Benefits and Limitations of Available Technologies for Irrigation Scheduling in Agronomic Crops

STAMP Smart Technologies for Agricultural Management and Production

Introduction:

Irrigation of field crops traditionally was centralized in arid regions of the United States. Over time, the benefits of irrigation over dryland production systems in humid regions were realized and resulted in a 534 percent increase in irrigated acreage in Louisiana alone since 1959.

Acreage of crops that require irrigation to stabilize yield, such as corn and soybeans, also have increased in recent years, resulting in an increased need for supplemental irrigation during critical growth periods. Adding irrigation capacity to any agronomic production system is a large financial investment, which includes upfront costs for equipment and installation and ongoing costs such as fuel, maintenance and labor.

It is critical to strive for high levels of irrigation efficiency to continue to have sustainable and profitable water resource applications. Irrigation scheduling using the soil water balance or through direct measurements of soil moisture are two strategies for efficient irrigation.

What is Irrigation Scheduling?

Irrigation scheduling is the determination of the crop water requirement so the crop is supplied with water at the right time and at the right amount to ensure minimal stress and yield loss due to tail-water runoff or deep percolation. Tail-water runoff occurs when excessive water flows over the surface of the soil, does not infiltrate and exits the edge of the field. Deep percolation occurs when the water infiltrates through the soil below the active root zone and is subsequently not available to the plants.

To minimize stress and optimize yield, some producers over-irrigate, resulting in inefficient irrigation practices. Over-irrigating often can decrease yields in most agronomic crops because of anaerobic or waterlogged soil conditions and loss of nitrogen due to denitrification and nutrient leaching. Even when over-irrigating does not decrease crop yields, it can reduce profits through excess irrigation costs.

Studies have reported that using an irrigation scheduling tool has the potential to reduce water use by 10 percent to 50 percent without reducing yields. Profitability of irrigation is essential because of the average cost of $4 per acre-inch across water sources and fuel types, and each furrow-irrigated event averages 3 acre-inches of water. The costs of pumping certainly will increase as fuel prices rise and aquifers decline.

To enhance productivity and minimize water waste, it is important to understand the benefits and limitations of each irrigation scheduling method to ensure the proper selection and use.

Soil Water Balance (Checkbook Method)

The soil water balance, also called the "checkbook method," is an irrigation scheduling tool that attempts to account for water moving in and out of the active root zone, resembling the balancing of a checkbook with deposits and withdrawals. This approach can be as simple or complicated as the manager desires.

Most soil water balances require the collection of crop evapotranspiration as the output and rainfall and irrigation as inputs. This method typically can get managers in the "ballpark" for needed irrigation events, which is an improvement over making an uninformed decision.

A weakness of the soil water balance strategy is that the components are estimated and not directly measured in the root zone. For example, if a 2 inch rainfall event were to occur, it is difficult to determine how much of the water from that event infiltrated and can be considered usable to the crop. These deficiencies can be corrected by combining simple inputs and outputs with more sophisticated approaches that integrate soil-water status, wind speed, solar radiation, relative humidity, crop stages, canopy temperature and canopy coverage.

The soil water balance method also requires detailed record keeping throughout the growing season. In addition, managing the collected data to determine irrigation decisions can be tedious. There are existing tools to simplify the soil water balance method, such as the atmometer, Woodruff Chart or software programs that provide timely and precise irrigation recommendations. All these tools will allow successful irrigation estimation. Although many universities have available programs, the program provided by University of Arkansas readily can be adapted to Louisiana conditions.

Direct Measurement:

Quantifying available soil moisture can be used as an independent irrigation scheduling tool or included in the soil water balance strategy to overcome the challenges associated with estimating infiltration/runoff from irrigation and rainfall events. These systems will continue to evolve with new technologies and advancements. Soil moisture can be measured using gravimetric methods based on soil water potential (tension) or volumetric methods.

Gravimetric Measurements

A tensiometer is a sealed, airtight tube filled with distilled water with a semiporous ceramic tip and a pressure gauge (Figure 1).

The tensiometer estimates the force a plant would need to exert to access soil water by measuring tension. As the soil begins to dry, soil water potential is greater than it is within the tube and water exits through the ceramic tip. This creates a negative pressure (tension) within the tube that is recorded with the pressure gauge. As soil becomes wet from rainfall or irrigation and soil water content increases, the water potential within the tube becomes greater than the surrounding soil, forcing water to re-enter the tensiometer and lowering the pressure.

Fig. 1. Diagram of a tensiometer.

During the production season, tensiometers provide a quick means of determining actual soil water estimations compared to gravimetric/volumetric water content estimation. The installation and use of tensiometers in the field takes both time and planning. If they are installed incorrectly or do not maintain an adequate seal, they can produce inaccurate measurements.

Tensiometers are easy to use and inexpensive, ranging from $25-$100 based on manufacturer and intended depth. Therefore, they easily can be used for high intensity irrigation monitoring.

Similar to other methods, interpretation of the readout is influenced by soil type. Tensiometers only function within a certain pressure range before the airtight seal is broken and integrity is lost. Although the device can be used across a range of soil water content and soil types, it is not recommended that tensiometers be used in soils with a clay content higher than typical clay loams.

Gypsum block/electrical resistance block sensors (Figure 2) measure the electrical resistance between two enclosed electrodes in a block of porous material. The electrodes attach to insulated wires that travel to the surface of the soil. These wires then can be connected to a resistance meter with a voltage source, data logger or telemetry system to determine soil water potential based on resistance within the block.

Fig. 2. The Irrometer Watermark is an example of an electrical resistance block.

Similar to tensiometers, gypsum blocks measure soil water potential based on the water moving through a porous material. The gypsum block dries as the surrounding soil dries, subsequently decreasing electrical resistance. Traditional gypsum blocks are inexpensive, costing $3 to $10, although updated sensors reach up to $50 or so. Readers can be purchased for about $200 to $300, and data loggers can be purchased for $500 or more. Infield reading can be conducted quickly and easily, but installation does require much time and preparation.

Soil temperature affects the accuracy of soil moisture readings and results in the need for calibration. Similar to the tensiometers, these sensors are most beneficial in soils that create a sealed connection with the sensor, such as soils with high clay content, but are not recommended in sandy soils and shrink-swell soils (such as Sharkey clays) because of the potential for poor contact between the sensor and the soil.

In addition, gravimetric sensors are highly affected by substances dissolved in the soil water. While not a widespread issue, water with a high salt content can be troublesome. Furthermore, these sensors should be replaced annually.

Volumetric Measurements

Volumetric water content sensors (Figures 3 and 4) are the most advanced water sensors on the market. These sensors estimate soil moisture by measuring the permittivity, which is the time it takes for an electric pulse or electromagnetic wave to travel through a known volume of soil.

While many soil components (minerals, nutrients and air) contribute to soil permittivity, the permittivity of water is substantially higher than that of any other component. Therefore, it can be assumed the major shifts in these numbers are due to fluctuations in soil water. For this reason, the permittivity is related to the volume of water in the soil and thus indirectly measures the volumetric water content.

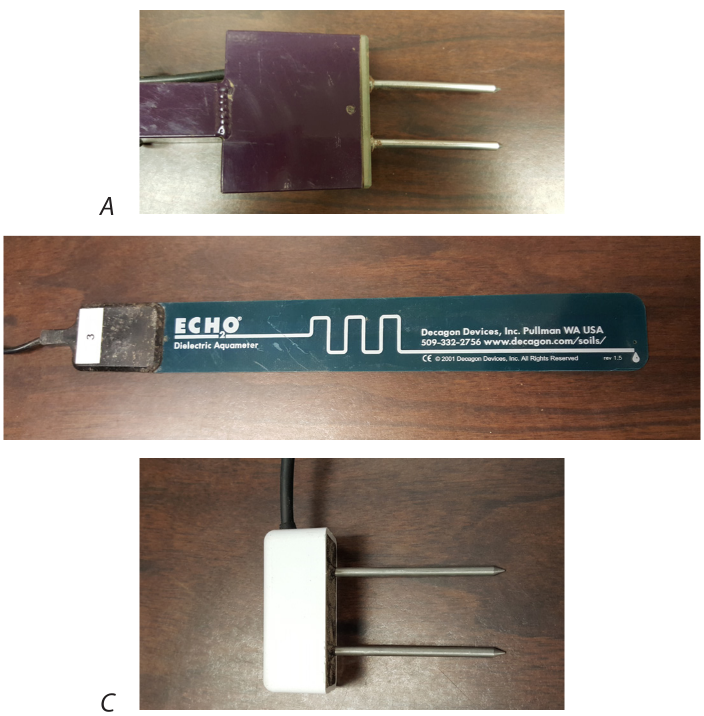

Fig. 3. Three examples of sensors that estimate volumetric water content: A) Spectrum Technologies TDR 300, B) Decagon Devices ECH2O, and C) Decagon Devices GS1.

These sensors work consistently across many soil types and textures, with little need for calibration compared to gravimetric methods. Caution should be used on shrink-swell clays because the loss of contact between the sensor and the soil can produce inaccurate readings. In addition to soil moisture, additional measurements such as soil temperature and electrical conductivity can be incorporated into certain sensor technologies.

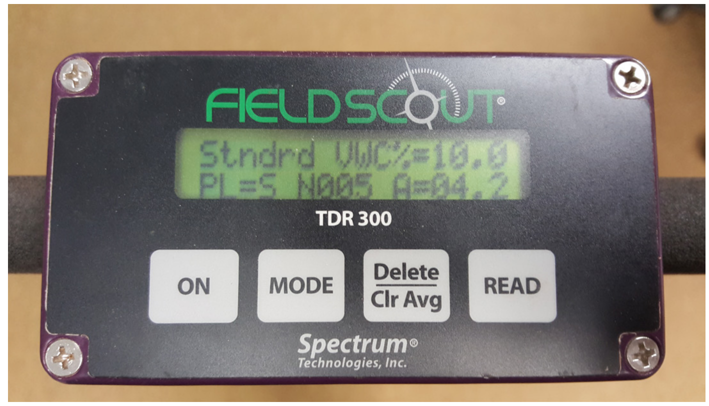

Fig. 4. Example output of an instantaneous volumetric water content reading from the Spectrum Technologies TDR 300 (VWC%=10.0). Some sensors can also read temperature and electrical conductivity (not pictured).

Cost is the primary limiting factor associated with these sensors. The price of each sensor varies based on the information desired. Volumetric sensors can range from $70 to more than $150, while the sensors that collect other parameters range from $175 to $250. The reader/logger technologies are similar to the devices associated with gravimetric sensors and are similarly priced.

Conclusions

There are many instruments and tools that can aid with proper irrigation scheduling. The variety of available technologies can make it difficult to choose the best and most cost-effective methods.

Tools that are flexible and provide more detailed information often are more costly, while tools that may be more economical initially often have limited utility and accuracy. When selecting any combination of irrigation scheduling tools, it is essential that the tools and technology are compatible with the intended goals of the production system and the producer.

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