ESTIMATING DAILY AND SEASONAL CROP WATER USE OF HIGH PLAINS CROPPING SYSTEMS USING REMOTE SENSING AND CROP MODELING

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ABSTRACT

A procedure is described for estimating daily and seasonal crop water use (CWU) using a "spectral crop coefficient" determined from remote sensing data. This procedure is easy to evaluate from available weather and remote sensing data, and provides results that are specific to individual fields. The approach is demonstrated using data from 26 agricultural fields (mostly cotton and pasture) in the Texas High Plains.

INTRODUCTION

Conservation of water resources has become a critical issue in the Texas High Plains and other semi-arid and arid portions of the world. Strategies for conserving scarce water resources might involve the use of cropping systems that require less water while still providing an attractive economic return to producers. Critical to the comparison of different cropping systems is the ability to assess the amount of water actually used in growing a crop. This is commonly called the crop water use (*CWU*), and it is essentially equal to the transpiration of the crop. Knowing *CWU*, one can determine the water use efficiency (WUE) of the crop (in terms of the biomass produced per unit of water transpired), along with the efficiency of applied irrigation (in terms of *CWU* per unit of irrigation applied to the crop).

Many procedures have been suggested for estimating *CWU*. A common, relatively simple approach to estimating daily *CWU* involves multiplying a crop coefficient K_c by the daily value of potential evapotranspiration ET_0 for a well-watered vegetated surface (Allen, 2003),

$$CWU = K_c \times ET_0 \qquad \text{[Eq. 1]}$$

Here, ET_0 is calculated from ambient weather conditions, and K_c is determined empirically for a specific crop. The value of the crop coefficient normally varies over the duration of the growing season, increasing from a value near zero early in the season to a value near 1 in mid-season.

Maas et al. (2004, 2005) extended this concept by evaluating the crop coefficient from remote sensing observations. Equation 1 may be re-written,

$$CWU = K_{sc} \times ET_0 \qquad \text{[Eq. 2]}$$

where K_{sc} represents a "spectral crop coefficient" numerically equivalent to crop ground cover (GC). GC can be easily estimated from remote sensing observations, and its use in place of the standard empirically determined K_c allows the estimation of *CWU* to be specific for each field application. Using data obtained from a dryland cotton field near Littlefield, TX, Maas et al. (2005) showed that this approach was capable of reasonably estimating *CWU* at various times during the growing season.

Crop GC can be easily estimated using satellite remote sensing observations in the red and near-infrared spectral bands. Since satellite observations occur infrequently due to the overpass schedule of the satellite and the availability of cloud-free sky conditions, a method is needed to estimate *CWU* for the days without remote sensing observations. The approach used in this study relies on a crop growth simulation model (Maas, 1993a, 1993b; Ko et al., 2005) to estimate crop GC on each day of the growing season, allowing calculation of daily *CWU* using Equation 2. Daily values of *CWU* can then be summed over the course of the growing season to produce seasonal estimates of *CWU*. In this article, we present preliminary results obtained for a number of cropping systems that demonstrate the efficacy of this approach.

MATERIALS AND METHODS

Results of the spectral crop coefficient approach were obtained for 26 agricultural fields in the Texas High Plains during the 2005 growing season. Landsat-5 images containing the study region were analyzed to determine ground cover (GC) in each study field. Five Landsat images (Table 1) were used for this analysis.

Table 1. Landsat-5 overpass dates.

10 May 2005
13 July 2005
30 August 2005
1 October 2005
17 October 2005

Daily weather data used in running the model simulations for each field were obtained from the West Texas Mesonet. These data were also used in calculating daily potential evapotranspiration (ET_0) for each day of the growing season for use in Equation 2.

RESULTS AND DISCUSSION

An example of simulated crop GC and daily *CWU* is presented in Figures 1 and 2, respectively, for an irrigated cotton field in the study. In Figure 1, the daily values of GC simulated by the model provide a continuous description of ground cover for the crop over the growing season, and may be compared to the five observed GC values derived from Landsat observations. The shape and magnitude of the GC curve affects the distribution of daily *CWU* values in Figure 2, which exhibits a peak in *CWU* values during the period of maximum ground cover.

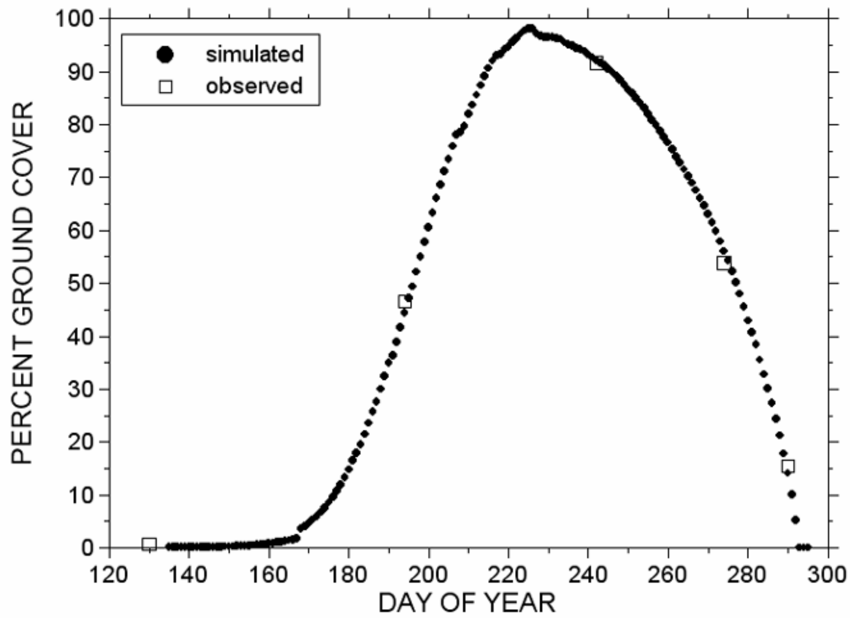

Figure 1. Simulated and observed values of crop ground cover for an irrigated cotton field in the study.

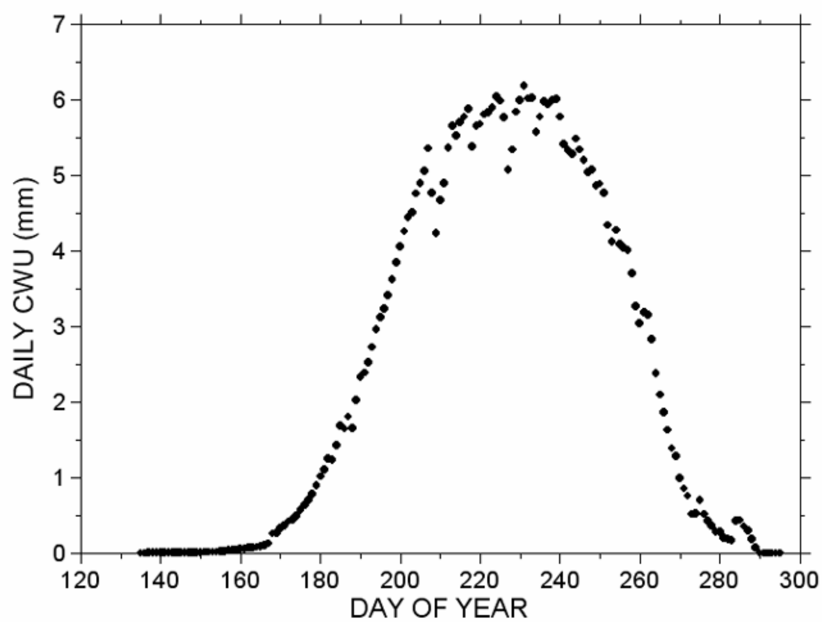

Figure 2. Estimated daily crop water use for the field in Figure 1 computed using Equation 2.

Table 2. Accumulated daily *CWU* over the period from day 121 through day 295 for various fields in the study.

Crop	*CWU* (mm)	*CWU* (in)
irrigated cotton	408	16.1
irrigated cotton	389	15.3
irrigated cotton	421	16.6
irrigated cotton	267	10.5
irrigated alfalfa	819	32.2
irrigated cotton	303	11.9
irrigated cotton	391	15.4
irrigated pasture	293	11.6
irrigated pasture	289	11.4
irrigated pasture	281	11.1
irrigated pasture	282	11.1
irrigated pasture	345	13.6
irrigated pasture	413	16.3
irrigated cotton	345	13.6
irrigated pasture	173	6.8
irrigated cotton	290	11.4
irrigated pasture	209	8.2
irrigated cotton	381	15.0
irrigated pasture	265	10.4
irrigated pasture	345	13.6
irrigated cotton	242	9.5
irrigated cotton	260	10.2
irrigated cotton	224	8.8
dryland cotton	138	5.4
dryland cotton	173	6.8
irrigated cotton	259	10.2
irrigated cotton	340	13.4
irrigated cotton	279	11.0
irrigated cotton	312	12.3
irrigated pasture	465	18.3
irrigated cotton	441	17.4
irrigated cotton	345	13.6
irrigated cotton	358	14.1
irrigated cotton	358	14.1
irrigated cotton	280	11.0
irrigated cotton	280	11.0
irrigated cotton	402	15.8
irrigated cotton	322	12.7
irrigated cotton	386	15.2
irrigated cotton	378	14.9

Table 2 shows estimates of seasonal *CWU* for various fields in the study. Total potential evapotranspiration (ET_0) for the growing season was 1033 mm (40.7 in). Seasonal *CWU* for irrigated crops and pastures was considerably more than corresponding values for dryland crops. The greatest seasonal *CWU* (819 mm, or 32.2 in) was estimated for irrigated alfalfa, with a value approaching 80% of the potential value.

CONCLUSIONS

The spectral crop coefficient approach was able to show differences in daily and accumulated *CWU* among the fields in this study. Differences appeared to be related to vegetation type and irrigation. These preliminary results on *CWU* were obtained during a year with above-average rainfall during the first half of the growing season. Results may be different in years with different precipitation characteristics.

REFERENCES

Allen, R. G. 2003. Crop Coefficients. In: Stewart, B. A., and T. A Howell (Eds.), *Encyclopedia of Water Science*. Marcel Dekker Publishers, New York. p. 87-90.

Ko, J., S. J. Maas, R. J. Lascano, and D. Wanjura. 2005. Modification of the GRAMI model for cotton. *Agron. J.* 97:1374-1379.

Maas, S. J. 1993a. Parameterized model of gramineous crop growth: I. Leaf area and dry mass simulation. *Agron. J.* 85:348-353.

Maas, S. J. 1993b. Parameterized model of gramineous crop growth: II. Within-season simulation calibration. *Agron. J.* 85:354-358.

Maas, S., R. Lascano, D. Cooke, C. Richardson, D. Upchurch, D. Wanjura, D. Krieg, S. Mengel, J. Ko, W. Payne, C. Rush, J. Brightbill, K. Bronson, W. Guo, and S. Rajapakse. 2004. Within-season estimation of evapotrasnspiration and soil moisture in the High Plains using YieldTracker. Proc., 2004 High Plains Groundwater Resources Conference. Lubbock, TX. p. 219-226.

Maas, S., N. Rajan, J. Duesterhaus, R. Lascano, and J. Ko. 2005. Remote sensing approach for estimating daily crop water use. Proc., 20th Biennial Workshop on Aerial Photography, Videography, and High Resolution Digital Imagery for Resource Assessment. ASPRS, Weslaco, TX. (CD-ROM)