IRRIGATION WATER MANAGEMENT IN SOUTH CAROLINA – TRENDS AND NEEDS

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Abstract. As water resources become limiting due to population growth, competition, drought, and quality degradation, efficient and wise use of irrigation water in agriculture and landscape increase in importance. In South Carolina, irrigators need up-to-date information and know-how as well as simple and practical methods and technologies to efficiently utilize the advantages of irrigation to remain competitive. Faculty members at Clemson University are addressing these needs, e.g., the newly hired lead author is charged with developing an interdisciplinary and nationally-recognized research and extension program in irrigation water and systems management in South Carolina. In doing so and in collaboration with other experts, initial efforts were to assess the state of irrigation water management in South Carolina as well as its technical and educational needs. Although baseline information is not yet complete due a significant lack of data and literature on irrigation in South Carolina, a reasonably sufficient picture has emerged. Performance of the irrigation system, i.e., uniformity and efficiency, is highly important, but not discussed herein. A program is thus established that seeks to address the irrigation needs through developing and delivering key irrigation management and agro-meteorology information resources and technologies in a state-wide, integrated approach to help irrigators manage their systems for high water productivity (i.e., more crop, less drop) and improve efficiency. In the spirit of this water conference, we present this incomplete picture as well as the emerging irrigation research and extension program, seeking to expand efforts and impact by building trans-disciplinary and multi-location collaboration with other water experts.

IRRIGATION IN SOUTH CAROLINA - TRENDS

Yearly precipitation across South Carolina shows a mean annual value of 48 inches. A major portion of this is consumed by soil evaporation and plant transpiration (i.e., evapotranspiration, ET) which is 34 inches (or 71% of annual rainfall). Although annual rainfall in South Carolina normally exceeds crop ET, it is often poorly distributed which could significantly reduce productivity and profit. For example, rainfall during the summer growing season for cotton (June to August) is 14.8 inches (mean of 1995 to 2003) while its water requirement is about 25 inches. Most summer rainfall in South Carolina is in the form of thunderstorms, and with its effective contribution to root zone soil water storage and thus ET is lower than the total rainfall by up to about 25% and more depending on runoff and leaching losses. This means summer cropping is nearly certainly in water deficit or stressed if not irrigated. Neglecting stored soil water, this estimate indicates a need for about 12 to 16 inches of irrigation at 85% efficiency to meet full cotton water use.

Irrigation Water Use

Water use in South Carolina is linked closely and directly to the State’s population (Badr et al., 2004), with the overall water demand projected to increase by nearly 50 percent by the middle of this century (Castro and Foster, 2000). In South Carolina, irrigation is expanding and becoming a common practice to supplement rainfall. Supplemental irrigation increases productivity of rainfed crops, provides assurance against crop failure due to intermittent drought, and can enhance product quality. Supplemental irrigation in agriculture and landscape accounts for nearly a quarter of State’s water usage (Badr et al., 2004). Its growing importance to the livelihood of farming communities heightens the pressing need for a state-wide irrigation education, research, and extension.

On the national level, South Carolina ranks 32th for total irrigated acreage. The number of farms in South Carolina is about 25,000 with a harvested cropland of about 1.5 million acre (USDA-NASS, 2002). The number of irrigated farms in 2002 was 1918. Estimates of irrigated acreage vary considerably by source, i.e., USDA-NASS reports are in the mid 90,000s while estimates by Cooperative Extension at Clemson University (Bryan Smith: www.clemson.edu/irrig/acreage.htm) are in the 160,000 acre range. Reasons for the large discrepancies
are not clear, but the latter is a more direct survey of all county extension offices as shown in Figs. 1 & 2. As shown, irrigation acreage stood at 165,406 acre in 2004 (or 11% of total harvested cropland). Note that none of the above estimates include the substantial turf acreage on South Carolina golf courses.

The South Carolina Departments of Natural Resources (DNR) and Health and Environmental Control (DHEC) report estimates of water use in 2000 at 253 and 97 million gallons per day for irrigated agriculture and golf courses, respectively (see e.g., Badr et al., 2004). The South Carolina Water Use Report by DHEC shows a total of 12,173 million gallons of water used in 2003 for the 90,900 irrigated acreage reported by USDA-NASS. This translates to 4.6 inches of water per acre of irrigated land in 2003. The same report shows annual water use in irrigated agriculture in 2002 at 29,688 million gallons, which is more than twice as large as the reported use in 2003. The source of the temporal variation in water use is not discussed in the report, but it may be traced to differences in rainfall, that was about 9 inches higher in 2003 than in 2002. This example illustrates the large impact of rainfall variations on demand for irrigation water. Irrigation water usage and acreage estimates are generally poor in South Carolina because of inadequate reporting procedures. Greater efforts by national and state agencies are needed to secure more complete survey and monitoring of irrigation acreage and water use than is currently done.

Irrigation Types

Of particular importance in South Carolina is the observation that 85% of the irrigation systems are sprinkler type (center pivot, wheel roll, travelling gun, hand move, and solid set) among which center pivot ranks first at 57% followed by travelling guns at 23% (Fig. 1). Drip irrigation (surface and subsurface drip and micro-spray) acreage stands at 12% and surface irrigation at 3%. Major irrigated crops in South Carolina are cotton and corn, accounting for over 50% of all irrigated crops followed by fruits and vegetables at about 15% and mostly irrigated by micro-sprays and drip (Fig. 2).

The fact that nearly the entire irrigated land in South Carolina is under pressurized systems is a significant advantage in attempts to improve system efficiency and uniformity as sprinkler (except travelling guns) and drip systems can deliver 85 and 95% efficiency, respectively, with proper maintenance. The disadvantage is that there are additional energy requirements for pressurizing these systems, of which 75% use electric, 23% diesel, and the remaining 2% use gasoline-powered engines. Conversion of the existing diesel to the cleaner electric motors can reduce operating cost, help system automation, and reduce contamination due to fuel leakage.

Fig. 1. Trend of Irrigated Acreage by Type of System in South Carolina. (2001 & 2002 data missing)

IRRIGATION WATER MANAGEMENT - NEEDS

There are many challenges facing today's farmers, particularly those with high-input irrigated production systems. In order to efficiently utilize irrigation, irrigators need up-to-date information and know-how as well as simple and practical tools and technologies. Many of these needs are multi-commodity and shared on the national level. However, irrigation management in our humid region is much more challenging than in arid zones because of frequent but unpredictable rainfall, coupled with mostly sandy soils of high spatial and profile variability, e.g., in texture and water holding capacity, that are prone to develop shallow restricting layers. Because of this, management guidelines developed elsewhere do not always apply and thus must be refined to be effective. A plausible solution to field variability is in matching it with an equally variable irrigation application. The technology to do this is known as precision agriculture or site-specific application.

Our research program takes advantage of the recent advances in soil- and crop-sensing technologies as well as concepts and tools developed in precision agriculture that are made applicable to production fields in the humid Southeast. Of particular importance is achieving adoption of proven sensor technologies and management tools by producers and consultants. To facilitate this, we are in the process of rejuvenating the inactive South Carolina Irrigation Society, providing a desperately needed forum for timely exchange of relevant science and promising practices among scientists, action agency personnel, consultants, and practitioners. Other extension activities are to build a web-based video library designed to demonstrate selected practices and techniques that are applicable in South Carolina to improve irrigation efficiency and/or conserve water, and developing a comprehensive irrigation water management information database to facilitate information sharing and improve
educational opportunities related to irrigation water management across the region.

Site-Specific Management

Recent major increases in cost of energy and fertilizers, declining groundwater levels and streams, and frequent drought have significantly elevated the economic importance of water and energy conservation. Precision farming can meet this need by offering advanced tools and techniques to integrate a systems, yet holistic and practical, approach to efficient, productive, and profitable production. A strong element of our work will concentrate on testing and refining precision agriculture technology and tools, within which science-based and robust irrigation scheduling will be addressed for effective integration. Baseline work has been underway by Clemson researchers, who have developed and tested a variable-rate lateral irrigation system for site-specific application of water (Khalilian et al., 2007).

Crop Water Use

Most advances in irrigation water management during the past few decades are largely due to our increased ability to measure near-surface meteorological variables for crop water use (or ET) estimation, complemented by progress in soil and plant sensor technology and system automation and control (Farahani et al., 2007). One area of importance is determination of crop ET for the different climate areas in the state for irrigation scheduling and design, and for efficient water resources allocation and analysis. Lack of an area-wide research on water use by major crops in South Carolina along with significant changes in crop varieties requires an evaluation of existing crop water use estimates and methods. Lysimetry and soil water balance methods are implemented to measure crop water use. These will be complemented by other robust techniques such as Bowen ratio/Energy balance measurements of ET at Clemson experiment stations.

SCAgMet

Another area of need is access to readily available and near real-time agro-meteorology data for ET estimation and irrigation management. An online search revealed inadequate agricultural meteorology data and irrigation guidelines in South Carolina. Most producers rely on rules of thumb rather than sound science and data for scheduling, and there is reliance on crop growth coefficients and irrigation schedulers from the neighboring states that may or may not apply to South Carolina conditions.

Networks of agricultural meteorology stations in the U.S. and elsewhere provide a wealth of online data to estimate reference crop ET as well as near real-time irrigation information for research and practice. Continuing effort is needed to further encourage the wider use of readily available climate data by consultants and practitioners in addition to installing new stations and networks to fill the many existing and large-area gaps in the Southeast region. In South Carolina, for example, there is no network of reference ET data for ET-based irrigation scheduling or an irrigator-friendly website with up-to-date irrigation information. A state-wide agro-meteorology network is a need in South Carolina.

An initiative is thus underway to design and install the first automated network of agricultural meteorology stations in South Carolina (SCAgMet) with the capability of near real-time (hourly) web dissemination of meteorology-based irrigation and water management information. This state-of-the-art SCAgMet network will use cellular IP-assigned communication capabilities for data retrieval with automated data quality control and post processing procedures. The network will offer utility in agriculture as well as turf, hydrology, water resources, frost monitoring and disease forecasting to name a few. The SCAgMet network is designed with a projected capacity of 92 stations (two per county), with five stations to be installed in the fall of 2008. Cluster (or similar spatial) analysis of past climate data from South Carolina will be used to identify zones of climate homogeneity for effective station placement. Priority is given to zones with a greater irrigated acreage, and thus need, for irrigation information. Lessons learned in the design and installation of other networks (e.g., in FL, GA, NC, and OK) will guide this endeavor. Each station costs about $6000 and potential sponsors are welcome to secure a station for that price and at their agricultural site (that meets our minimum standard for site condition and fetch).

Drip Irrigation

A major topic that needs research and extension work is the management of mulched, drip irrigated vegetables in South Carolina. How much and how does rainfall contribute to crop water uptake? How should such crops be irrigated and fertigated to minimize leaching caused by the wetted volume draining below the root depth under the dripline? Are there simple tools that can be used? How best do we use ET estimates from weather stations when the root area is not the same as the canopy area? These are some of the growers’ questions to be addressed in our research program. A recent survey of South Carolina Watermelon Association members indicated that nearly all members utilized drip irrigation and some level of fertigation. Other major fruit and vegetable crops grown in South Carolina, including strawberries, peppers, tomatoes, eggplant, muskmelons, squash, and cucumbers, use drip irrigation. Growers have to make decisions on how frequently to irrigate and how long to run their system each time. Without good irrigation management information many growers tend to over-irrigate to eliminate the risk of under-irrigation and the resulting
crop water stress and yield loss. Over-irrigation is a form of risk insurance that would not be necessary if better information and tools were available.

**Irrigation Scheduling**

Good irrigation management starts with irrigation scheduling, the science of determining when and how much to irrigate and for what purpose. The purpose may be to maximize yield, profit, or water use efficiency. Scheduling techniques vary from visual crop stress, soil moisture by the NRCS feel method, check book scheduling, scheduling via pan evaporation, atometer, or meteorology data, using soil moisture measurements, and crop-based scheduling. For simplicity, irrigation scheduling methods are classified into ET-, soil-, and crop-based, realizing that in practice, a combination of two methods may be used.

Many ET-based irrigation scheduling programs estimate daily crop ET from calculated reference ET and crop coefficients. Use of this widely-practiced methodology is a difficult task in South Carolina in general and in vegetable production in particular because of a severe lack of locally-developed or -calibrated crop coefficients. As part of our crop water determination program, crop coefficients will be developed for major South Carolina crops to promote ET-based scheduling.

Monitoring soil profile water content is a proven technology to schedule irrigation, i.e., soil-based scheduling. Experience shows that in the absence of automation for reading the sensors and triggering the irrigation, soil moisture monitoring is cumbersome and time consuming and not welcomed by many growers. Newer probes provide continuous soil water monitoring and can be set up to report wirelessly to a server and made available via internet. Output graphs show growers precisely where there water and nutrients are and how much water is available to the plant. One of the main challenges with the advanced soil moisture monitoring probes is to make affordable their use in field water management.

Knowledge of the effect of water stress at various crop growth stages on yield and means of quantifying crop water stress are needed for crop-based irrigation scheduling. Active plant transpiration controls canopy temperature, but when transpiration is limited due to depleted soil water, canopy temperatures increase. Thus, canopy temperature can be used as an indicator of crop water stress. Remotely sensed canopy temperature measured using infrared thermometry has been related to crop water stress and has been used to determine irrigation timing (Geiser et al., 1982). What is missing is the development of the lower and upper threshold temperature functions for different crops in South Carolina for irrigation timing, another aspect of our research program.

**Fig. 2. Irrigated Crops in South Carolina**

**SUMMARY**

Water scarcity and conservation are one of the world’s most pressing environmental concerns. Nearly all U.S. states are challenged to maintain an available, high-quality water supply in regions encompassing million irrigated acres. As demand for water grows, there is increasing economic, social and environmental urgency for improved irrigation water management and efficiency. It is thus incumbent upon scientists and educators to enjoin the skills, knowledge and commitment to effectively address shortcomings in irrigation water management and efficiency.

**LITERATURE CITED**


