Scheduling Irrigation for Agronomic Crops Using Estimation Methods

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STAMP Smart Technologies for Agricultural Management and Production

Introduction

Proper irrigation scheduling is vital to sustainable agricultural practices. Despite averaging more than 48 inches of rainfall per year in Louisiana, rain doesn't always occur at times to support crop yields, which makes irrigation necessary. Over-irrigating will negatively affect the crop by leaching nutrients and increasing erosion or surface runoff that can carry pollutants into local water bodies. Limiting over-irrigation has the potential to address concerns about diminishing water resources, increasing environmental regulation and rising costs of irrigating agriculture.

Irrigation management is best accomplished by implementing a scheduling technique or combination of techniques that is most convenient for the irrigator. Confidence in irrigation scheduling methods encourages long-term adoption of agricultural water management. Multiple methods or tools are available to irrigators, such as the water budget, woodruff charts, atmometers and soil moisture sensors.

Water Budget (Checkbook Method)

The water budget is the method of maintaining a soil water balance. It involves keeping track of the parameters that affect water movement within the root zone (Eq. 1). The method is most appropriate where daily reference evapotranspiration (ET_O) and rainfall are available from good quality weather data sources. It is commonly called the "checkbook method" because it is similar to keeping a c heckbook balance. Definitions of the parameters within the spreadsheet can be found in the Glossary of Terms.

Equation 1. Calculation for estimating the soil water level based on the water level at the previous time step and multiple factors affecting movement of water in the soil.

$$SWL_i = SWL_{i-1} - ET_c + R_e + I_e - P_d - RO$$

SWL_i = Soil water level on day i

SWL_{i-1} = Soil water level on day i-1

ET_C = Crop evapotranspiration

R_e = Effective rainfall

I_e = Effective irrigation

P_d = Deep percolation

RO = Surface runoff

A soil water balance requires the following information:

- **Soil physical characteristics** – provides suggested values for field capacity, permanent wilting point, maximum allowable depletion and maximum root depth.
- **Variety-specific crop information** – aids in determining irrigation needs based on crop growth stages by using crop coefficients and growing season length.
- **Weather conditions** – adjusts for field condition changes such as rainfall.
- **Initial moisture conditions** – sets the threshold for triggering irrigation and initial moisture in the soil on day 1.

The SWL on the first day is chosen based on field conditions at the time of planting. Each day after the first day, the SWL is calculated using Eq. 1. The best time to verify your soil water balance is after a large rainfall that causes the field to reach field capacity or higher. The soil water balance should show maximum soil moisture on that day.

The ET_C is estimated from reference evapotranspiration (ET_O) that can be calculated from weather station data and adjusted for the specific crop using a crop coefficient (K_C) (Eq. 2). Many weather systems automatically calculate ET_O from weather data and provide the value directly. If you do not have access to ET_O and would like to try irrigation scheduling, please contact Dr. Stacia Davis (sdavis@agcenter.lsu.edu). Crop coefficients specific to Louisiana are not readily available for many crops, but can be approximated from other sources (Table 1). These values can also vary across irrigation method, soil types and plant varieties.

Equation 2. Calculation for estimating crop evapotranspiration from reference evapotranspiration using a crop coefficient.

$$ET_c = K_c * ET_O$$

Table 1. Examples of crop coefficients for commonly grown crops in Louisiana using out-of-state long-term averages except for cotton where they were determined using weighing lysimeters in northeast Louisiana (Kumar et al. 2015).

Seasonal Growth Stage	Cotton	Soybean	Corn	Grain Sorghum
Early	0.42	0.3	0.22	0.22
Mid	1.44	1.22	1.27	1.11
Late	0.62	0.56	0.39	0.61

Effective irrigation and effective rainfall are the portions of the total that actually infiltrate the root zone and are beneficial to the plant. In a soil water balance, it is estimated as the portion of water that raises the SWL to field capacity. The remaining portion of the water would be considered surface runoff or deep percolation.

As with any model, it is important to start with accurate input data to receive informative and usable output. If this information is not readily available for your cropping system, long-term average values can be substituted. For best results, the soil water balance can be managed using a spreadsheet. Some examples of currently available tools were developed by Michigan State University and Purdue University.

Woodruff Chart

The Woodruff Chart is a tool developed by Woody Woodruff (1910-2003) of University of Missouri. The Woodruff Chart is useful for performing a simplified soil water balance using a printed paper chart and a pencil. Information about crop, soil type, irrigation method, emergence date and number of days until relative maturity are required to make the initial chart. Selection of the type of crop, emergence date and relative maturity help to determine the plant water needs at various growth stages. The soil type and irrigation method aid in determining how much water can be applied per irrigation event or how much rainfall can be effective. Additionally, historical ET_C is needed to determine the average water losses on a daily basis throughout the growing season. Typically, historical ET_C is calculated from 30 years of information; however, as many years as available can be used when differences in weather patterns between the current and averaged years are considered.

Using the initial information, two lines are generated on the chart that represent the maximum amount of water held in the soil (top line) and the threshold to trigger an irrigation event (bottom line) (Fig. 1). Soil moisture should stay between these lines throughout the season to maximize yield. Each day, a line is drawn horizontally by the producer that equals one calendar day along the x-axis (vertical line to vertical

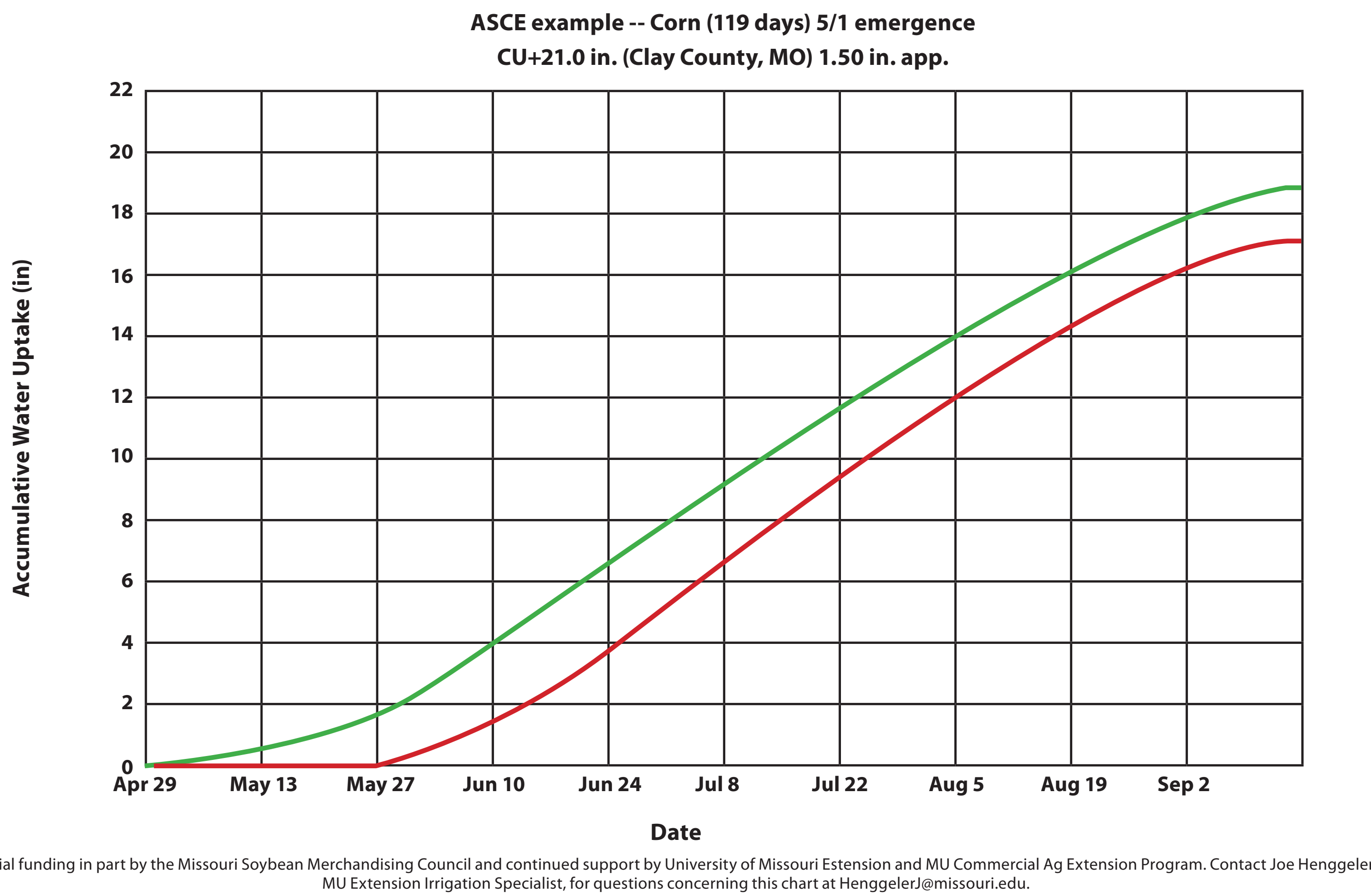

Figure 1. Example of a Woodruff Chart created by the University of Missouri (http://agebb.missouri.edu/irrigate/woodruff/).

line). If rainfall occurs, a line that equals the depth of the event is drawn vertically from the horizontal line. If the rainfall results in exceeding the top line, the depth above the line is considered as a loss to the system due to surface runoff or deep percolation. Thus, the horizontal lines drawn by the producer should never exceed the top line. If the producer-drawn line touches the bottom line on the chart, irrigation is required and should be scheduled, also marked by a vertical line, so that it will not exceed the top line.

Long-term survey results by Joseph Henggeler, also of the University of Missouri, has shown that the Woodruff Chart was successful at increasing average yields compared with both the Arkansas Scheduler and not scheduling irrigation at all. This has resulted in an economic impact with an estimated $54 million added annual gross profits for Missouri farmers since 2001 (Henggeler 2009). Though these charts are not readily available in Louisiana, they can be created by contacting the LSU AgCenter through the parish Agricultural and Natural Resources extension agent or Dr. Stacia Davis (sdavis@agcenter.lsu.edu). Long-term survey results by Joseph Henggeler, also of the University of Missouri, has shown that the Woodruff Chart was successful at increasing average yields compared with both the Arkansas Scheduler and not scheduling irrigation at all. This has resulted in an economic impact with an estimated $54 million added annual gross profits for Missouri farmers since 2001 (Henggeler 2009). Though these charts are not readily available in Louisiana, they can be created by contacting the LSU AgCenter through the parish Agricultural and Natural Resources extension agent or Dr. Stacia Davis (sdavis@agcenter.lsu.edu).

Atmometer

The atmometer is a water-filled tube measuring 3-4 inches in diameter and 12 inches tall (Fig. 2). The top of the tube is covered in a green fabric that simulates ET_O from a reference plant leaf. A clear tube with inverted markings indicate the water level within the opaque main tube. The water level aligns with zero when the tube is full. As the water level drops due to evaporation through the green fabric, a cumulative estimate of water loss is visualized using the depth markings. A movable red ring around the small, clear tube can be used as a trigger threshold for irrigation.

Figure 2. Example of an atmometer.

Example: Irrigation should begin for a particular crop in a particular field when 2 inches of water has evaporated from the tube. After aligning the red ring with the 2 inch measurement mark, the atmometer should be viewed each day until the water level falls at or below the red ring, indicating that the time to irrigate has been reached.

Utilizing an atmometer is a trial-and-error process for each crop and location. Since the depth represents ET_O and not ET_C, the cumulative depth measurement is a guideline that must be translated to crop water requirements. As a result, there are no firm recommendations for selecting the trigger point. Also, individual devices can be inconsistent when compared with each other due to the simplicity of the device.

Soil Moisture Sensors

The goal of a soil moisture sensor for agricultural irrigation is to give a visual representation through real-time feedback of the changes in soil moisture within the root zone. Sensors are often substituted for the soil water balance. If the sensor provides good information, the irrigator can see the loss of soil moisture from ET_C each day and the gain in soil moisture from infiltration when rain or irrigation occurs.

A set of sensors, three to four in number, are typically placed at a single location within a field. Sensors are placed at multiple depths that cover the current crops potential rooting zone (e.g. 4, 12, 24, 48 inches). Information is collected from each sensor at each depth (sensor set), thus providing the soil moisture status for that irrigation area. Additional sensor sets should be installed at multiple sites on the farm that have different irrigation needs. For example, a separate set of sensors should be installed for every change in soil type, crop type or microclimate, such as sun/shade/wind differences. A set of sensors also should be installed about half to two-thirds down from the polypad in a representative location of the field. Additional information about sensor measurement types and general pricing can be found in LSU AgCenter Publication 3454.

An example of soil moisture sensor data for cotton planted on a sandy clay loam field is shown in Fig. 3. In this example, three sensors were installed with one sensor located at each of the following depths: 6 inches, 18 inches and 24 inches. For this part of the growing season, the most critical sensor was located at 18 inches. Estimations of the soil water characteristics can be made from the graph where field capacity is around 45 to 50 percent (Section A: 24-inch sensor at equilibrium) and permanent wilting point is around 20 percent (Section C: 6-inch sensor at equilibrium).

In the area denoted as section B, a distinct stair-step pattern shows the removal of moisture from the soil profile through ET_C occurring during the daytime (vertical portion of the line in section B) accompanied by the nighttime resting period where ET_C is minimal (horizontal portion of the line in section B). Large stair steps indicate that the plant is able to transpire easily; thus, there is adequate soil moisture. Section C shows the opposite, where no transpiration occurs because little moisture is readily available to the plant, thus creating stressed conditions. Irrigation should occur during the transition between sections B and C.

It is easy to look back at a graph with all of the data and see when irrigation should have occurred; however, it's not as easy to decide when to irrigate in the moment. By the time the change in the size of the stair step is noticeable in the data, the irrigator might have already fallen behind. Thus, it is recommended that a soil water balance be used in conjunction with the soil moisture data to plan irrigation events ahead of time. If that is not a feasible option, a threshold such as 50 percent depletion of available water, calculated as 32.5 percent for this example (dotted line), is suggested.

Conclusion

It is important to irrigate only when necessary during these times of low crop prices, rising irrigation costs and the need for maximizing yield. Too much irrigation or too little irrigation both will do harm. Reigning in variable costs such as irrigation by watering less might save energy costs, but it will cause drought stress and reduce yields. Similarly, applying too much water also will reduce yields and unnecessarily raise energy costs. Thus, appropriate irrigation strategies will aid the irrigator in maintaining normal or above-average yields. Irrigation scheduling is a beneficial agricultural practice.

References

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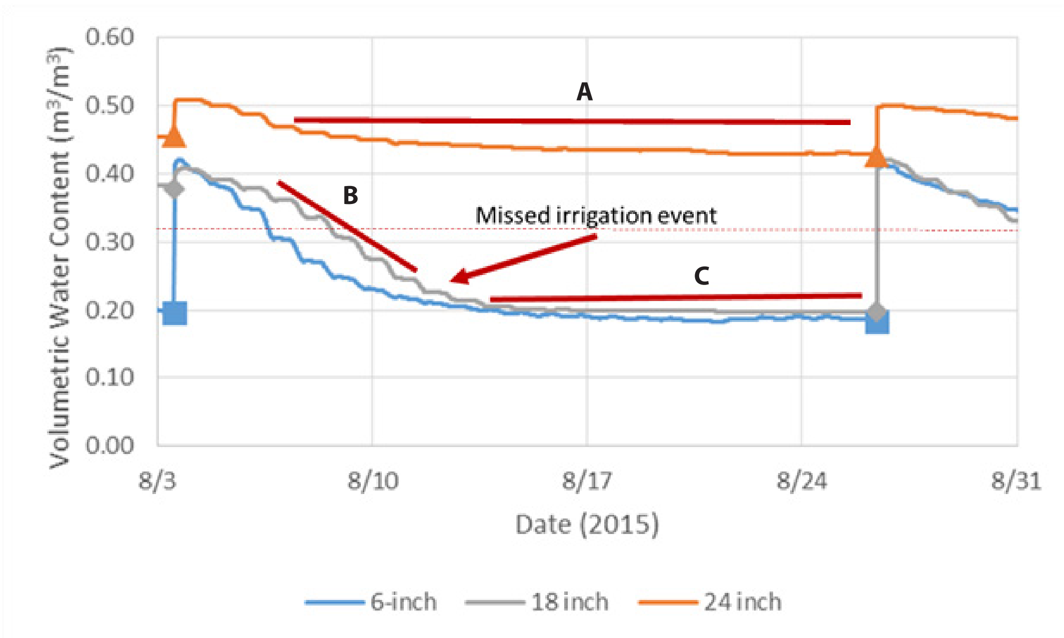

Figure 3. Example of soil moisture sensor data that depicts a missed irrigation event.

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