Demonstrating subsurface drip irrigation as a climate adaptation strategy for sustainable crop production in South Carolina

José Payero[1], Rebecca Davis[2], Ahmad Khalilian[3]

AUTHORS: [1,2,3] Edisto Research and Education Center, Clemson University, 64 Research road, Blackville, SC 29817, USA.

REFERENCE: *Proceedings of the 2014 South Carolina Water Resources Conference*, held October 15-16, 2014 at the Columbia Metropolitan Convention Center.

ABSTRACT. There is strong evidence that the climate is changing, which has been linked to anthropogenic increases in concentration of greenhouse gases in the atmosphere. Predictions are that in the future we are to expect a hotter climate with more frequent climate extreme events such as droughts and floods. Farmers in South Carolina have a high exposure to climate risk since most row crops in the state are traditionally produced under dryland conditions. Dryland production, however, is risky because it can severely limit yields and farm profits during drought periods. Adoption of irrigation, on the other hand, stabilizes yields from year to year and can significantly increase yields and profits. Farmers in South Carolina are rapidly adopting irrigation and irrigated acreage doubled from 1997 to 2011, increasing considerably since 2002 at a rate of 9,184 ac/year. However, most row-crop farmers who irrigate use Center Pivot systems, which require large and square fields and do not adapt well to small or odd-shaped fields. Most fields in the state, however, are small and odd-shaped, which has limited the adoption of irrigation by many farmers. An option for these farmers is to use Subsurface Drip Irrigation, which is even more efficient than center pivots and adapts well to this type of fields. This paper focuses on work that is currently underway at the Edisto Research and Education Center of Clemson University to evaluate and demonstrate the technical and economic feasibility of using Subsurface Drip Irrigation for row crop production in South Carolina.

INTRODUCTION

Although South Carolina receives considerable amounts of rainfall, in the order of almost 50 inches per year, yields of major crops are still very low compared to potential irrigated yields. Results from the USDA Census of Agriculture (USDA, 2010) for 1997, 2002, and 2007 (Table 1) show that average dryland yields for major row crops like cotton, soybeans, wheat, peanuts, and corn in South Carolina during those three years were considerable lower than what can be achieved with irrigation. For example, for grain corn, the average dryland yield was 73.3 bu/acre, while Dobermann and Shapiro (2004) showed mean attainable irrigated corn yield ranging from 195 to 275 bu/acre. Therefore, irrigation could significantly increase yields and total crop production in the state. Part of the problem is that the temporal distribution of rainfall does not coincide with the temporal distribution of crop water requirements, therefore, dryland crops are usually water-stressed during part of the growing season.

Table 1. Average dryland yields of row crops in South Carolina during 1997, 2002, and 2007 (USDA, 2010).

Crop	1997	2002	2007	Avg
Cotton (ba/acre)	1.4	0.6	0.9	0.97
Soybeans (bu/acre)	22.6	16.4	17.2	18.7
Wheat (bu/acre)	46.9	37.1	28.6	37.5
Peanuts (lb/acre)	2,835	2,234	2,928	2,666
Grain Corn (bu/acre)	90.3	40.6	89	73.3

In addition, because of the prevalence of sandy soils, with low water holding capacity, little of the rainfall occurring in the off season would be stored in the soil profile to be used by the crops during the growing season. At the same time, crop production in South Carolina is predominantly dryland, which is more susceptible to climate uncertainties than irrigated production. For example, the average percent irrigated acres of five major row crops harvested in South Carolina in 1997, 2002, and 2007 (Table 2) was only around 5.5%. This means that a severe drought could devastate crop production in the state and create severe economic hardship for dryland farmers.

Table 2. Percent irrigated acres harvested in South Carolina during 1997, 2002, and 2007 (USDA, 2010).

Crop	1997	2002	2007	Avg
Cotton	4.85	7.13	9.01	7.0
Soybeans	1.50	2.08	2.02	1.9
Wheat	1.05	2.51	2.44	2.0
Peanuts	4.61		14.67	9.6
Grain Corn	5.96	6.22	8.58	6.9
Average	**3.6**	**4.5**	**7.3**	**5.5**

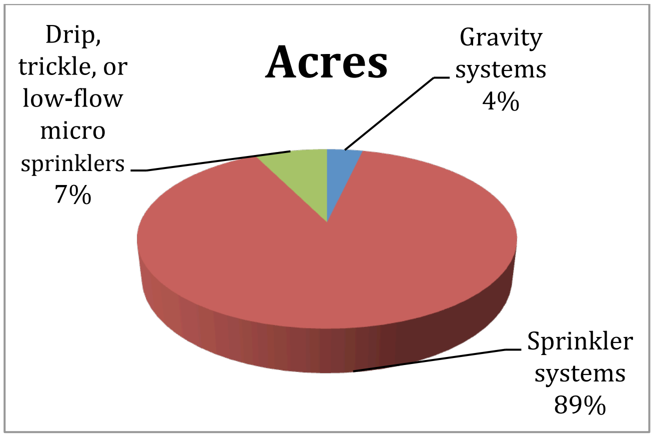

Figure 1. Percent irrigated acres by irrigation system in South Carolina.

Many farmers in the state are becoming aware of this risk and have been adopting irrigation as insurance against potential drought. Irrigated acreage has been increasing considerably since 2002, at a rate of 9,184 acres/year. However, most row-crop farmers who irrigate use Center Pivot systems, which require large and square fields and do not adapt well to small or odd-shaped fields. Sprinkler systems, mostly center pivots, account for around 89% of irrigated acres in the state (Fig. 1). Most fields in the state, however, are small and odd-shaped, which has limited the adoption of irrigation by many farmers.

An option for these farmers is to use Subsurface Drip Irrigation (SDI), which is even more efficient than center pivots and adapts well to this type of fields. But, only around 7% of acres in the state are irrigated using drip systems, especially surface drip systems, which are normally used to irrigate vegetables and orchards. This paper focuses on work that is currently underway at the Edisto Research and Education Center (Edisto REC) of Clemson University (Blackville, SC) to evaluate and demonstrate the technical and economic feasibility of using SDI for row crop production in South Carolina.

PROJECT DESCRIPTION

Although SDI systems have been used successfully for row crop production for decades, especially in Western and mid-western states (Lamm and Trooien, 2003; Ayars et al., 1999; Payero et al., 2008) their adoption in South Carolina, like the adoption of irrigation in general, has been very limited. Part of the problem is that farmers need information on the benefits, especially on the economic viability of SDI, in addition to other aspects such as design, installation, management and maintenance requirements. Khalilian et al., (2000) evaluated several aspects of SDI during an experiment with cotton conducted from 1997 to 1999 at the Edisto REC. The focus of the study was on investigating optimum drip tape spacing, drip tape depth, and tillage practices. They also investigated the yield and water-savings advantage of SDI compared to dryland production. They found that during the three years, irrigation with SDI increased cotton yields by an average of 65% (494 lb/acre), representing an additional income of $395/acre over dryland cotton, assuming a cotton price of $0.80/lb. Building on these results, and trying to respond to enquires from farmers about SDI, a new SDI research and demonstration facility was recently established at the Edisto REC. This facility will be used to investigate how to best manage irrigation and crop nutrients (through fertigation), focusing on sensor-based irrigation scheduling and irrigation automation options. It will also be used as a SDI demonstration site for farmers, crop consultants and extension agents.

METHODS

Installation of the SDI research/demonstration facility, which occupies a net area of 1.8 acres, was initiated in spring of 2014. This area was divided into 4 blocks of 10 plots each for a total of 40 plots (Fig. 2). Each plot has four drip laterals installed every other row at a depth of around 10 inches. Each plot can accommodate 8 crop rows planted at a row spacing of 38 inches. Irrigation and flushing can be controlled independently for each plot. Therefore, there is a water supply line (1" PVC pipe) and a flushing line (3/4" PVC pipe) connected to each plot. The laterals were Typhoon 875 0135F (Netafim USA, Fresno, CA), which have a diameter of 0.875 inches, drip emitters spaced every 18 inches, which provide a nominal flow rate of 0.36 GPH at 10 PSI of pressure. The drip tapes were connected to the water supply and flush lines using flexible hose. Either stainless still wire or plastic connectors were used to connect the flexible hose to the drip tape.

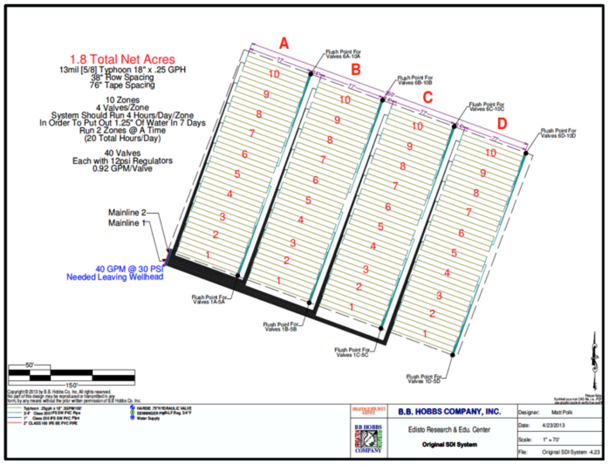

Figure 2. Plot layout for SDI system at Edisto REC.

Figure 3. Shank system used to install the drip tapes.

The flexible hose was connected to that PVC pipes of the water supply and flush lines by gluing it to either a PVC "T" or an elbow. The drip tapes were installed using a shank system built in-house (Fig. 3), which was pulled by a tractor. The tractor was equipped with a Real-Time Kinematics (RTK) GPS system with centimeter-level accuracy to obtain good alignment of the drip laterals. After the drip laterals were buried, a trencher was used to open trenches (1 feet wide x 3 feet deep) to house the water supply and flushing PVC pipes (Fig. 4).

The water supply lines were all routed to a wooden shed installed at the edge of the field. The shed serves as the control center for the SDI system (Fig. 5) and was located next to the submersible pump that supplies water to the system, pumped from a deep well. Inside the shed, four manifolds were constructed, one for each block of plots (10 plots). The manifolds contain a series of water control devices for each water supply line.

Figure 4. (a) Digging a trench with a trencher, and (b) water supply lines inside one of the trenches.

Figure 5. (a) Water supply lines connected to SDI control center, and (b) control manifolds for each plot.

The water control devices include an electronic flow meter, an electrical/manual solenoid valve, a pressure regulator, a pressure gauge, and an air vent. This arrangement allows electronic and/or manual control and quantification of the timing and amount of water applied to each plot. The flush lines at the end of each plot were brought to above-ground risers at the edge of the field in groups of five plots. (Fig. 6a).

In addition to applying irrigation water, the system is also equipped for chemigation, especially for the injection of liquid fertilizer, which would be spoon-fed to the crop to match the nutritional needs of the crop. The system is also set up to inject other chemical like chlorine, which is needed for regular maintenance to prevent the growth of algae and bacteria that could clog emitters. For this, a chemical injection diaphragm pump was installed inside the shed (Shurflo 800 series) with a nominal flow rate of 1.4 gpm. Two chemigation tanks were also installed outside the shed, one to store liquid fertilizer and a smaller one to store a chlorine (bleach) solution (Fig. 6b).

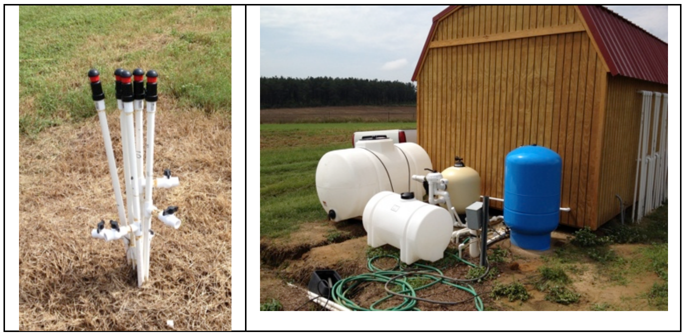

Figure 6. (a) Flushing risers, and (b) Pump, sand filter, chemigation tanks, and pressure tank.

A pressure tank (Amtrol Well-X-Trol) with a capacity of 86 gal was installed after the pump to maintain a stable pressure in the system without the pump needing to operate continuously (Fig. 6b). A pressure switch was installed to automatically turn the pump on and off based on pre-set minimum and maximum pressure thresholds. A sand media filter (Pentair Triton II, model TR60), with a capacity to handle a flow rate of 60 gpm was also installed (Fig. 6b).

RESULTS

After the installation of field components was completed, all plots were planted to cotton to initiate two irrigation experiments. One of the experiments is evaluating the performance of nine cotton varieties under full irrigation and deficit irrigation. The other experiment is evaluating different irrigation scheduling options, including the use of different types of soil moisture sensors (Watermark 200 or Decagon EC-5), weather station data, or ETgage measurements to decide when to irrigate. Although the results of these experiments are not yet available, the SDI system has shown to be well suited to this type of experiments. However, the system was managed manually in 2014 since automation devices had not been installed.

DISCUSSION

Although the system is working and performing well when operated manually, our goal is to fully automate irrigation. Automation components will be added during the off-season to be ready for the next growing season. Rather than obtaining an off-the-shelf irrigation controller, which usually has limited capabilities for sensor-based irrigation automation, we will create a system that can make smart irrigation decisions. This means, creating a system that can take real-time inputs from a variety of sensors installed in the field and from the internet, with data transmitted to the SDI control center either using wired or wireless communication. Also, our aim is to create a system that can record, interpret, and display these inputs in real time and automatically make management decisions and trigger appropriate actions.

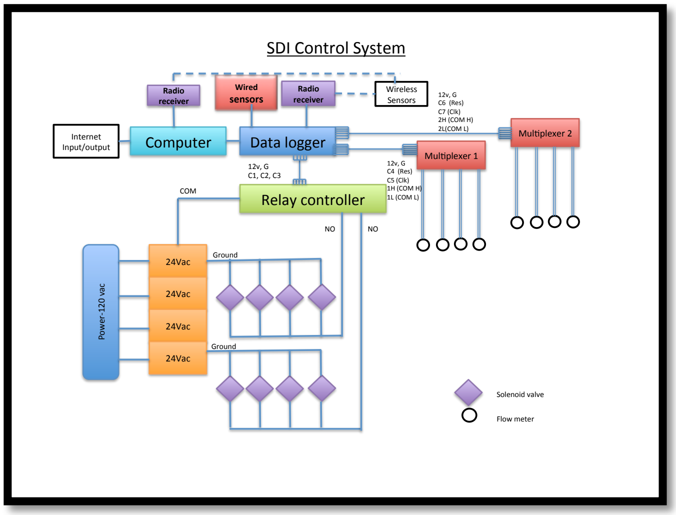

Figure 7. Diagram of SDI automation system.

The future automation system will follow the logic diagram in Fig. 7. A CR1000 data logger and control system (Campbell Scientific, Inc., Logan, UT) will be used to control automation. Attached to the data logger, two multiplexers (AM16/32B) will be used to increase the number of input channels on the data logger to be able to read the flow outputs from the 40 flow meters. Relay controllers (SDM-CD16AC) will be used to control the solenoid valves and other devices. The data logger will be attached to a desktop computer running the LoggerNet software, which supports programming, communication, and data retrieval between dataloggers and a PC.

LITERATURE CITED

Ayars, J.E., Phene, C.J., Hutmacher, R.B., Davis, K.R., Schoneman, R.A., Vail, S.S., Mead, R.M. 1999. Subsurface drip irrigation of row crops: a review of 15 years of research at the Water Management Research Laboratory. *Agricultural Water Management* 42:1-27.

Dobermann, A. and Shapiro, C. 2004. Setting a realistic corn yield goal. *NebGuide G481*. University of Nebraska-Lincoln, 4 pp.

Khalilian, A., Sullivan, M.J., and Smith, W.B. 2000. Lateral depth placement and deep tillage effects in a subsurface drip irrigation system for cotton. *Proceedings of the 4th Decennial Symposium*, Nov 14-16, Phoenix, AZ, ASAE, pp 641-646.

Lamm, F.R., Trooien, T.P., 2003. Subsurface drip irrigation for corn production: a review of 10 years of research in Kansas. *Irrigation Science* 22:195-200.

Payero, J.O., D.D. Tarkalson, S. Irmak, D. Davison, and J.L. Petersen. 2008. Effect of irrigation amounts applied with subsurface drip irrigation on corn evapotranspiration, yield, water use efficiency, and dry matter production in a semiarid climate. *Agricultural Water Management* 95: 895-908.

USDA, 2010. 2007 *Census of Agriculture: Farm and Ranch Irrigation Survey (2008)*. Vol. 3, special studies, part 1 (AC-07-SS-1). United State Department of Agriculture, National Agricultural Statistics Service. 268 pp.