Estimating crop evapotranspiration through integrated surface and satellite observations

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Abstract. *. Knowledge of crop water requirements is paramount to efficient irrigation scheduling and optimum water use efficiency. However, accurate monitoring of such parameters can be challenging. Satellite imagery provides very extensive spatial measurements but remains very expensive and still need to be validated with surface observations at numerous locations. . Therefore, the goal of this study was to conduct surface observations of crop evapotranspiration data (ET) and crop coefficients (K_c) in an effort to compare them with satellite imagery at a later stage. Surface observations were developed through lysimeter studies where ET data were collected daily and measurements of crop ground cover were performed weekly to derive relationships between crop coefficients and fractional cover. The crop coefficients were obtained for processing tomatoes grown under sub-surface drip irrigation. This paper presents the preliminary results obtained from the first year study. Data indicated that the crop coefficients obtained at peak season were relatively higher than those generally reported for tomatoes. Results also showed good correlation between fractional cover and crop coefficients (r2 = 0.91).*

Keywords. Crop coefficient, water requirement, irrigation scheduling, lysimeter.

Introduction

Estimation of crop water requirements is critical to efficient irrigation scheduling and optimal management of water resources. A common method of irrigation scheduling involves estimation of crop water use by multiplying a weather-based estimate of reference evapotranspiration (ET_o) with a crop coefficient (K_c) specific to a particular crop. Coefficients have been compiled for numerous crops and are available through sources such as FAO56 (Allen et al., 1998), University of California's Basic Irrigation Scheduler, and California State University's WATERIGHT system. These crop coefficients varied during a growing season and are often reported as only four values representing main stages of growth. Therefore, development of a crop coefficient curve can sometimes be difficult, and in some cases, such as for many horticultural crops, data are not available. In addition, adjustment for local conditions can be very challenging because of the variety of cultural practices, climate, soil type, irrigation method, and planting density observed for individual fields.

Accurate development of K_c values is expensive and difficult to develop and most research has focused on crops with large acreage (wheat, corn and cotton in particular). Yet, vegetable and fruit production is important in states like California, and knowledge of K_c is paramount to efficient irrigation and water conservation. Satellite remote sensing offers an efficient way to observe crop development and generate critical crop parameters over large areas with reasonable spatial and temporal resolution. However, current satellite-based approaches are still difficult to run in real-time and need to be validated against surface observations of crop development and evapotranspiration. The most accurate approach to generate surface observations of crop evapotranspiration is through lysimeter studies. Lysimeters are heavy soil tanks positioned on a scale capable of measuring very small changes in weight due to soil evaporation and plant transpiration. These measurements taken in field crops to generate ET_c and in fields planted with a reference grass to obtain ET_o are then used to derive crop coefficients.

Previous lysimeter research has demonstrated a good relationship between crop coefficients and surface measurements of fractional ground cover, F_c (Bryla et al., 2010; Ayars et al., 2003; Williams & Ayars, 2005; Allen & Pereira, 2009). These relationships can then be applied to satellite observations obtained over large areas; however, they have only been developed for a limited number of cropping systems. Therefore, the overall goal of this study was to continue building these relationships for additional crops and testing the hypothesis that relationships between F_c and K_c are consistent across different canopy architectures. Specifically, the objectives of the research presented in this paper were to: 1) conduct lysimeter studies to determine crop coefficients for processing tomatoes grown under sub-surface drip irrigation, 2) develop relationship between crop coefficients and ground cover, and 3) determine the water use efficiency of the cropping system.

Materials and Methods

The study was conducted at the University of California Westside Research & Extension Center (WSREC), in Five Points, CA during the 2011 and 2012 growing seasons. The Center has two large weighing lysimeter facilities, each containing a 15-tonne soil tank (2 m x 2m x 2.25 m) positioned on a scale system capable of measuring small weight changes of less than 0.01 kg. The lysimeters are located in the center of two adjacent 1.7-ha (4.2 acre) fields. One lysimeter is planted with grass to measure the reference ET (ET_o). The second lysimeter, referred to as crop lysimeter, is planted with a particular crop of interest to obtain its actual ET.

This reported study focused on the development of ET and crop coefficient curves for processing tomatoes grown under drip irrigation. The tomato crop was transplanted both in the crop lysimeter and in the surrounding field on 60-inch beds. The tomatoes were planted 12 inches apart along the beds and were irrigated with a sub-surface drip irrigation system installed at 12 inches. The cultural practices and fertilizer applications followed the WSREC schedule.

The lysimeter was replenished each time an equivalent of 0.08” of crop ET had been withdrawn from the soil tank. The surrounding field was irrigated based on the ET data obtained from the crop lysimeter. Irrigation was applied daily. The parameters measured during the growing season included: daily ET_c, K_c, and water application; weekly ground cover and crop height; as well as yield and water use efficiency at the end of the growing seasons. Ground cover was obtained from a Tetracam infra-red camera. Water use efficiency was calculated as the ratio of crop yield over water applied.

Results and Discussion

The results presented in this paper include the preliminary data obtained from our first-year field study. Figure 1 shows the crop coefficient values obtained during the 2011 growing season. Due to operating problems that occurred with the grass lysimeter, the daily Kc values were calculated by dividing the crop evapotranspiration measured by the crop lysimeter with the reference evapotranspiration obtained from the California Irrigation and Management Information System station located a few hundred feet from the tomato field. The data indicated that the K_c curve followed the regular bell-shape. However, it showed that the average K_c values were: 1) higher than those reported by Allen et al. (1998) or Hanson and May (2006) at mid-season representing flowering and early fruit development stages (50 to 80 days after transplant), and 2) lower at the vegetative, earlier flowering, and ripening stages of the growing season.

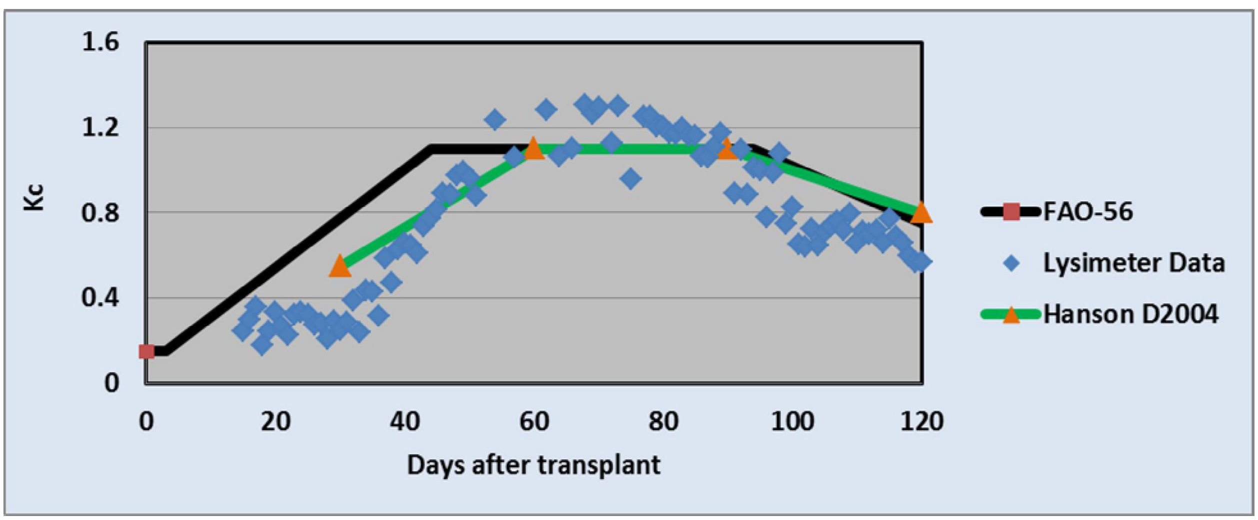

Figure 1. Crop coefficient curve developed during the 2011 growing season (preliminary data)

The relationship between fractional ground cover and crop coefficient is presented in Figure 2. Data showed a good correlation between the two parameters with a r^2 of 0.91. During most of the growing season, crop coefficient values increased with increasing fractional ground cover. At the end of the growing season, both parameters declined due to crop senescence. It was noteworthy that, for a period of about ten days, crop coefficient values started declining (80 days after transplant) while fractional ground cover still kept increasing until 90 days after transplant.

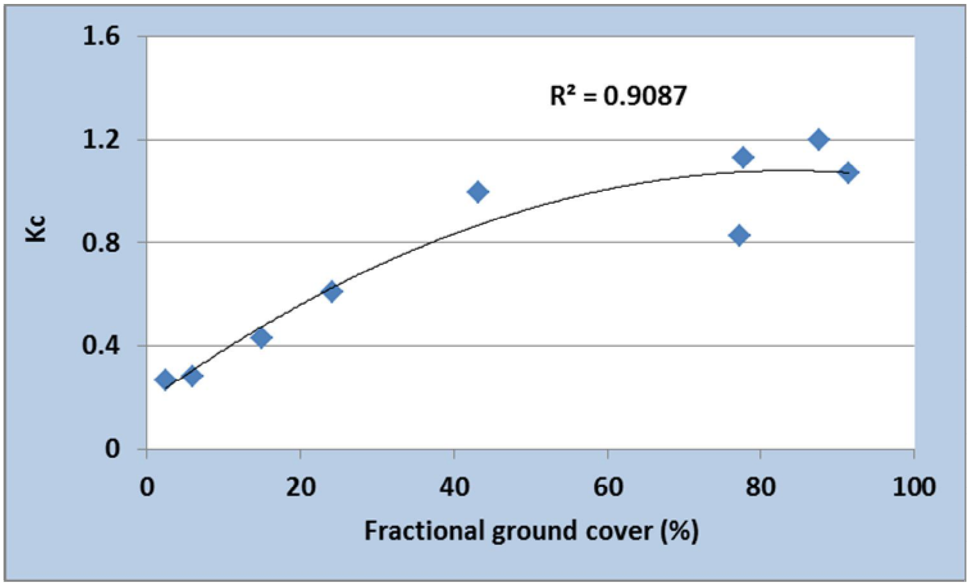

Figure 2. Crop coefficient as a function of fractional ground cover obtained during the 2011 growing season (preliminary data)

In this first season, tomato yield reached 39 tons per acre. Water use efficiency was 1.8 tons per acre per inch of water applied, which was consistent with data reported by Hanson and May (2006) for the region.

Conclusion

The preliminary findings summarized above represent those obtained from a first year field study conducted on processing tomatoes grown under subsurface drip irrigation. The goal of the overall research is to develop new crop coefficients or update crop coefficients for crops grown under different cultural practices than those reported in the literature. Ultimately, the aim is to develop relationships between fractional ground cover and crop coefficients for a variety of crop architecture and to compare these surface observations with satellite imagery that could then be used on a much larger scale.

The preliminary results of this first year field study showed that, compared to data reported in the literature, the crop coefficients for processing tomatoes grown under drip irrigation were lower at the vegetative, earlier flowering, and ripening stages of the growing season and greater at flowering and early fruit development. The data also showed a good relationship between fractional ground cover and crop coefficient. Additional lysimeter studies need to be conducted to confirm these results.

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