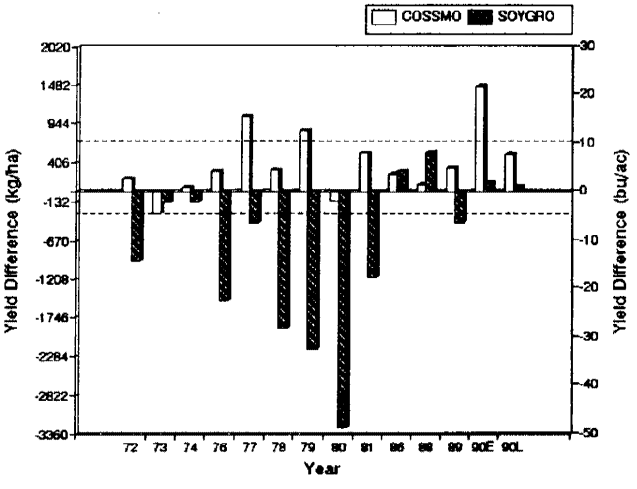

Figure 1. Difference between predicted and observed soybean yields for Forrest variety.

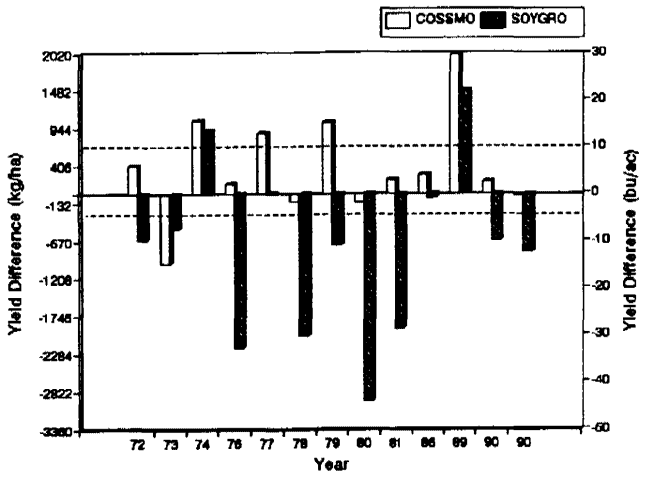

Figure 2. Difference between predicted and observed soybean yield for Ransom variety.

as compared to SOYGRO differences (mean of -690 kg/ha (-10 bu/ac), sample standard deviation of 1170 kg/ha (17.5 bu/ac)) indicated that the combination of DRAINMOD and SOYGRO represented the soil-water interactions associated with a drainage system better than SOYGRO alone did.

This preliminary validation, while limited in soil types, indicated COSSMO has the potential to become a tool for evaluating water management effects on crop growth. Further validation is needed under a variety of soil conditions before a general release of COSSMO is feasible. Efforts are underway to obtain additional data for further validation.

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