Crop Growth and Soil Water Spatial Variability under a Variable Rate Center Pivot

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Abstract

Managing irrigation spatially can enhance water conservation and optimize water applications. Information and guidelines are needed on how to spatially precision-apply irrigation water with these systems. In this research, we investigated using soil electrical conductivity (EC) to delineate management zones for spatial water applications using variable rate irrigation systems. Our preliminary results indicated potential correlations between soil EC, spatial plant growth, and stomatal resistance.

Introduction

The reasoning for spatial water application is based on local site-specific problems that included spatial variability in topography, soil type, soil water availability, landscape features, cropping systems, and more recently for water conservation. Three examples of this include: 1) rocked outcrops in the Pacific Northwest, where water application to is discouraged because these areas are not suitable for crop production. 2) Rolling terrain, where water applications upslope can produce runoff resulting in dry soils upslope and ponded soils at nearby lower elevations under the same irrigation system. 3) Retrofit of existing pivots in Georgia and South Carolina under the USDA- Natural Resources Service Environmental Quality Incentives Program (EQIP) program using site-specific controls to enhance water conservation. These variable rate irrigation systems have recently been approved by as a best management practice for conserving water by the USDA-Natural Resources Service.

Although the technology for spatially applying water is available and has high grower interest, science-based information is needed on how to precision-apply water with these systems. Commonly, farmers with retrofitted systems are making educated guesses about spatial water application rates, based on past experience in their fields. Some researchers are working with growers to use soil electrical conductivity (EC) maps of fields together with historic yield maps to develop management zones (Lund, et al. 2001). Soil EC measurements in non-saline soils are driven primarily by soil texture and soil moisture. Those same factors correlate highly to the soil's water-holding capacity. Thus, an EC map can serve as a proxy for soil water-holding capacity, resulting in soil EC and yield maps that frequently exhibit similar spatial patterns. Sadler et al. (2005) identified critical needs for site-specific irrigation research that included decision support systems for spatial water application and improved real time monitoring of field conditions with feedback to irrigation systems.

To address these needs for determining an optimum method for prescribing spatial water application using variable rate irrigation systems, we initiated a study to evaluate soil based measurements (EC and soil water content) and their impact on plants. The objective of this paper was to evaluate the spatial plant response to water and soil properties on a highly variable coastal plain field.

Materials and Methods

In 2006, an experiment was initiated in a producer's field that has a center pivot retrofitted for site-specific irrigation. The field is approximately 40 ha in size, with half planted with corn and half planted with cotton. The farmer rotates these crops between sides annually. The grower's initial plan was to use the site-specific center pivot system to irrigate the corn and cotton separately, but not to vary water application rates within each crop. Soil electrical conductivity was measured with a Veris 3100 EC Soil Mapping System in April 2006. An EC map of the field is shown in Figure 1.

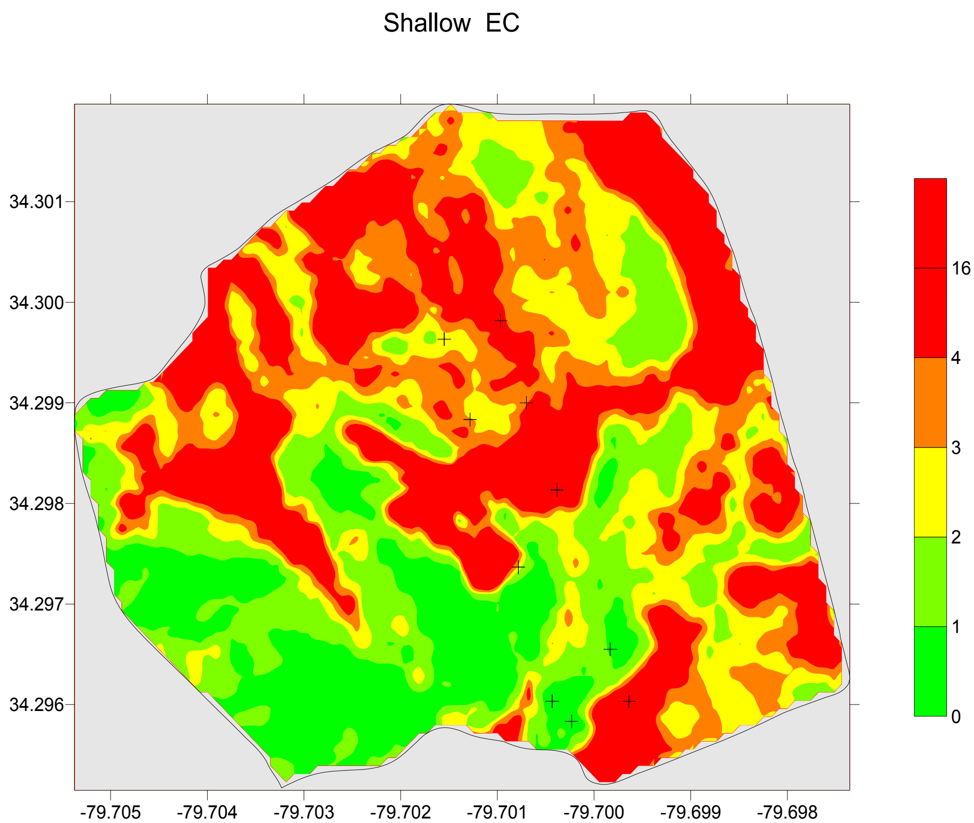

Figure 1. Soil EC map of the entire field. Crosses show approximate location of the 10 sampling points where data on cotton growth and water status were collected through the growing season.

To assess variability within this field and to provide guidance for spatially irrigating within the cotton crop, ten 0.1-ha areas on each side under the center pivot were monitored. Selection of sites was based on EC, slope, and surface soil texture. At each of these ten sites, an access tube was installed for a Delta-T PR2/6 Profile Capacitance Probe measuring water content at six depths (10, 20, 30, 40, 60, and 100 cm). Soil water content was determined regularly through the growing season.

Leaf stomatal resistance was monitored on the uppermost fully expanded leaf with a Decagon Leaf Porometer (Decagon Devices, Pullman, WA). Cotton plant height was measured on 10 plants at each site from June through mid-August.

At the end of the season, a two-row cotton picker with a yield monitor was used to collect yield data at six of the ten sites. Wet soil conditions at harvest prevented sampling for yield at four of the sampling sites.

Results

The rainfall plus irrigation for 2006 growing season had several periods of 5-10 days with little to no water application (Figure 2). These short periods without rainfall (5-10 days) are common through the growing season in the southeastern US. The rainfall from late June though July had 20-25 days with no rainfall or irrigation which allowed for the measurement of crop stress parameters.

During the period from June 29, 2006 to July 18, 2006 with no rainfall, leaf stomatal resistance was measured on three dates (6/29, 7/7, and 7/18). During this period, the stomatal resistance increased for the 10 sites as water stress intensified. The stomatal resistance increased faster at sites with low and with high soil EC than at sites with intermediate EC.

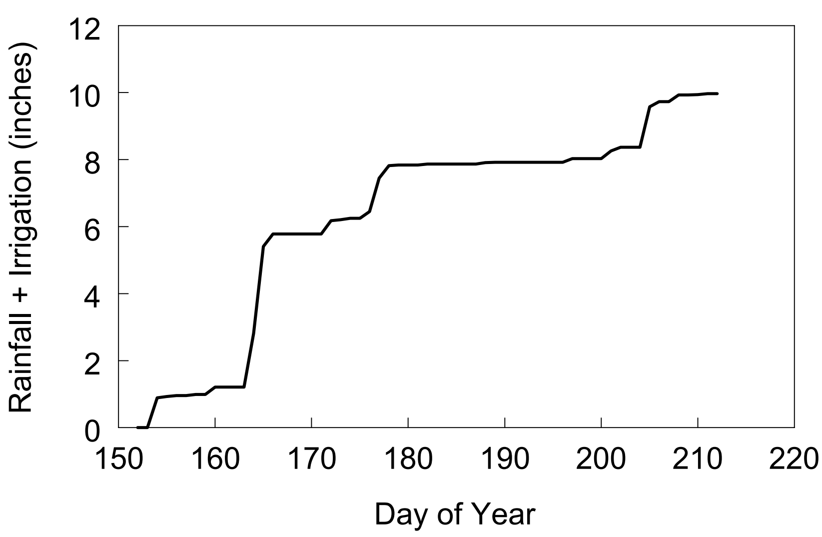

Figure 2. Cumulative irrigation and rainfall for the 2006 cotton crop.

Cotton plant height varied substantially among the different sites. Plants grown on high EC soils were larger early in the season. When stress occurred around day 190, height did not change much for the cotton on the lowest and the highest EC soils. Meanwhile, cotton on soils with intermediate EC levels continued to grow during this time. Yields for the six sites sampled ranged from about 1350 kg seed cotton per ha to 2450 kg seed cotton per ha.

Conclusions

These preliminary data suggest there is potential for using soil EC for spatial irrigation management on southeastern US coastal plain soils. Plant growth responses and stomatal responses to water deficit stress varied for the different soil EC levels. Initial spatial irrigation applications could potentially be delineated using soil EC. Additional studies are planned with more in-depth evaluations on additional study sites.

References

Lund. E.D., C.D. Christy, and P.E. Drummond. 2001. Using yield and soil electrical conductivity (EC) maps to derive crop production performance Informaiton. 8 pp. In P.C. Robert et al. (ed.) Precision agriculture [CD-ROM]. Proc. Int. Conf., 5th, Minneapolis, MN.

Sadler, E.J., R.G. Evans, K.C. Stone, and C.R. Camp. 2005. Opportunities for conservation with precision irrigation. J. Soil and Water Cons. 60:371-379.