INFILTRATION AND EVAPOTRANSPIRATION FOR COTTON GROWN WITH REDUCED TILLAGE ON GOLDSBORO LOAMY SAND

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ABSTRACT

Despite abundant rainfall, southeastern sandy Coastal Plain soils can be droughty because of their low water holding capacity. A frequency domain reflectometry sensor was used to measure amount of rainfall that infiltrated into the soil and was taken up by roots of cotton grown in reduced tillage. Sensors measured volumetric soil water content at 30-min time steps and 4-inch depth intervals to 40 inches. Changes of soil water content were separated into infiltration, evapotranspiration, deep percolation, and runoff using rain gauge measurements and software designed specifically for this experiment. At mid-season, cumulative infiltration was 75 to 85% of the rainfall with spikes up to 90% during storm peaks when water would have ponded on the soil surface. Later in the season, during a wet period, cumulative infiltration dropped to 60% because the lower part of the profile was full, unable to accept infiltration. Evapotranspiration, measured as reduction of soil water content that did not drain deep into the profile, was highest in the top foot and decreased exponentially below that depth. Even though the soil dried out easily and even though it was disrupted deeply under the row to disrupt a hard layer and promote root growth below it, most water for plant growth came from the top foot, the zone that had been tilled.

INTRODUCTION

In the southeastern Coastal Plains, except for years of drought which can be devastating (http://nc.water.usgs.gov/ and http://sc.water.usgs.gov/), rainfall is abundant, averaging more than 45 in y^{-1} (http://www.dnr.state.sc.us/climate, http://www.nc-climate.ncsu.edu/). Yet water is the limiting growth factor almost every year because crops normally experience periods of no rain for two weeks or more (Sheridan et al., 1979) which in these low-water-holding-capacity sandy soils (0.08 g g^{-1}) can cause yield-reducing stress (Sadler and Camp, 1986). Uptake of water and nutrients is further inhibited by a root restricting hard layer located just below the Ap horizon (Busscher et al., 2002).

Effective rainfall is the amount of rainfall that is held in the soil profile for plant root uptake. Effective rainfall can be estimated in a table lookup procedure (http://www.fao.org/documents/) or by calculation (http://aben.cals.cornell.edu/faculty/walter/GreenAmpt v4.doc). It can also be measured by determining differences in water content with time as roots take water from the soil. These measurements can be made with a number of devices that quantify soil matric potential or soil water content as it changes with time, such as time tensiometers, time domain reflectrometry sensors, or neutron probes (Wiedenfeld, 2004; Burt et al., 2005). We used a Sentek EnviroSCAN sensor (Sentek Pty Ltd, Stepney, SA, Australia) that uses capacitance probes to measure volumetric soil water content with frequency domain reflectometry. Our objective was to use water content measured on half-hour basis and rainfall measured at a nearby weather station to calculate infiltration and crop uptake throughout the growing season.

MATERIALS AND METHODS

In May 2005, two varieties of cotton were planted in plots at the Pee Dee Research Center of Clemson University near Florence, SC using reduced tillage methods: no surface tillage, in-row deep (14 in) tillage with a KMC (Kelley Manufacturing Co, Tifton, GA) subsoiler on 38 in row widths in plots that were 25 ft wide and 50 ft long.

Plots were located on a Goldsboro loamy sand. Goldsboro was a moderately permeable, deep, moderately well drained soil that formed in Coastal Plain marine sediments. Goldsboro typically had 20- to 30-in depths to seasonally high water tables. It had Ap and E horizons that were 12 to 14 in deep with 2 to 8% clay content and 0.5 to 2% organic matter. These horizons typically had 1 to 3 meq per 100 g cation exchange capacity. Without deep disruption with a subsoiler, the E horizon can have strengths that restrict root growth. Below this was a Bt soil horizon, a sandy clay loam with 18 to 30% clay content and 0 to 0.5% organic matter. The B horizon typically had 2 to 4 meq per 100 g cation exchange capacity with more structure than the Ap and E.

In late May, cotton was planted with Case-IH series 900 planters (Case IH, Racine, WI) at a rate of 4 plants ft^{-1}. Nitrogen (80 lbs N a^{-1} as ammonium nitrate) was applied in a split application - half at planting and half one month later. Nitrogen was banded approximately 2 in deep and 6 in from the rows. Lime, P, K, S, B, and Mn were applied as needed, based on soil test results and Clemson University Extension recommendations. Weeds were controlled with roundup. Insects were controlled by applying aldicarb (0.75 lbs ai a^{-1} of 2 methyl 2 (methylthio)propionaldehyde O methylcarbamoyloxime) in furrow for thrips [Frankliniella occidentalis (Pergande)]; other insecticides were applied as needed.

In mid October, cotton was chemically defoliated. In November, seed cotton yield was harvested using a two-row spindle picker and bagged. Each harvest bag was subsampled, and the subsample was saw-ginned to measure lint percent. Lint percentage was multiplied by seed cotton yield to estimate lint yield.

EnviroSCAN sensors (Syntek Pty Ltd, Stepney, South Australia) were installed in two replicates of each variety to scan water contents every half hour at 4 in depth intervals to 40 in. Sensor data were stored in a CR21X (Campbell Scientific, Inc, Logan UT) and downloaded weekly. Rainfall data were collected from weather station Site Number 2037 of the National Water and Climate Center of the National Resources Conservation Service of USDA that was located about 400 yards away from the sensors. Data from the weather station were collected on an hourly basis.

Soil water content data were analyzed using mass balance in a simple QBasic program to calculate infiltration, evapotranspiration from the profile, upwelling from below the zone of measurement, and deep percolation to soil below the zone of measurement. Data were collected starting on day of year 153 (June 1) to day of year 259 (September 15), the cotton growing season. Any subsurface lateral flow that might have added water to the zone of measurement was assumed equal to flow out of the zone. Because of discrepancies in the data, the lower three zones (28 to 40 in) were ignored unless otherwise specified.

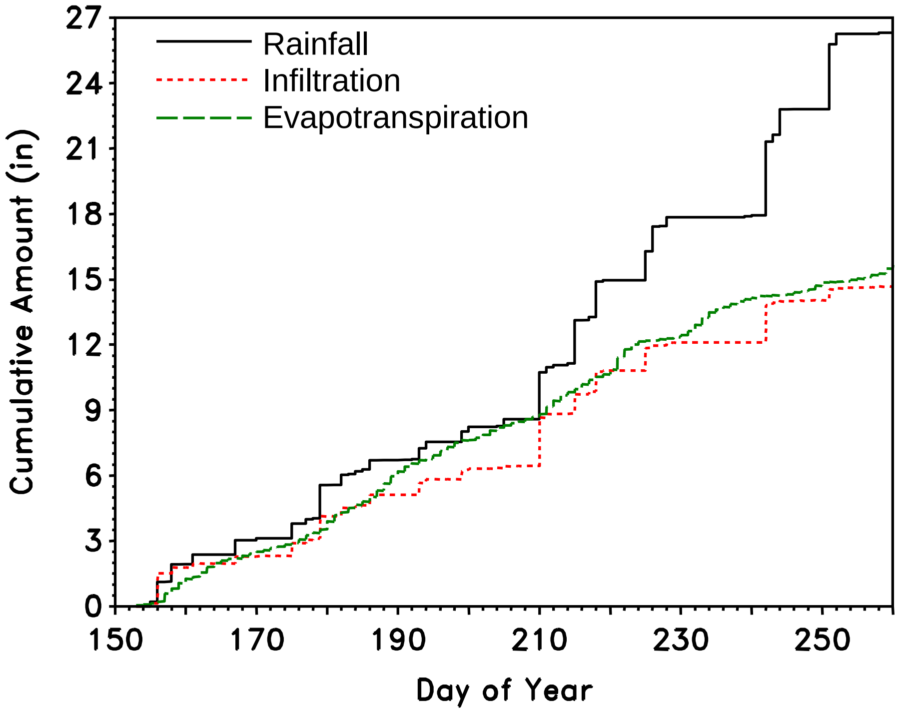

Figure 1. Cumulative amounts of rainfall, infiltration, and evapotranspiration for cotton calculated at plot #1.

Infiltration was calculated as an increase in soil water content during or near a rainfall event filling the soil at the surface and continuing down the profile. Deep percolation was calculated as loss of water out the bottom of the profile without changes in water content above. Upwelling was calculated as a gain of water in the bottom of the profile without losses in water content immediately above. Evapotranspiration was calculated as loss of water content from the profile that was not deep percolation. Data were fit to simple equations using Tablecurve 2D (Systat, Point Richmond, CA), EXCEL (Microsoft, Corp., Redmond, WA), and SAS (SAS 2000).

RESULTS AND DISCUSSION

Rainfall, infiltration, and evapotranspiration were calculated as cumulative amounts to smooth out any differences in time measurement between weather station and the soil sensor data collection (plot #1 of the 4 measured plots shown as an example in Figure 1). Infiltration throughout days 153 to 210 generally ranged between 75 to 85% of rainfall (plot #1 shown as an example in Figure 2) with spikes during storm peaks when water would have ponded on the soil surface. After day 210, the lower part of the profile was usually full of water as a result of tropical storms and tropical depressions passing through the area. Since the profile was relatively full, less water was able to infiltrate; more of it ran off the surface or evaporated. This lowered the cumulative (Figure 1) and average (Figure 2) amounts of infiltration from 75 to 85% down to 55 to 70% for all 4 plots.

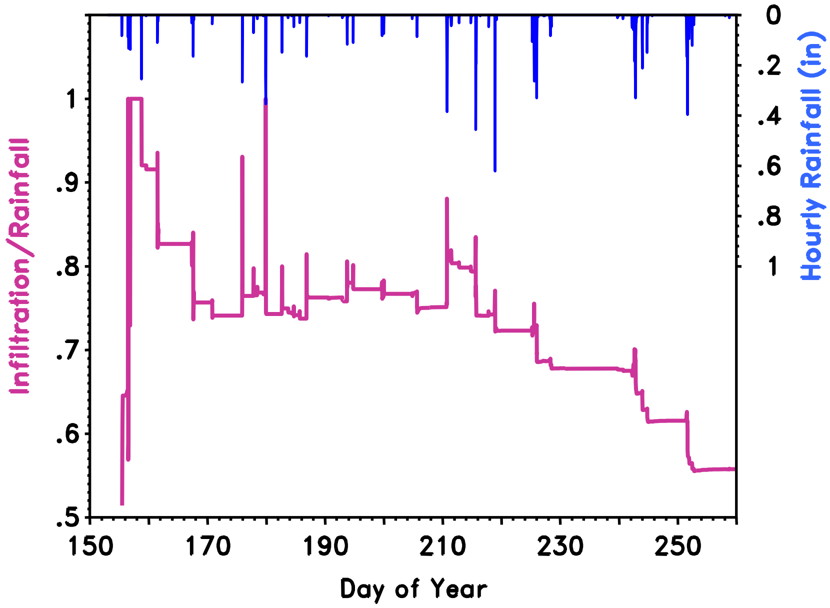

Figure 2. Ratio of infiltration to rainfall and hourly rainfall totals as a function of day of year from May 31 to September 16, 2004.

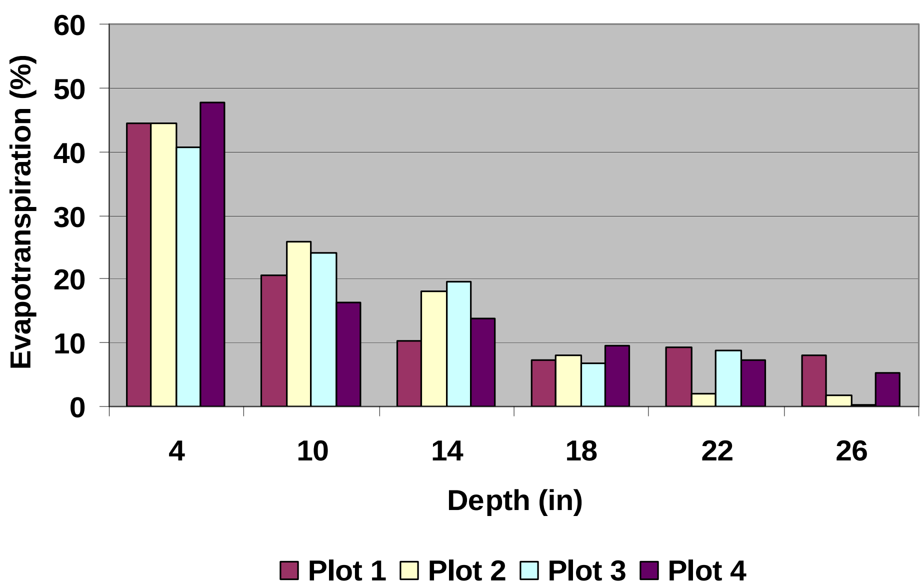

Figure 3. Changes in water content with depth used to calculate evapotranspiration.

Evapotranspiration from the soil was mainly (41 to 48%) from depths 0 to 8 inches (Figure 3); next highest was 16 to 26% from depths 9 to 12 inches; below that it diminished exponentially with depth. Season long upwelling from the wetter, lower part of the profile into the upper dryer part of the profile was calculated to be from 1 to 1.5 in and movement of water upward in the profile as a result of root activity (upwelling that appeared to bypass sections of the profile) was calculated to be less than .05 in.

CONCLUSIONS

Mid-season cumulative infiltration was 75 to 85% of the rainfall with rates topping 90% as a result of ponding during storms. Cumulative infiltration dropped to 60% after the lower part of the profile filled with water as a result of late-season tropical storms. Evapotranspiration was highest in the top foot which contributed 64 to 70% of plant root uptake; it decreased exponentially below that. Since the soil had been deep tilled to break up the hard genetic layer in the rows in these soils, we expected water to be taken from deep in the profile, below the zone of tillage; however, two-thirds of the water for plant growth came from the top foot where the soil had been subsoiled. This may have been a result of the wet weather during the growing season.

DISCLAIMER

Mention of trademark, proprietary product, or vendor does not constitute a guarantee or warranty of the product by the U.S. Dept. of Agriculture does not imply its approval to the exclusion of other products or vendors that may also be suitable.

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