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Irrigation Scheduling Based on Soil Moisture Sensors and Evapotranspiration

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Summary
Irrigation scheduling is crucial to effectively manage water resources and optimize profitability of an irrigated operation. Tools that can be customized to a field's characteristics can greatly facilitate irrigation scheduling decisions. Soil moisture sensors and the evapotranspiration (ET)-based KanSched are two of the tools that could be implemented in an irrigated farm. Focusing on the installation of soil moisture sensors, demonstration set-ups were established at the Southwest Research-Extension Center plots in Garden City, Kansas, and in a producer's field, each with three types of moisture sensors at different depths. Among others, this project validates the importance of moisture sensors being installed as early as possible in a representative location with good soil-sensor contact. The moisture sensors, at the least, help in determining when irrigation water should be applied or scheduled. Furthermore, in implementing an irrigation schedule, the irrigation manager considers the irrigation system capacity, the amount that can be efficiently applied, the soil intake rate, and other relevant factors.

Introduction
Faced with weather uncertainty and water supply limitations, irrigation scheduling becomes extremely crucial in effective water management and profitability optimization in an irrigated farm.

Irrigation scheduling involves determining when and how much water to apply to meet specific management goals – generally to prevent yield-limiting crop water stress. Effective irrigation scheduling helps optimize profit while minimizing inputs such as water and energy cost. The factors that affect irrigation scheduling include the type of crop, stage of development, soil properties, soil-water relationships, availability of water supply, and weather conditions (temperature, wind, rainfall, and others) (Younker, 2012).

As the medium where water could be stored for the crops to extract, soil provides a crucial interplay between the crop and water. The upper drained limit of root-zone soil water is determined by the soil's water-holding capacity — which, for irrigation water management purposes, is known as field capacity. The desired lower limit for optimal crop growth can be a more variable value depending on the crop, the stage of growth, and management goal. Often it is referred to as the managed allowable depletion or MAD. A common MAD is 50 percent of the total available soil water-holding capacity. The normal goal of the irrigation scheduling procedure is to help the irrigation manager track the amount of water in reserve above a minimum soil water balance level to prevent water stress to the growing crop (Rogers, 2012).

Evapotranspiration (ET), or crop water use, is a measure of the rate water is extracted from the soil. The term combines two processes of water loss from the system, evaporation — the loss of water from the soil and plant surface, and transpiration — the beneficial use of water by the crop. This method of estimation is based on weather parameters (e.g. solar radiation, temperature, humidity, wind speed) and crop growth stage.

The ET information can be used for irrigation scheduling by accounting for the water balance in the soil profile. It is often described as being similar to a checkbook accounting procedure — except in this case, root zone soil water content, rather than money, is the account balance. Deposits to the account would be effective rainfall and irrigation, and withdrawal is the crop water use. Unlike a checkbook, if the account balance becomes too large, additional deposits are lost to surface water runoff or deep percolation. If the balance is too low, optimal crop growth might not be achieved (Rogers 2012).

Knowing the amount of water in the soil at any time is the key to effective irrigation scheduling. Soil water content could be measured directly, using manual gravimetric sampling, and indirectly, using sensors such as neutron probe (NP) and time domain reflectometry (TDR) (Chavez, 2012). For all practical purposes, soil moisture sensors that indirectly measure water content operate based on surrogate properties (i.e. soil dielectric permittivity, electrical resistance, and soil water potential, among others). They are generally used for irrigation scheduling at the farmer's field. Most of these sensors have the advantage of being near real-time, automatic data logging, nondestructive, and telemetry-compatible, as compared to gravimetric sampling. Commercially available soil moisture sensors differ from each other mainly in operating frequency, sensing materials and design, and multiple-sensing capabilities.

Soil Moisture Sensor-Based Scheduling

With advances in microcomputer and communication technology, a variety of soil sensors are gaining momentum in the suite of irrigation tools. The main selling point for this technology is telemetry and its continuous near real-time measurements delivered to the irrigation manager through a computer or other handheld communication devices. With the advancement in design and electronic components, some soil moisture sensors have a smaller footprint on the field with sensors at multiple depths. However, to be useful for management, soil water sensors must be accurate around 0.02 to 0.04 inch/inch (Evett, et al. 2014). Since soil water sensors typically are sensitive only to the soil immediately around them — and since most sensors are small — it is prudent to have two or more sensors installed at different depths. This not only reduces uncertainty but also promotes understanding of soil water content changes in response to irrigation and crop water uptake. Depths of 6 and 18 inches or 6 and 24 inches are common. In general, irrigation events should be scheduled above the MAD of 50% water content for the specific soil or 50% of the relative water used.

ET-Based Scheduling

In the early 1990s, K-State Research and Extension introduced an Excel spreadsheet program to help facilitate ET-based irrigation scheduling. The program eventually evolved into KanSched. The features of KanSched have been shown to be useful to a variety of climatic conditions and irrigation capacities.

KanSched is a free, user-friendly computer program that can be easily used to develop an irrigation schedule (access KanSched at www.bae.ksu.edu/mobileirrigationlab). KanSched has several versions (Excel – KanSched1, standalone program – KanSched2, and web-based – KanSched3) to suit the needs and platforms of users. The KanSched3 program is currently available as a beta version and requires users to set up individual accounts and identities. However, once done, KanSched3 appears very similar to the KanSched2 standalone version (Rogers and Alam, 2007).

KanSched uses daily and field inputs to calculate ET. The field inputs can be tailored to the individual field's soil characteristics, emergence, maximum rooting depth, crop characteristics, and crop coefficients, among others. The daily inputs are typically reference ET and rainfall, along with measured soil moisture content, if available (Figure 1). Reference ET could be taken from an ET gauge nearby, the SWREC Irrigation website, or from the K-State Weather Data Library. After entering the field and daily information, KanSched will automatically update the root zone water level and develop a seasonal management chart that plots soil water values, rainfall, and irrigation amount (Figure 2). Note that in the soil water chart, the cursor can be placed in the chart area to get a date and soil water content value reading. These features of KanSched allow the irrigation manager to manage the soil water content to the desired MAD.

Procedures

Telemetry does not address the other issues with soil water sensors, including accuracy of the readings, optimum or representative site selections, and timely and proper field installation. Focusing on the installation of soil moisture sensors, K-State Research and Extension — in collaboration with the Ogallala Aquifer Program — established demonstration plots, one in the Southwest Research-Extension Center research plots and the other in a producer's field. In each plot, three types of moisture sensors were installed, specifically Decagon 10HS, Watermark, and Campbell Scientific's CS655 at 1-, 2-, and 3-ft depths, along the corn rows.

Results and Discussion

The following are the summarized results of the study:

- Soil water sensors should be installed in the field as early as possible to achieve adequate soil settling around the sensors.
- While good soil-sensor contact is important, some sensors are difficult to properly install without disturbing the soil profile.
- The learning curve for some sensors is relatively steep, and establishing confidence in the measured values takes time.
- After-sales support is vital in product selection.
- Soil sensor costs are associated with three components: equipment, installation, and telemetry/service subscription.
- Cables must be protected from possible rodent damage by adequately burying them or enclosing them in conduits.

- A good representative location should also consider equipment size and traffic as well as subsequent seasonal field operations.

It was evident that — among the different sensors — proper installation (i.e. good soil contact and location at the right time) was the key to the optimum sensor performance.

Conclusion

Irrigation scheduling tools that can be customized to a field's characteristics can greatly facilitate the irrigation scheduling decision process. In implementing an irrigation schedule, the irrigation manager also considers the system capacity, the amount that can be efficiently applied, the soil intake rate, and other factors.

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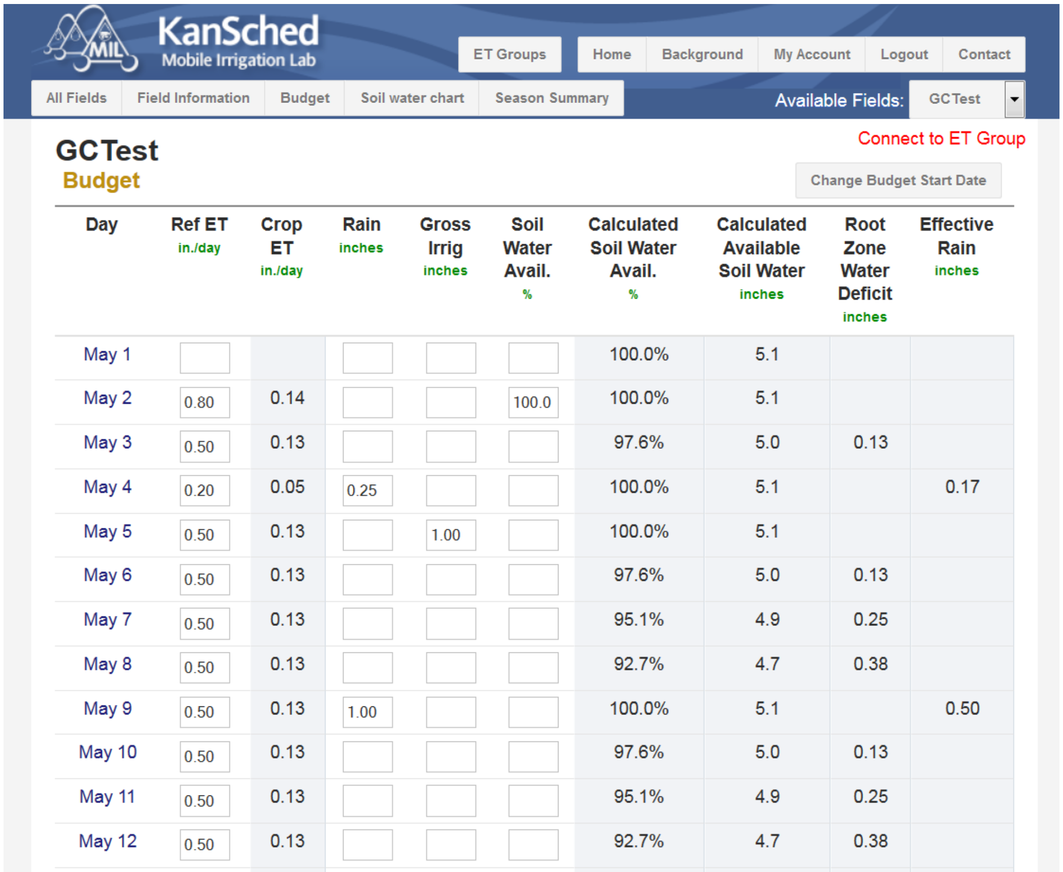
KanSched
Mobile Irrigation Lab
ET Groups | Home | Background | My Account | Logout | Contact
All Fields | Field Information | Budget | Soil water chart | Season Summary
Available Fields: GCTest
Connect to ET Group

GCTest
Budget
Change Budget Start Date

Day	Ref ET in./day	Crop ET in./day	Rain inches	Gross Irrig inches	Soil Water Avail. %	Calculated Soil Water Avail. %	Calculated Available Soil Water inches	Root Zone Water Deficit inches	Effective Rain inches
May 1						100.0%	5.1		
May 2	0.80	0.14			100.0	100.0%	5.1		
May 3	0.50	0.13				97.6%	5.0	0.13	
May 4	0.20	0.05	0.25			100.0%	5.1		0.17
May 5	0.50	0.13		1.00		100.0%	5.1		
May 6	0.50	0.13				97.6%	5.0	0.13	
May 7	0.50	0.13				95.1%	4.9	0.25	
May 8	0.50	0.13				92.7%	4.7	0.38	
May 9	0.50	0.13	1.00			100.0%	5.1		0.50
May 10	0.50	0.13				97.6%	5.0	0.13	
May 11	0.50	0.13				95.1%	4.9	0.25	
May 12	0.50	0.13				92.7%	4.7	0.38	

Figure 1. KanSched3 Budget page, where Reference ET, Rain, Gross Irrigation, and Measured Soil Water Available are entered daily.

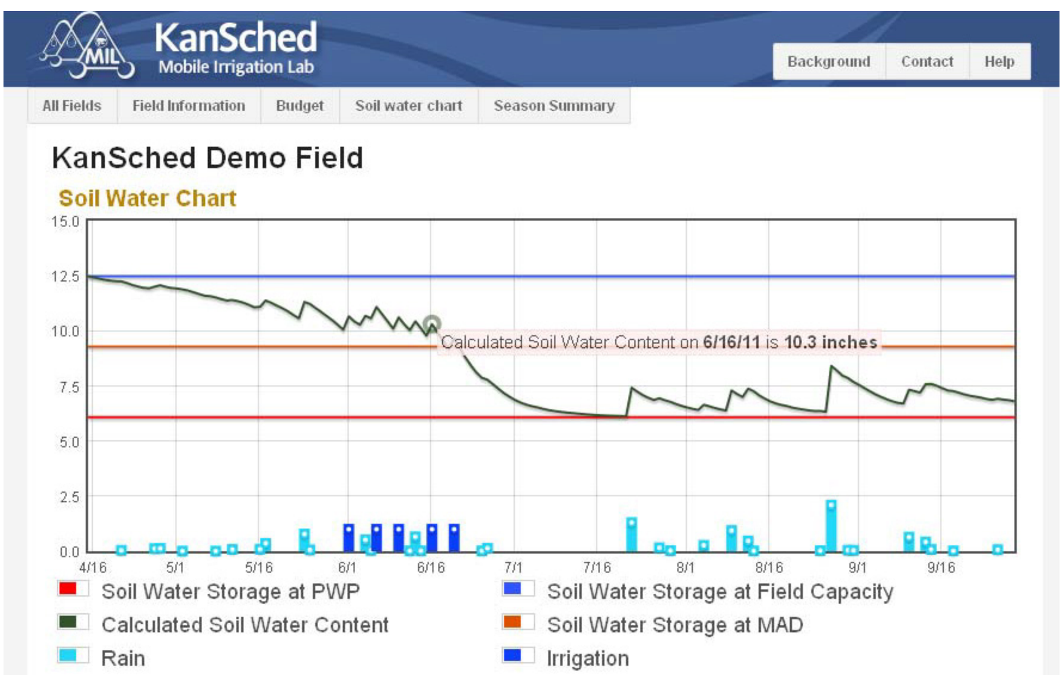

Figure 2. KanSched3 soil water chart generated for the given field.

Figure 3. Three different soil moisture sensors (Watermark, CS655, and Decagon 10HS) installed at different depths (1, 2, and 3 feet) were established in the SWREC plot and a farmer's field.