Scheduling Irrigation for Corn in the Southeast

C.R. Camp and R.B. Campbell,
Coordinators

1. INTRODUCTION

C.R. Camp and R.B. Campbell[1]

NEED FOR IRRIGATION

The Southeastern Coastal Plain (fig. 1.) has a humid, subtropical climate and a mean frost-free growing season of about 250 days. Its annual rainfall normally equals or exceeds evapotranspiration (ET) and may be adequate for crop production; however, it is often not well distributed during the crop growing season. Total rainfall during the growing season often does not satisfy ET requirements, and plant water stresses occur. More importantly, drought periods that are of sufficient duration and intensity to cause reductions in crop yield can occur. Sheridan et al. (1979) showed that 22 consecutive days with less than 6 mm of rainfall on any day could be expected every other year. In the Coastal Plain, crops suffer from water stress after 3 to 7 days without rainfall because of the low water-holding capacity of soil and low soil volume explored by plant roots. The combination of soil physical properties and high probability of short-term drought makes it unlikely that high yields can be realized yearly from crops with high water requirements, such as corn.

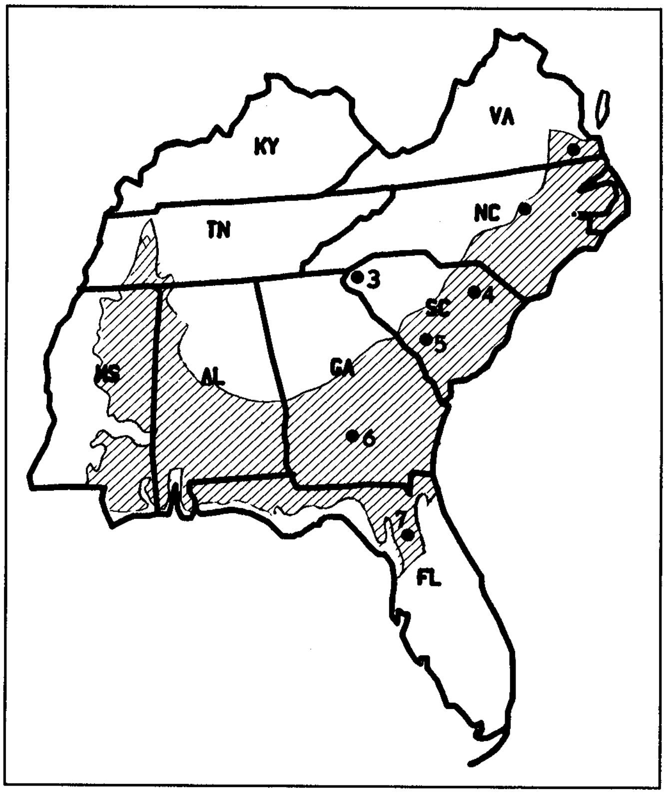

Figure 1.
Field research sites for a regional irrigation scheduling research project in the Southeastern Coastal Plain (shaded area) include 1, Suffolk, VA; 2, Clayton, NC; 4, Florence, SC; 5, Blackville, SC; 6, Tifton, GA; and 7, Gainesville, FL. Computer-based water balance computations for all locations except Suffolk, VA, were performed at 3, Clemson, SC.

In addition to a coarse texture and very low water-holding capacity, many of the soils have compacted layers. This compaction, caused by tillage, traffic, or genetic characteristics, restricts plant rooting to very shallow depths (0.30 m to 0.45 m). Plant nutrients, especially nitrogen, are easily leached through the soil profile of many soils following rainfall or a combination of rainfall and irrigation that exceeds soil storage capacity. Farmers have used deep tillage techniques, such as subsoiling and chisel plowing, to disrupt the compacted soil layers in an attempt to increase rooting depth and uptake of both water and nutrients from the subsoil. Much of the rainfall during the growing season results from afternoon convective thunderstorms, which can be moderate to

[1] Agricultural engineer and soil scientist (retired), respectively, U.S. Department of Agriculture, Agricultural Research Service, Coastal Plains Soil and Water Conservation Research Center, Florence, SC 29501.

high in intensity. Consequently, much of this rainfall is lost as surface runoff and is not used effectively for plant transpiration. If heavy rainfall follows irrigation or other rainfall, adverse soil aeration problems can arise and last for several hours to a few days (Campbell and Phene 1977).

Corn is important to the region but generally does not rank high as a cash crop because it is utilized primarily as an intermediate product for poultry, hogs, dairy, and beef. When quantities of feed grains produced are compared with feed grains used, it is apparent that most States in this region are grain deficient (Bauer and Burch 1981). Although the growing season is long, most of the corn grain is produced by short-season hybrids planted very early in the spring to minimize the effects of drought, heat, or high insect pressures during the summer. The reproductive growth stage of corn is most critical and is very sensitive to even short periods of moisture stress (Shaw 1977).

The need to irrigate corn in the region is well documented (Van Bavel and Carreker 1957, Van Bavel et al. 1957, Van Bavel and Lillard 1957, Sheridan et al. 1979). Irrigated cropland has increased 40 to 400% for most States of the region during the last decade. A significant portion of this land is devoted to corn production (table 1). Further growth of irrigation in the region is projected for the near future.

Water supplies are generally adequate in the Coastal Plain, but energy costs for pumping water from wells and reservoirs will require careful economic analyses during both the design and management of irrigation systems. Because of the relatively short growing season required for corn in this region, many farmers are producing other crops before or after corn to increase land and equipment utilization and enhance economic return. With the rapid expansion of irrigated corn land and with the soil, climate, and cultural problems associated with crop

Table 1.
Area irrigated and in corn production in the Southeastern United States in 1984 and changes in irrigated area since 1975

State	Irrigated area	Change since 1975	Irrigated corn area	
	ha	%	ha	%
Alabama	65,448	+403	24,300	37
Florida	759,517	-2	31,590	4
Georgia	481,950	+417	131,625	27
Mississippi	190,350	+42	N/A	N/A
North Carolina	82,588	+81	14,580	18
South Carolina	56,962	+260	16,200	28
Virginia	35,438	+100	6,075	17
Tennessee	11,097	+40	3,969	36

Source: Irrigation Journal (1985).

production in the region, there is a critical need for knowledge of crop water requirements and for irrigation management technologies which will efficiently and effectively satisfy those crop water requirements.

IRRIGATION MANAGEMENT METHODS

Several irrigation management methods have been suggested for humid regions, but few have been accepted by irrigation managers in the Southeastern United States. The use of soil-water potential (tensiometers) to manage irrigation is widely recognized and recommended (Bruce et al. 1980, Rhoads 1982), but is not widespread (Lambert 1980). Instrument cost, maintenance requirements, and time and labor requirements are the most common reasons cited for not using tensiometers.

Evaporation from containers such as National Weather Service Class A evaporation pans and other metal containers of various sizes have been used either to physically simulate a soil-water balance or to estimate potential ET in water balance procedures (Westesen and Hansen 1981, Doty et al. 1982). Some researchers have covered these containers with screen to reduce contamination and water loss caused by animals and have found that evaporation is reduced to a value nearly equal to potential ET (Campbell and Phene 1976).

Various adaptations of the water balance technique have been developed but are restricted to specific crops, soils, or climatic regions and require tedious recordkeeping or interpretation of charts and figures (Lambert 1980, Doty et al. 1982, Gregory and Shottman 1982). These methods require knowledge of the soil-water retention characteristics, measured or estimated daily ET, measured rainfall and irrigation amounts, and initial soil-water storage.

Computers have been widely used for several years in arid regions to eliminate tedious recordkeeping associated with water balance methods and to estimate daily ET based upon daily meteorological inputs (Jensen et al. 1970, Kincaid and Heermann 1974). Although efforts have been made to adapt this technology to humid regions and to incorporate rainfall predictions into the decision-making process, the use of computers in scheduling irrigation is neither widely recommended nor practiced by irrigation managers (Rochester and Busch 1972, Lambert 1980). Difficulties in estimating daily ET and in accurately assessing infiltration, runoff, and deep percolation losses from humid-region soils are suggested as reasons these methods are not widely accepted.

Development of water balance methods for programmable calculators (Kincaid and Heermann 1974) and personal computers (Lambert 1980) and the increased availability of these machines provide the opportunity for using a single computer to schedule the irrigation of several locations, which may differ widely in soil, crop, and climate. An additional benefit of computer-based methods is the capability to forecast seasonal water resource needs so that either irrigation equipment may be matched to existing water resources or additional water resources may be developed to satisfy irrigation requirements.

Regardless of the method used in managing irrigation, soil variability and water application variability within the management unit must be recognized and included in the decision-making process. In the case of discrete soil-water-potential measurements (tensiometer), the number and location of instruments in relation to spatial variability of soil physical properties must be considered in the design of the monitoring system as well as in the interpretation of measurements. Likewise, knowledge of plant available soil water and crop rooting depth for soils in the management unit is critical for successful application of any water balance procedure whether it be based on the use of computers, manual bookkeeping, or an evaporation pan simulator.

In all methods, control sites must be selected within the management unit so that they adequately represent soil and crop conditions for the entire unit. These key control sites will then be used to determine the timing and amount of irrigation water to be applied. With the development of automated irrigation machines and suitable soil-water sensors, it will be possible to vary the irrigation application to satisfy soil needs within a management unit during a given irrigation cycle. Even in this case, some compromise will be required because soil changes will seldom coincide with irrigation machine movement patterns.

REGIONAL COOPERATIVE RESEARCH

Little data are available in the Southeastern United States comparing irrigation scheduling methods, comparing methods for estimating daily ET, or in determining crop water requirements. A critical need exists to evaluate irrigation scheduling methods and to assemble a data base quantifying water use by crops in this region. Consequently, a group of interested researchers organized a regional work group to accomplish some of this research.

Because the research was funded in part by the Agricultural Research Service of the U.S. Department of Agriculture, the Coastal Plains Soil and Water Conservation Research Center acted as coordinator for the project. Participants included the North Carolina Agricultural Research Service at Clayton; the South Carolina Agricultural Experiment Station at Florence, Blackville, and Clemson; the Georgia Agricultural Experiment Station at Tifton; and the University of Florida Institute of Food and Agricultural Sciences at Gainesville. Field research sites were located at Clayton, NC; Florence, SC; Blackville, SC; Tifton, GA; and Gainesville, FL (fig. 1). Research was conducted at all of these locations during 1979, 1980, and 1981.

Objectives of this research were (1) to evaluate a computer-based water balance (CBWB) irrigation scheduling technique for the region, (2) to compare corn growth, yield, and water requirements when irrigation is scheduled by the CBWB method versus the tensiometer method, (3) to assemble crop-water-use data in relation to meteorological data for the region, and (4) to evaluate the CBWB procedure from a user's point of view, particularly with respect to input parameter selection and interpretation of output guidance.

Because this research was only partially funded by ARS, individual researchers often incorporated these research objectives with others specific to their location. In some cases, additional irrigation scheduling methods, additional crops, and tillage variables were included in the experimental design. Individual researchers also selected management criteria for the tensiometer method that were most appropriate for their soils and locations.

The CBWB procedure was developed and operated by J.R. Lambert at Clemson (fig. 1). Weather forecasts were provided to Dr. Lambert for each location twice weekly during the growing season by M.E. Brown, National Weather Service Office in Columbia, SC. Irrigation schedules and data were communicated directly between Dr. Lambert and individual locations.

Similar research was subsequently initiated in 1980 at Suffolk, VA, by personnel of the Virginia Agricultural Experiment Station and ARS under a different program (fig. 1). However, timing and goals of this effort were not such that identical procedures could be used. The specific computer-based scheduling procedure used at the Virginia location was different from that used by the work group but was similar in concept. Their results, including a description of the scheduling procedure used, are included in this report because of many similarities.

Except for two chapters, this report is organized by individual locations where the research was conducted. Scientists responsible for research at each location prepared the respective reports to stand alone and are technically responsible for their content. The detailed descriptions of the CBWB and weather forecasting procedures are two separate chapters. Figures showing the CBWB performance at each location are reported in a standard format to facilitate comparison among locations.

REFERENCES

Bauer, L.L., and T.A. Burch. 1981. South Carolina Agriculture. S.C. Agr. Exp. Sta. Bull. 636, Clemson Univ., Clemson, SC.

Bruce, R.R., J.L. Chesness, T.C. Keisling, J.A. Pallas, Jr., D.A. Smittle, J.R. Stansell, and A.W. Thomas. 1980. Irrigation of crops in the Southeastern United States: Principles and Practice. U.S. Dept. of Agric., Agric. Res. Serv., ARM-S-9. (Series discontinued)

Campbell, R.B., and C.J. Phene. 1976. Estimating potential evapotranspiration from screened pan evaporation. Agric. Meteorol. 16:343-352.

Campbell, R.B., and C.J. Phene. 1977. Tillage, matric potential, oxygen and millet yield relations in a layered soil. Trans. ASAE 20(2):271-275.

Doty, C.W., C.R. Camp, and G.D. Christenbury. 1982. Scheduling irrigation in the Southeast with a screened evaporation pan. Proc. Specialty Conf. on Environmentally Sound Water and Soil Management. Am. Soc. Civ. Engr., Orlando, FL., July 20-23 pp. 475-483.

Gregory, J.M., and R.W. Shottman. 1982. Irrigation scheduling procedure for subhumid regions. Trans. ASAE 25(5):1290-1294.

Irrigation Journal. 1985. 1984 Irrigation Survey. Irrig. J. 35(1):25-32.

Jensen, M.E., D.C.N. Robb, and E. Franzoy. 1970. Scheduling irrigation using climate-crop-soil data. J. Irrig. Drain Div., Am. Soc. Civ. Engr., 96(Ir):25-28.

Kincaid, D.C., and D.F. Heermann. 1974. Scheduling irrigation using a programmable calculator. U.S. Dept. Agric., Agric. Res. Serv. ARS-NC-12. (Series discontinued)

Lambert, J.R. 1980. Irrigation management - Humid areas. Proc. 2nd Nat'l. Irrig. Symp., Irrigation Challenges of the 80's. Oct 20-23, 1980. Lincoln, NE. Am. Soc. Agric. Engr. Pub. #6-81. pp. 175-184.

Rhoads, F.M. 1982. Scheduling irrigation and fertilization for maximum yield and minimum environmental pollution in the Southeast. Proc. Specialty Conf. on Environmentally Sound Water and Soil Mgmt. Am. Soc. Civ. Engr., Orlando, FL. July 20-23. pp. 460-466.

Rochester, E.W., and C.D. Busch. 1972. An irrigation scheduling model which incorporates rainfall predictions. Water Resources Bull. 8(3):608-613.

Shaw, R.H. 1977. Climatic requirment. In G.F. Sprague, (ed.) Corn and Corn Improvement. Agron. No. 18, Am. Soc. Agron., Inc., Madison, WI.

Sheridan, J.M., W.G. Kneisel, T.K. Woody, and L.E. Asmussen. 1979. Seasonal variation in rainfall and rainfall-deficit periods in the Southern Coastal Plain and Flatwoods Regions of Georgia. Georgia Agric. Exp. Sta. Res. Bull. 243, 73 pages.

Van Bavel, C.H.M., and J.R. Carreker. 1957. Agricultural drought in Georgia. Georgia Agric. Exp. Sta. Tech. Bull. NS15.

Van Bavel, C.H.M., and L.A. Forrest, and T.C. Peele. 1957. Agricultural droughts in South Carolina. S.C. Agric. Exp. Sta. Bull. 447, June, 1957.

Van Bavel, C.H.M., and J.H. Lillard. 1957. Agricultural drought in Virginia. Virginia Agric. Exp. Sta. Tech. Bull. 128. April, 1957.

Westesen, G.L., and T.L. Hanson. 1981. Irrigation scheduling using washtub evaporation pans. Proc. Am. Soc. Agric. Engr. Irr. Scheduling Conf., Dec. 1981, Chicago, IL. ASAE Spec. Publ. 23-81. pp. 144-149.