Determination of Evapotranspiration (ET) for Desert Durum Wheat using Weighing Lysimeters in the Lower Colorado River Region

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Introduction

Over 7.2 million acre feet (9 billion m^3) of Colorado River water are diverted in California and Arizona. Approximately 4.2 million acre feet (5 billion m^3) are diverted at the Imperial Diversion Dam near Yuma to largely irrigate crops in the lower Colorado River region of southern California and Arizona. This region includes the Coachella and Imperial Valleys of southern California, the lower Colorado River food plain of southern California and Arizona, and a segment of the Gila River flood plain in Arizona. Disputes over water between nations, states, municipalities, and agriculture and urban interests are commonplace. Agriculture interests, including those in the lower Colorado River region, are being challenged to use water more efficiently.

The Lower Colorado River Region of Arizona, California and their environs represent more than 750,000 acres of irrigated cropland producing multiple crops each year. This region is commonly used for the production of high value horticultural crops, forages, and Durum wheat.

Efficient irrigation depends on knowledge of when to irrigate, how much water to apply (water depth), and how to operate the irrigation system to apply the required water depth efficiently. The first two questions pertain to irrigation scheduling while the third question pertains to system design and management. While irrigation management has been an issue, we have developed information aimed at efficient irrigation management for surface systems over the past decade with funding from the United States Bureau of Reclamation (Sanchez et al., 2008; Zerihun et al., 2001; 2005).

Irrigations are applied to replace water depleted from the plant root zone and leach salts that may have accumulated. However, not all water held by the soil is plant available. Both total soil water and total available soil water (TAW) are influenced by soil physical properties such as texture and structure. Standard soil moisture determination techniques can be used to determine the moisture content at field capacity (approximately 0.1 bar tension) and at wilting coefficient (approximately 15 bar tension) and the difference yields TAW. However, only a portion of the TAW can be extracted by a plant without a reduction in growth or production. The "Management Allowable Depletion" (MAD) is an index that represents this fraction of the total available water that a plant can extract from its root-zone without experiencing unacceptable levels of growth and yield reduction and this is usually determined experimentally for individual plant species. Also important is the effective crop root depth (D*r*) which depends on plant type, stage of growth, presence or absence of shallow water table and limiting soil horizons (such as hard pans). For maximum growth or production, the longest irrigation time interval is usually limited by the time period over which the allowable depletion amount (depth or volume) occurs. This amount depends on the total soil available water (TAW), the management allowable depletion (MAD) and the effective crop rooting depth (D*r*) (i.e. IR=TAWxMADxD*r*). Generally, wheat should be irrigated at 50% TAW.

The depletion of soil moisture can be measured directly by soil sensing devices or estimated from weather based ET measurements. Where ETc is calculated from ETo and crop coefficients (Kc), and ETo is calculated using weather based equations (eg. Penman Monteith or others). However, limited information exists to accurately estimate ET and appropriate crop coefficients for calculating ET from weather based ETo estimates for irrigation scheduling are lacking. The objective of this project was to use weighing lysimeters we recently constructed and installed to monitor evapotranspiration of Desert Durum wheat produced in the region. From these data we will calculate crop coefficients to be used in irrigation scheduling.

Materials and Methods

Four lysimeters were constructed using methodology described by others (Allen and Fisher, 1990). The lysimeters are 1.2 by 1.2 m in surface dimension and 1.2 meters deep. These lysimeters contain an inner metal box filled with soil attached to an outer metal box with load cells. These load cells are calibrated to record weight change (irrigation and evapotranspiration) with a data logger. These lysimeters have a drainage plumbing tree near the bottom and a port to access and extract drain water after each irrigation and leaching event. Soil horizons largely varying by soil texture were separated during excavation for installation, and these same horizons were layered within the lysimeters. These lysimeters were constructed and installed in the summer of 2007. The lysimeters were surrounded by a larger field area that was cropped identically to Durum wheat as that produced inside the lysimeters. Reference evapotranspiration (ETo) data collected from AZMET weather stations on site was used to calculate crop coefficients.

Durum wheat (cv. Havasu) was seeded and irrigated up Feb. 3, 2009. While the surrounding plot area was irrigated by basin, the lysimeters were irrigated by applying known volumes of water to each lysimeter. The lysimeter drains were pumped following each irrigation event and drainage volumes were recorded. The wheat was harvested June 1, 2009.

Results and Discussion

The lysimeter calibrations before seeding are shown in Figures 1 through 4. With the exception of lysimeter #2, the calibrations were excellent. Lysimeter #2 remained a problem throughout the season, limiting our ET estimations to those associated with the other lysimeters. We recently recalibrated lysimeter #2 and it looks much better so we anticipate we will collect meaningful data with this lysimeter during 2010.

The wheat stand in the area immediately surrounding the lysimeters in 2009 was disappointing and would likely result in exaggerated ET from the wheat within the lysimeters. We assume the poor stand was associated with difficulties of land preparation and the establishment of a suitable seedbed in the area adjacent to lysimeters. We have subsequently implemented methods to till this area with smaller equipment.

The estimated ET over the growing season is shown in Figure 5. Note that ET is always higher immediately after irrigation because the soil surface is wet but declines with time to a basal ETc until the next irrigation event. Total water use during the growing period was 42.7 cm (16.8 inches).   This is lower than the 65.5 cm (25.8 inches) reported by Erie (1982) for wheat in central Arizona planted in November. The lower water use may reflect the shorter growing season of wheat seeded following produce in southwestern Arizona.

To approximate a generalized crop coefficient (Kc) curve for spring seeded durum wheat we used an average between potential ET after irrigation and basal ETc (Figure 6).   This curve assumes an irrigation frequency similar to what we employed. The high Kc at the beginning reflects the irrigation required to initiate the crop. The ET of the young plants is lower. The Kc appears to approach a maximum value of 1.2 near maturity and declines as the wheat dries down.

The study was repeated in 2010. Unfortunately, the height differences of the lysimeters this season became problematic. The ground level within the lysimeters was a little higher than the surrounding field and was water 5 days earlier. Thus, the wheat within the lysimeters was taller than the surrounding field and ET was higher. The two figures that are specific to Lysimeter 4 show the water balance issue (Figure 7 and 8) including water stress and exceptionally high ET resulting from height differences between the field and the lysimeters. From the water balance it is demonstrated that we were clearly under watering within the lysimeters with water stress development at about peak ET or when approximately 100 mm of water had been extracted from the lysimeter soil.

Due to the disappointing results in 2010 from the lysimeter height issue, these studies will be repeated in 2011 at no cost to the sponsor. During 2011 we will seek to verify the Kc curve generated in 2009.

Literature Cited

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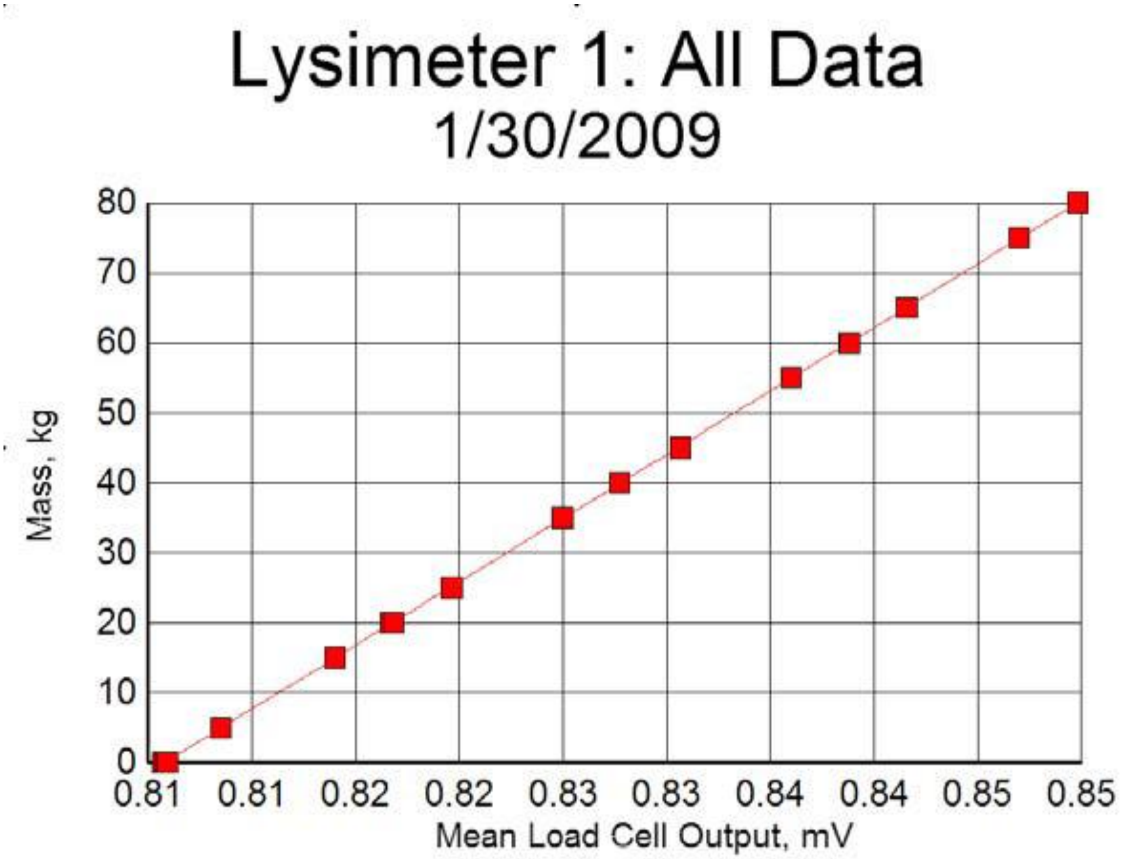

Figure 1. Calibration line of load cell output (mV) and mass (kg) for lysimeter #1.

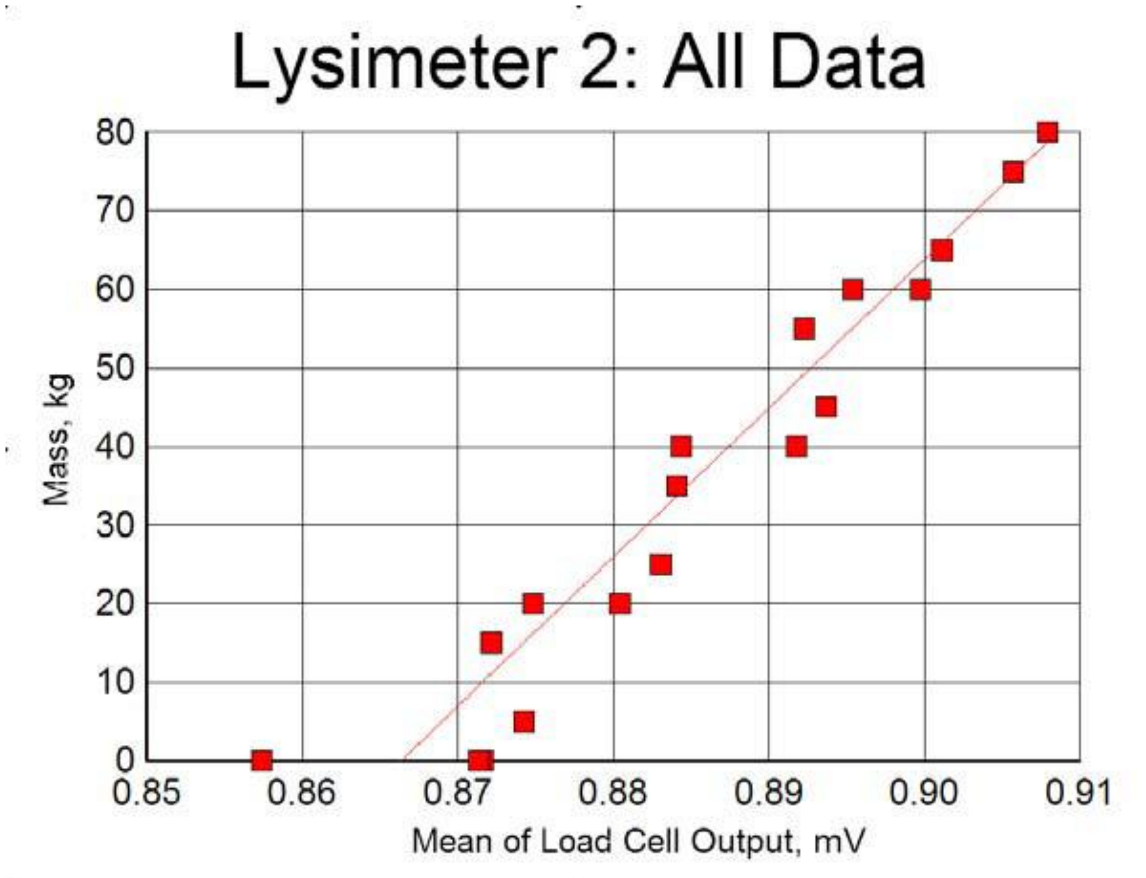

Figure 2. Calibration line of load cell output (mV) and mass (kg) for lysimeter #2.

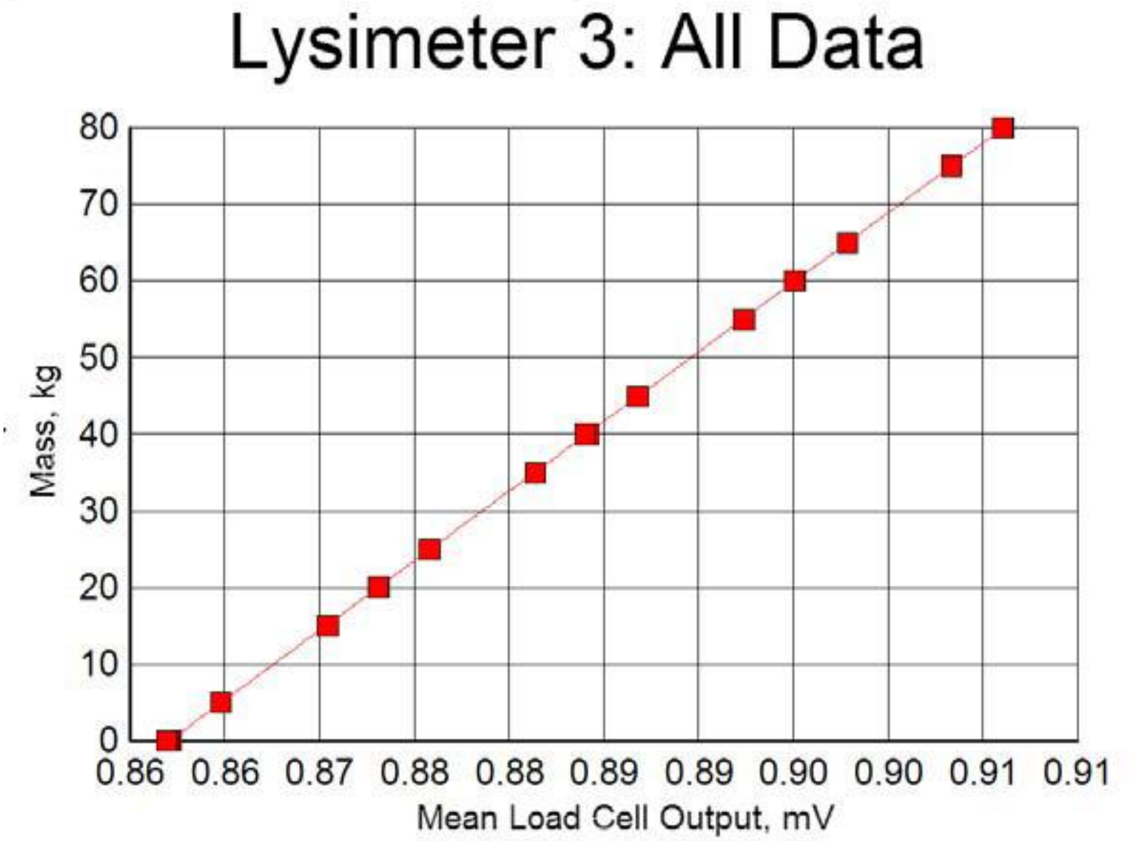

Figure 3. Calibration line of load cell output (mV) and mass (kg) for lysimeter #3.

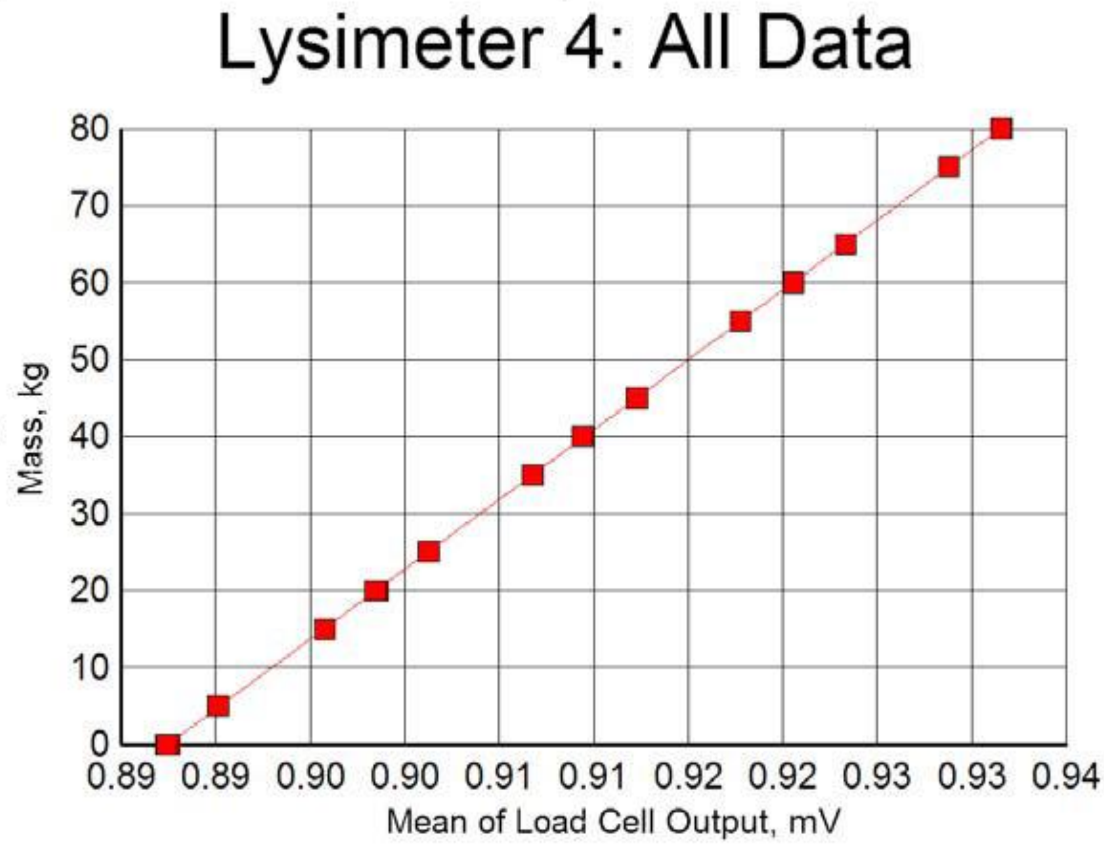

Figure 4. Calibration line of load cell output (mV) and mass (kg) for lysimeter #4.

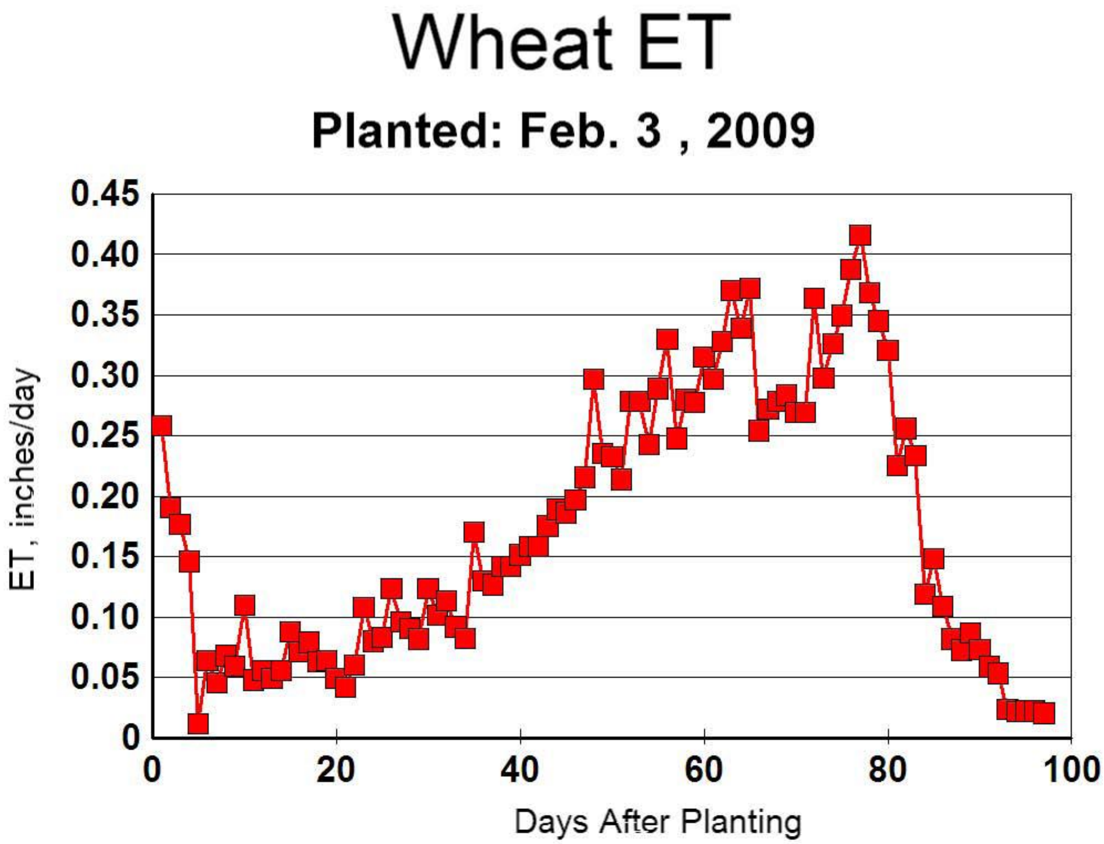

Figure 5. Estimated ET during growing season in 2009.

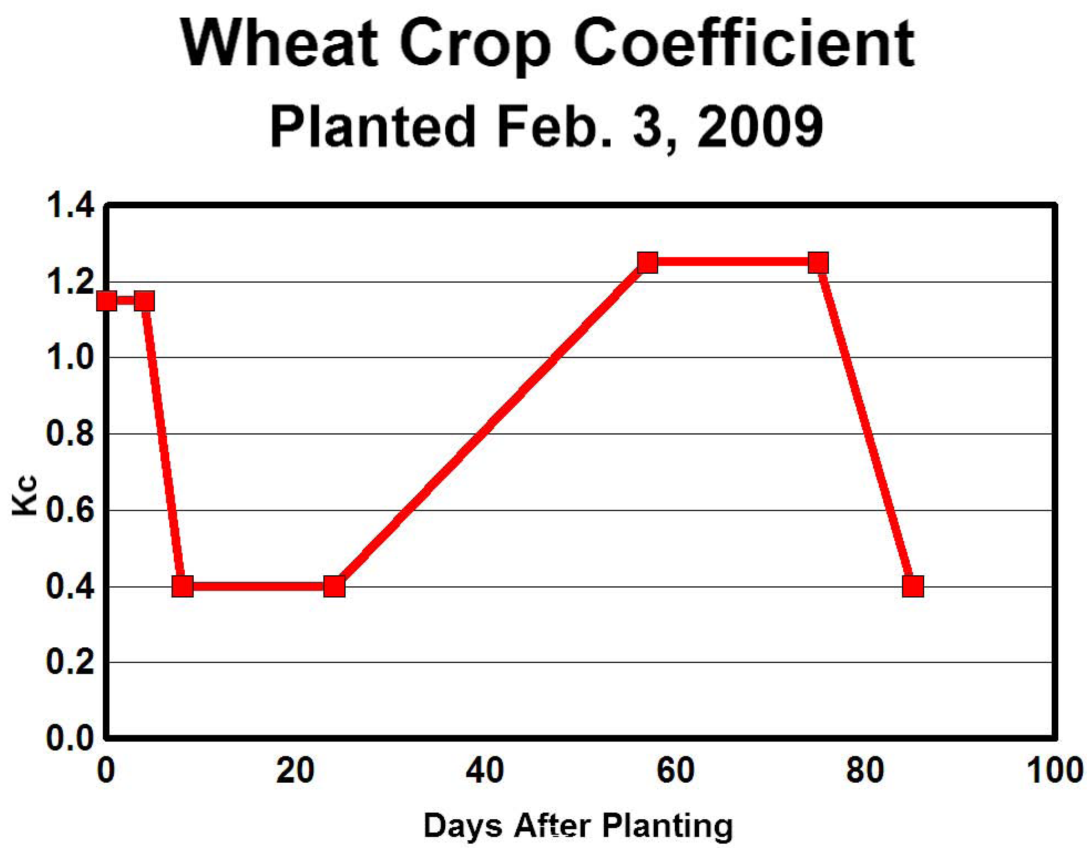

Figure 6. Calculated crop coefficients during 2009.

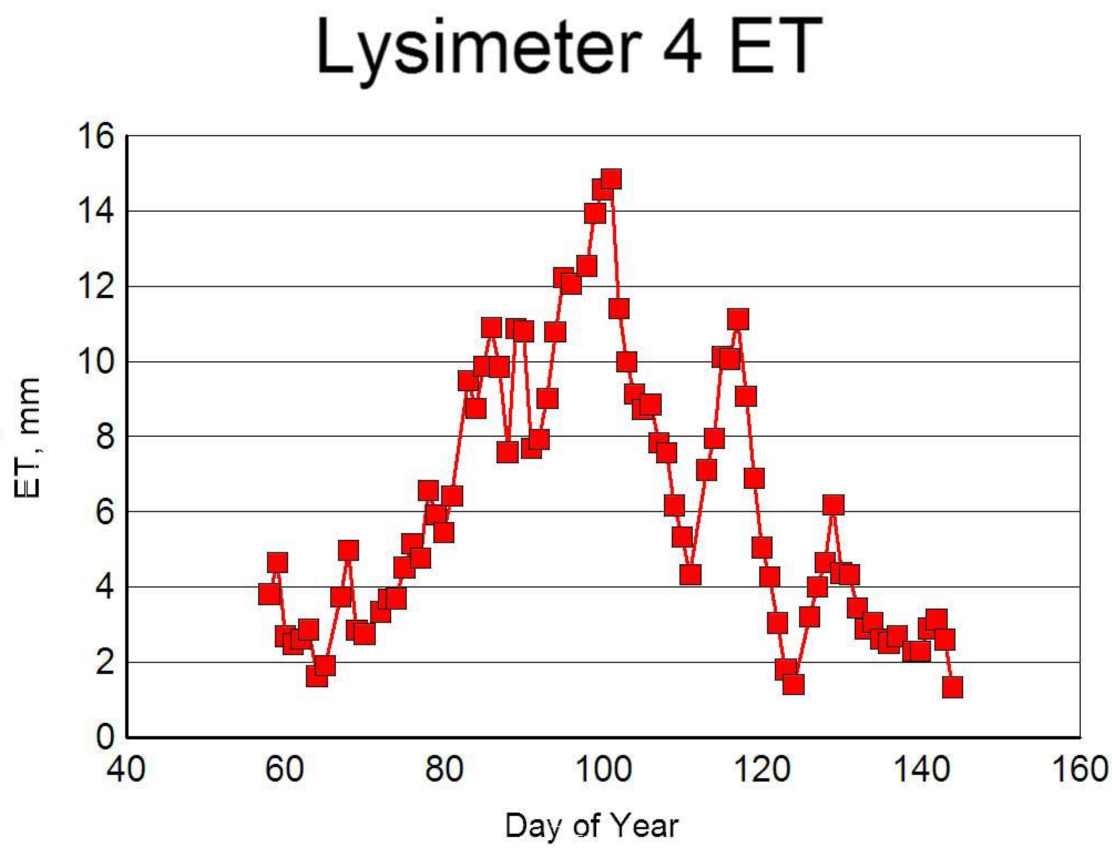

Figure 7. Estimated daily ET from lysimeter 4 in 2010.

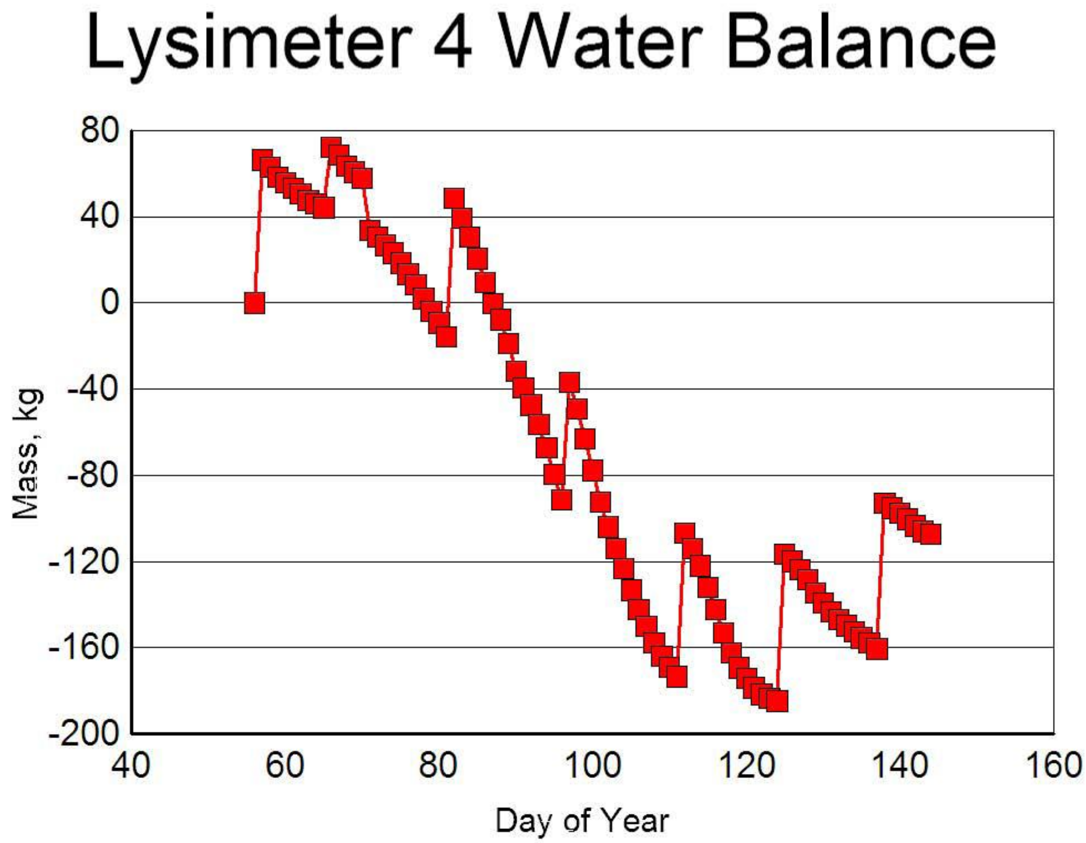

Figure 8. Calculated water balance in lysimeter 4 in 2010.