Determining Local Crop Coefficients for Efficient Irrigation Scheduling in Montana

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INTRODUCTION

There are over 2 million acres of irrigated land in the state of Montana (anonymous, 2009). Approximately 64% are gravity fed with water diverted from rivers such as the Sun, Yellowstone, Milk, Missouri, Jefferson, and Flathead, all of which are tributaries to either the Missouri or Columbia drainage systems. Conservation and protection of these water networks are of regional, state, and national concern. Additionally in the Flathead for example, there are water right concerns due to existing or developing water compacts between water users and the tribal community which could begin to restrict water availability. Strategic use of water that provides irrigators the highest economic gain is a research priority. Sustainable agricultural production within the lands managed under irrigation begins with efficient water management. In order to properly manage water resources, critical information such as crop water use is needed. The world-wide standard for irrigation scheduling uses the ASCE Standardized reference evapotranspiration equation (Allen et al., 2005). This equation was developed in concert with ARS scientists at Kimberly, ID during the 1990's and was adopted by the Food and Agriculture Organization in 1998 as a guideline to determine crop water requirements (Allen et al., 1998). The ASCE standard provides an approximation of crop water use that is ***rarely tested against measurements*** despite the widespread application of this approach.

Evapotranspiration (ET) is largely driven by ambient air temperature, atmospheric vapor pressure deficit, and wind speed. Regional weather stations routinely measure these parameters and the data are freely available for use. For irrigation scheduling, additional processing of this data is necessary; reference ET (ETo) must be calculated. Locally applicable crop coefficients (Kc) can then be used to convert the ETo into actual crop water use. Currently the Kc values used in Montana have been estimated using the documentation for the ASCE models, but have not been tested, which leads to inaccuracies. Independent regional verification is needed.

The eddy covariance method of measuring evapotranspiration (latent heat flux) from a surface can be used to derive crop coefficient values and improve ASCE approximations by dividing the daily ETo from a nearby weather station with the daily latent heat flux (Suyker and Verma, 2009; Harris and Stoy, 2015).

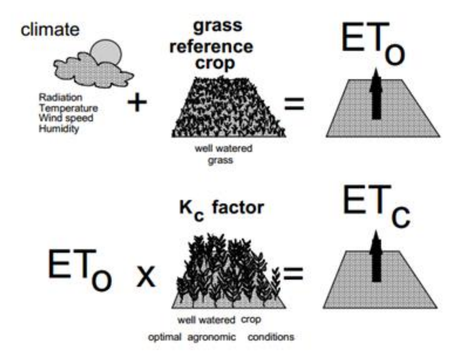

Figure 1. Illustration of determining crop ETc using reference ET (Allen et al., 1988)

OBJECTIVES

1) Measure crop water use of malt barley (near Huntley, MT) and spring wheat (near Kalispell, MT) in non-stressed irrigated environments in proximity to local weather stations.

1) Data collected will be used to develop water use Kc for local use.

1) Determine the relationship between growing degree days (GDD), heat units, and the duration from date of planting to physiological maturity and harvest, canopy ground coverage to estimate the time needed to reach the cardinal points of the Kc curve.

MATERIALS AND METHODS

Eddy covariance systems with CSAT-3 triaxial sonic anemometer and LI-7200 closed path infrared gas analyzer were mounted at 2-m and placed in a flood irrigated malt barley (Southcentral MT) and center-pivot irrigated spring wheat fields (Northwest, MT). The fetch were 150 and 250 m in Huntley and Kalispell, respectively.

Three dimensional wind speed, carbon dioxide concentration, and water vapor concentration were measured at 20 Hz. Half hour wind speed, sensible heat flux (thermals), water vapor flux (evapotranspiration) were analyzed using EdiRe freeware.

Crop growth scores, ground cover, biomass, and yield data were gathered. Average ground canopy coverage of the fields will be estimated using an available satellite data from the U.S. Geological Survey.

Data is only being presented for the work at Huntley, MT

- The study site was a 5.6 ha flood irrigated field of malt barley
- Soil type: Ft. Collins clay loam
- Conventional inversion tillage, leveling in fall
- Fertilized with 100-40-30 and incorporated fall 2014
- Barley was planted on Mar 23, at 47 kg ha^{-1} on 15 cm rows
- Variety: Moravian 115,
- Irrigation flood events: May 27-28, June 17-18
- Harvest July 20, average yield 5.3 Mg ha^{-1}
- Biomass accumulation, height, and growth staging were measured at four (points) locations approximately 50-m distal from the tower

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RESULTS

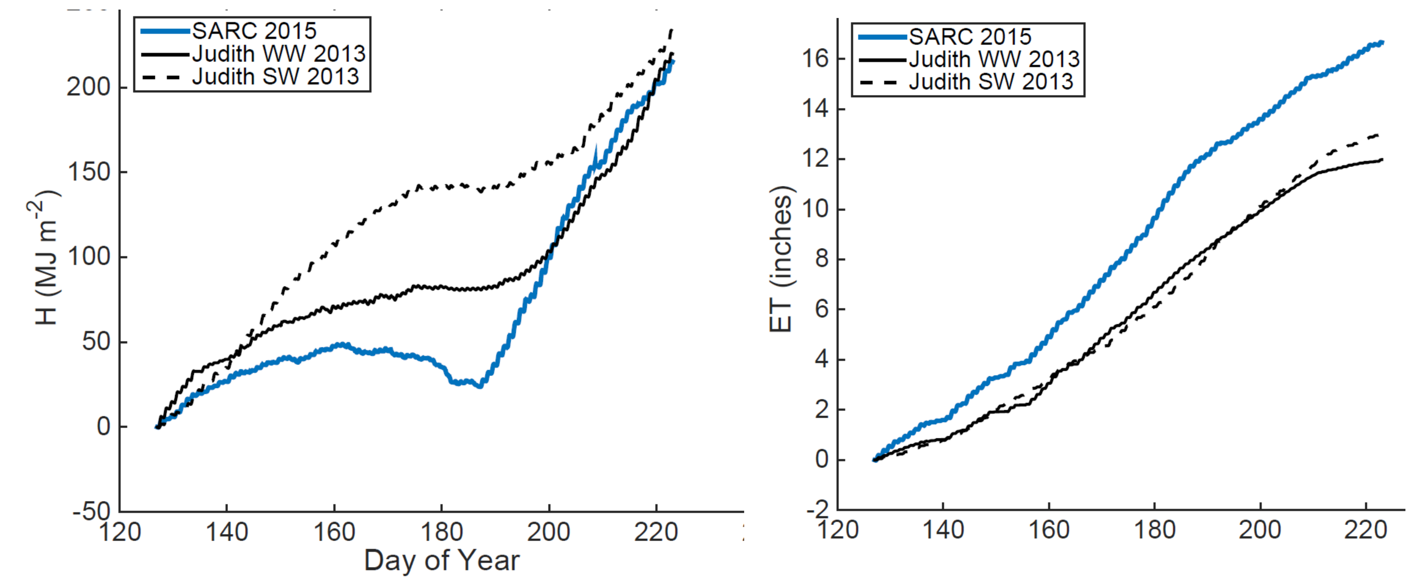

Figure 2. Initial estimate of energy flux from the barley crop using the eddy covariance tower (left), and reference ETo from the electronic weather station at SARC (right). The Judith locations were dryland wheat crops and are included for comparison.

Photo: Eddy Covariance Tower in an irrigated barley, Huntley (Southcentral MT)

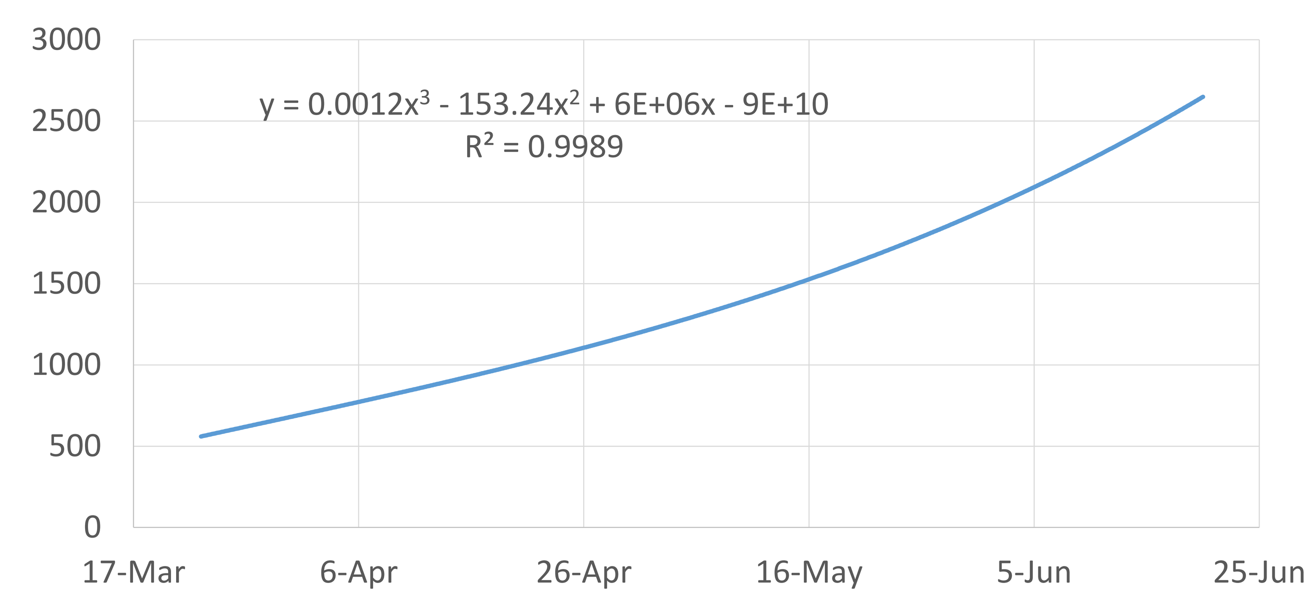

Figure 3. Growing degree day (base 32) accumulation during the growing season, Huntley.

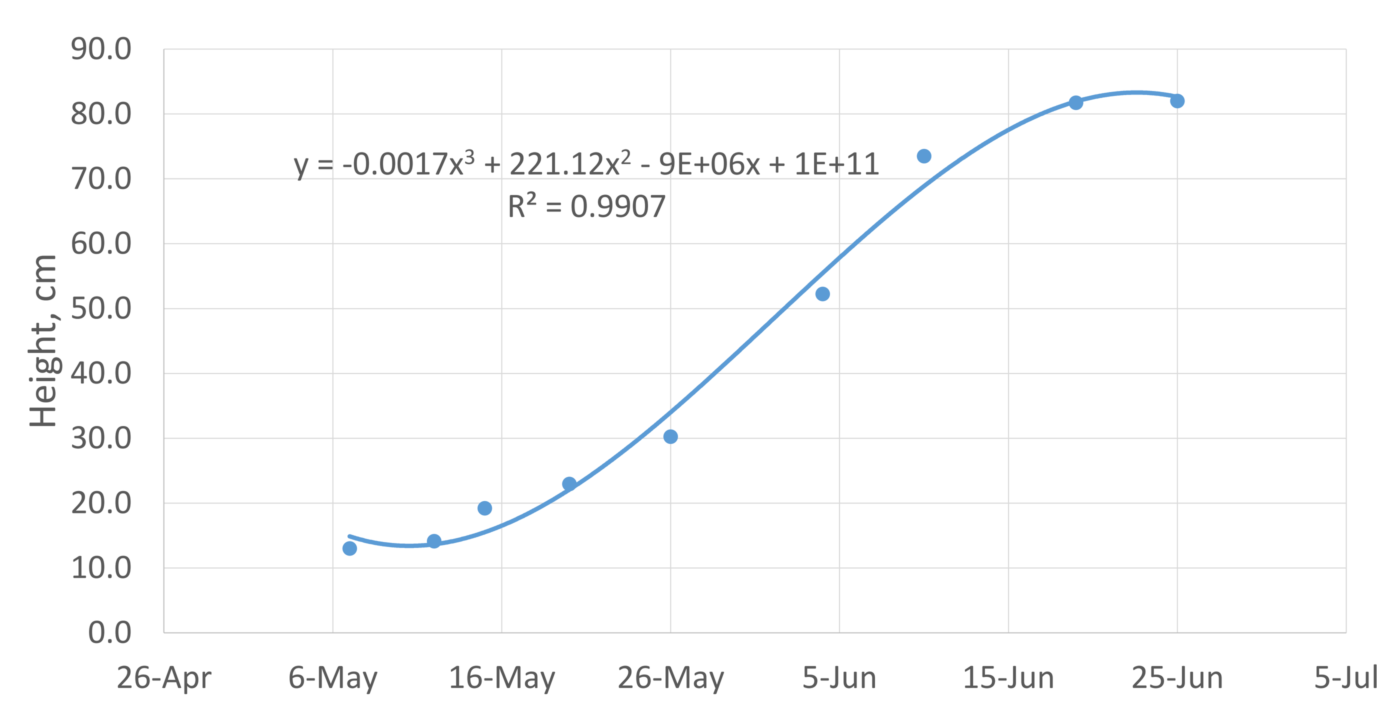

Figure 4. Average canopy height as measured at four reference (points) locations near the flux tower, Huntley.

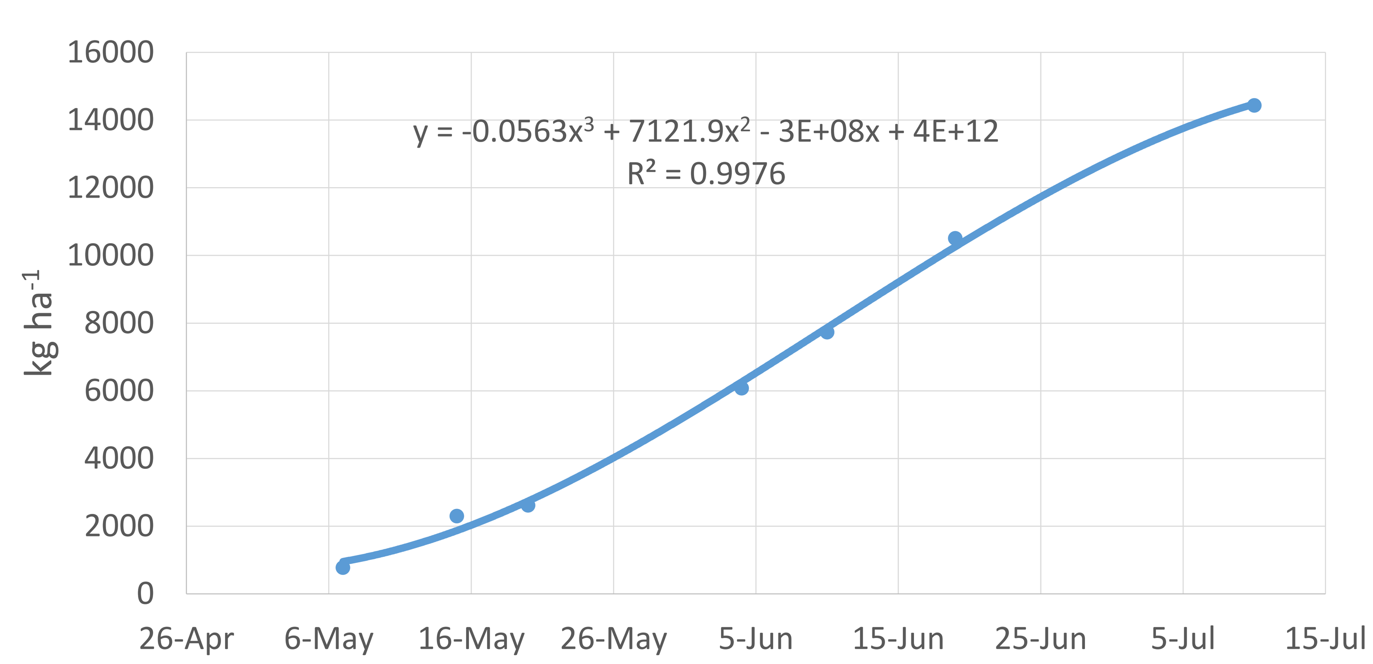

Figure 5. Above ground biomass accumulation from barley sampled at the four reference locations, Huntley.

Table 1. Growth stage observations through the season

Date	Observation	Feekes Stage
7-May	Tillering/ 4 leaf	1
12-May	5 leaf	2
15-May	6 leaf	4
20-May	6 leaf	5
26-May	7 leaf	6
4-Jun	Early boot	8
10-Jun	Heading	10.0
19-Jun	Seed set	10.5
25-Jun	Soft dough	11.2
10-Jul	Hard dough	11.4

Summary

- We are just at the beginning of evaluation of data for this study and all results should be considered tentative and subject to change as we clean up data sets. With that said, results from this location for the first year look very promising. The data from the second location near Kalispell also looks solid. That location is under a pivot, which complicates the analysis so we are not ready to present it here.

- At Huntley sensible heat flux declined beginning around DOY 160 (H, Fig. 2) which coincided with heading stage. At this stage, the crop had full canopy cover following an irrigation event. Crop transpiration which has surface cooling effect (negative flux) is inferred and remained very high until day 190 (which coincided with hard dough stage). In cereals, crop water use demand at this stage was reduced such that irrigation provided no yield response from this stage onwards (Torrion, unpublished). Moreover at this stage, leaf senescence had started. Therefore, the significant reduction of transpiration cooling effect coincides with a rising H. The majority of water loss from DOY 188 onwards was attributed to soil evaporation.

- The next step in analysis is to calculate Kc by dividing ET_c by Et_o and then use the ancillary data to predict Kc. If we are successful, we will be able to build an applicable Kc for each season based on inputs from a specific field and associated weather station.

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