Development of the Mississippi Irrigation Scheduling Tool-MIST

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Increasingly variable and uncertain rainfall patterns together with higher production input costs have led farmers to rely on supplemental irrigation to enhance production. While many irrigation methods have been developed for dry climates, few tools are available for humid, high rainfall areas. Moreover, most scheduling tools require extensive data collection, entry and simulation runs, limiting their practical utility during the production season. We have designed the Mississippi Irrigation Scheduling Tool (MIST) as a web-based, easy to use management tool for crop producers. An estimate of crop water use is made using the modified Penman Monteith to calculate daily evapotranspiration. The "checkbook" water balance method sums the water balance of the soil, plus water from rainfall or irrigation, minus water used by the crop or evaporated from the soil. This method indicates the need for irrigation when the soil water available to the plant falls below that which is readily available for crop growth. To enhance utility, the MIST has been implemented in a web interface, allowing producers to access the information from anywhere through tablet computers or smart phones. To reduce the data entry requirements, the system relies on national databases for automated integration with a water balance model. The system was tested at multiple production sites during the 2011, and 2012 growing seasons. This presentation will give details on the development of input parameters for the water balance calculation, including crop water use and soil moisture, and water balance during the growing season for corn and soybeans. Additional presentations in this session will describe the implementation of the user interface (Rice et al.), calibration and validation of the model (Prabhu et al.), and spatial accuracy of national databases (Thornton et al.). The MIST will provide producers, consultants and other professional colleagues with a reliable, accurate, and easy to use tool for improved water management.

INTRODUCTION

Unlike other areas of the South, Mississippi has enjoyed plentiful ground water resources and rainfall in excess of 40" per year. However, decreasing groundwater levels in the Alluvial Aquifer are a growing concern in certain areas of the Mississippi Delta. In neighboring states, serious groundwater depletion threatens future cropping options (Bennett, 2002). The challenge for Mississippi is to manage water resources appropriately, and provide sufficient water for crop production through droughty periods that occur during the growing season. Increasing volatility in recent weather patterns has resulted in no change in overall rainfall amounts but a decrease in the number of events and a concomitant increase in intensity (SWCS Climate Change, 2003). These changes in rainfall patterns decrease the usable rain that enters the soil profile. Moreover, the uncertainty of amount and timing of rainfall makes irrigation scheduling a particular challenge, as a high rainfall event immediately following an irrigation can result in water logging of the soils and impede crop growth.

Yields and profits from non-irrigated crops are typically lower than for irrigated fields, resulting in greater use of ground water (Evett et al., 2003). The increased pumping has resulted in an average decline from the alluvial aquifer of 300,000 acre feet of water per year for the past 10 years (Powers, 2007). However, the most commonly used method of scheduling irrigation is based on the "feel-of-the-soil", with no quantitative measure of crop or soil water status used (NASS, 2007). While less efficient than sprinkler application, surface (furrow) irrigation accounts for nearly 70% of the irrigated acres in the Delta (NASS, 2007).

Implementing timely and accurate irrigation scheduling on all soybean acres could yield a net increase of 52M bushels of soybeans produced in Mississippi. Similarly, Mississippi corn acreage has more than tripled to just under a million acres per year (NASS, 2013). Again, yield has increased steadily but the state's average corn yield per acre over the preceding twenty years (110 bu/ac) is 28 bu/ac below the US average. Although corn yield can be substantially increased with irrigation, much of Mississippi corn acreage remains non-irrigated. Implementing timely and accurate irrigation scheduling on all corn acres could yield a net increase of 30M bushels of corn produced in Mississippi. If an irrigation scheduling tool reduces the volume of irrigation water pumped, farmers will also realize a reduction in fuel expenses for operating pumping equipment. Further, new state water permits require implementation of water conservation measures; an irrigation scheduling tool, developed for state-specific soils and climate, is an accepted conservation method. Particularly critical to the continued success of agriculture in the Delta is development of accurate, easy to use guidelines for irrigation scheduling and application.

Our goal is to develop and deliver to producers an accurate, easy-to-use system for water management in crop production. The Mississippi Irrigation Scheduling Tool, MIST, is designed using the latest information of crop water use and irrigation scheduling, and implemented in a web-based format for continual access anywhere. To test and parameterize the system for Mississippi, we conducted on-farm experiments in 2011-2013, collecting information on crop growth, plant stage, and soil water. As the decision support tool is validated and delivered, water use and irrigation cost information will be collected and used to develop economic tools for future inclusion in the scheduler.

METHODS

The sole standard equation accepted for calculating evapotranspiration is the Penman-Monteith (Allen et al., 1998). As used in a daily scheduling tool, this equation requires daily measurements of maximum and minimum temperature and relative humidity, and total solar radiation and wind speed, to calculate a reference evapotranspiration (ET_o). Uncertainty in the accuracy of any measured parameter required for the calculation can exacerbate the influence of a given meteorological parameter on the calculation of ET_o (Sassenrath et al., 2012). Daily measured maximum and minimum temperature, maximum and minimum relative humidity, total wind run, and total insolation data were downloaded from the Delta Research and Extension Center Weather Center (DREC, 2013), tested for errors or missing data (Sassenrath et al., 2012), and used as inputs to calculate total daily evapotranspiration (ET_o) using the modified Penman-Monteith (Allen et al., 1998). Erroneous weather data were removed, and missing data were estimated by averaging readings from previous days.

In addition to determining a reference evapotranspiration, calculation of the soil water balance requires calculation of the daily crop evapotranspiration, calculated by multiplying ET_o by a crop-specific coefficient (Allen et al., 1998). The crop coefficient is an expression of the evapotranspiration of the crop in relation to that of a reference crop, usually grass or alfalfa. Crop coefficients can be estimated using in situ measurements of crop growth (Allen et al., 1998). For real time irrigation scheduling using surface or sprinkler irrigation systems, Allen et al. (1998) suggest the use of a single crop coefficient, in which the evaporation from the soil surface and transpiration from the plant canopy are combined. Alternatively, a dual crop coefficient can be developed that separates the evaporation and transpiration components of the coefficient (Allen et al., 1998). For the MIST, we calculate crop water use using a single crop coefficient developed from crop growth measurements.

Measurement of daily total rainfall and irrigation water added to the field are also needed to determine the daily soil water balance. Erroneous specification of any of these factors contributes to errors in the calculation of plant-available soil water (Prabhu et al., 2013). Soil water balance, the water available in the soil for plant uptake, can be calculated over the growing season as:

$WB_t = WB_y - ET_c + Rain_U + Irr$

where WB_y = soil water balance yesterday; less the water used by the crop, $ET_c = ET_o \times K_c$ = daily crop evapotranspiration, calculated by multiplying reference evapotranspiration, ET_o, by a crop coefficient, K_c; plus $Rain_U$ = usable rainfall; and Irr = amount of irrigation applied. The irrigation decision is based on the calculated soil water balance (WB_t) and the soil available water capacity. When the soil water balance falls below that needed to maintain good crop growth, as established by Mississippi State Extension recommendations, an irrigation is indicated.

The MIST is implemented in a web-based format to enhance access and ease of use. Details on the implementation are given in this volume by Rice et al. (2013).

RESULTS AND DISCUSSION

Soybean planting in Mississippi can occur over a very long window of time, beginning in March and continuing through June. Soybean production is also sensitive to available water, especially for early planting dates (Table 1). The challenge in developing the irrigation scheduling tool is to have crop coefficients for the many maturity groups, cultivars, and production systems commonly used in Mississippi. To this end, we measured plant growth in production fields under a variety of production settings.

Plant growth measurements taken throughout the growing season showed the expected rapid growth period until a plateau was reached near canopy closure, followed by a slow decline as the crop matured (Figure 1). The percent light intercepted gave a better and more consistent curve for various planting dates, cultivars, and production systems than did plant height measurements. The published crop coefficients (Allen et al., 1998) were modified based on rates and timing of measured changes in light interception over the growing season to develop crop coefficients for the Mississippi Delta. Crop coefficients adjust throughout the growing season to reflect changing plant ET_c rates with crop growth and maturation (Figure 1). Surprisingly little difference occurred between the different cultivars and planting dates for both corn and soybeans, indicating single crop coefficients for each crop will suffice (data not shown).

Water tension in the soil was measured throughout the growing season using Watermark soil moisture sensors placed at 6" increments to a depth of 36" in the production and research fields at each location. The water tension in the soil increases as the plant roots remove water from the soil (Figure 2). These measurements were compared to calculated measurements of plant ET to determine how well the MIST tracked soil water balance. The MIST tracked soil water balance, as indicated by measured changes in soil water tension. Further validation of the MIST output will be performed to determine the accuracy of the model prediction.

CONCLUSIONS

The primary beneficiaries of this research are Mississippi corn and soybean producers. Understanding soil and crop water relations, irrigation scheduling, and crop water management will enable crop producers to make water use decisions based on crop needs. Water management tools and the web-based irrigation scheduler will improve the cost effectiveness of water applications, improve crop yield and quality, and reduce excess water use in crop production. Knowledge of agricultural water needs will be beneficial in developing water management policies that are economically realistic and environmentally sustainable. All Mississippians will benefit from this research through the improved management of our water resources.

DISCLAIMER

Mention of a trade name or proprietary product does not constitute an endorsement. Details of specific products are provided for information only and do not imply approval of a product to the exclusion of others that may be available.

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Table 1. Impact of irrigation on yield of soybean with planting date.

Planting date	Yield, bu/ac		Increase with irrigation (bu/ac)	% loss without irrigation
	irrigated	non-irrigated		
4/14/2011	64.5	34.8	29.7	46.01
5/9/2011	58.8	36.5	22.3	37.90
6/20/2011	43.3	28.8	14.5	33.54

Figure 1. Development of a crop coefficient curve, based on published values and adjusted for Mississippi growing conditions using crop growth measurements from various production systems.

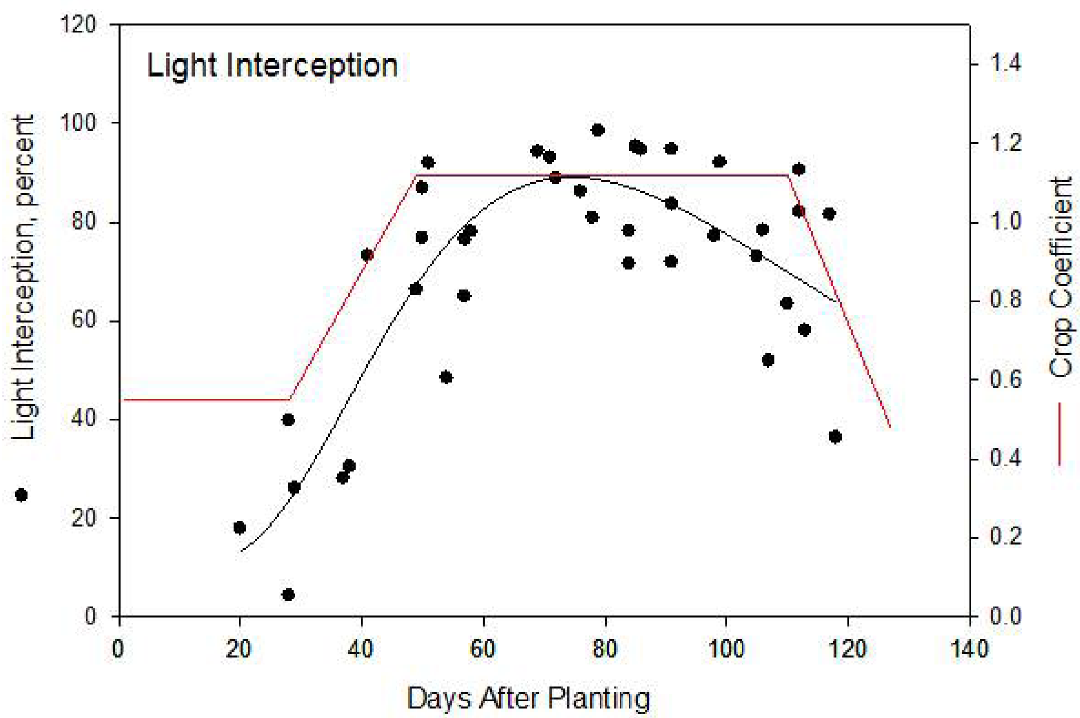

Figure 2. Comparison of changes in measured soil available water (soil water tension, psi) at 6, 12 and 18" depths in the soil with soil water balance calculated with the Mississippi Irrigation Scheduling Tool, through the growing season.