THE UNIVERSITY OF ARIZONA
Yuma Center of Excellence for Desert Agriculture

Arizona Citrus Research Council

Project Title & number	**Measuring Evapotranspiration of Lemons (19-03)**
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Executive Summary

Competition for water resources among nations, states, municipalities, and agricultural and urban interests are commonplace. Agricultural interests are being challenged to use water more efficiently. The accurate measurement of crop evapotranspiration (ETc) is important, but reliable ETc data for lemons were lacking. We installed a Large Aperture Scintillometer (LAS) within the Yuma Mesa to commence collecting ET data for lemons. Prior to installation, we contracted fabrication of platforms to accommodate both the transmitter and receiver units and affix them to wind machine towers spaced 1000 feet apart. Unfortunately, the LAS systems had not been used in this particular application and we faced tremendous technical difficulties in trying to make the instruments function as we envisioned. The units had to be returned to the vendor on July 14, 2020 for repairs and recalibration. We will augment these measurements with eddy covariance or sap flow measurements with funding obtained from the Yuma Mesa Irrigation and Drainage District.

Introduction

Paramount to efficient irrigation management are accurate estimates of crop evapotranspiration (ET) and the tools to use these estimates. Overall, it has been estimated that ET for citrus ranges from 800 to 1400 mm (Erie et al., 1982; Rogers et al., 1984; Rashid and Salim, 1986). The most detailed information specific to Arizona was collected by Erie et al., (1982) in central Arizona and he estimated 978 mm (39 inches) for Valencia oranges and 1198 mm (48 inches) for grape fruit. Detailed data specific to lemons in Arizona is generally lacking but it has been generally assumed lemon water use is close to grapefruit (Wright, 2000).

Recently, one significant lemon producing area, the Yuma Mesa Irrigation and Drainage District (YMIDD), participated in a pilot project where water saved by fallowing land was transferred for use in the Central Arizona Project area. This pilot program will be used as a precedent, for future water transfers from agriculture to urban and industrial users should deliveries from Lake Mead be reduced to shortage. It has recently been recognized that future water transfers will be based on crop consumptive use. This is especially important in the YMIDD where much of the drainage water is recovered by wells where it is returned to the system and partially meets our treaty obligated deliveries to Mexico. Hence it is very important that we utilize accurate ET estimates.

Over the past decade there have been significant advances in technologies to measure crop ET under field conditions. One such technology is Eddy Covariance (ECV). Eddies are turbulent airflow caused by wind, the roughness of the Earth's surface, and convective heat flow at the boundary between this surface and the atmosphere. ET occurs when water vapor in upward moving eddies is greater than in downward moving eddies. Sensible heat is positive when upward moving eddies are warmer than downward moving eddies. Water vapor, heat, and carbon dioxide transferred by eddies can be measured directly using ECV.

The ECV method is now a well-established, standardized, and state-of-the-art approach for measuring ET and results from ECV stations are considered reference quality. Nevertheless, ECV data have some shortcomings. First, ET values are locally, but not regionally, representative of environmental water fluxes. Second, ET values have a variable geographic footprint which is dependent upon uncontrollable wind speed, wind direction and other effects. These shortcomings mean that ET assessments over multiple farms and heterogeneous landscapes are difficult and potentially biased. An alternative approach that is better suited for larger scale ET studies is Large Aperture Scintillometry (LAS), a technique that allows ET measurements to be scaled up over space and time. Thus field estimates should be less susceptible to local bias and varying flux footprint, which in turn means that estimates from diverse cropping systems can be measured concurrently over scales approaching 5 kilometers. Thus, in these studies we used an LAS method for lemons.

Finally, there have been recent developments in the use of satellite imagery to estimate ET. A previous limitation was the infrequent flyovers relative to crop growth rates and low resolution of imagery. More recently, we have gained access to higher resolution data collected at a minimum of weekly flyover times. These data as well as the more-local estimates discussed above can eventually be made available to growers as mobile APP irrigation management tools.

The objectives of this project were to employ state of the art technologies to measure lemon ET and develop a database to be utilized in the development of user-friendly management tools. The project was part of a large Yuma Center of Excellence for Desert Agriculture (YCEDA) project in the lower Colorado River region aimed at modeling water and salt balance across multiple cropping systems.

Materials and Methods

An LAS system was deployed on July 18, 2019 onto the Yuma Mesa Experiment Station Farm. LAS is an established methodology for accurately measuring sensible heat flux over 1-5 km distances, a scale range greatly exceeding typical distances observed for H flux data collected with ECV systems, typically 100 – 200m for deployment at 2 m heights above crops.

The deployment involved relocating a wind machine tower to be aligned with another wind machine tower to cover lemon trees. In addition, adjustable stands and mounts were fabricated to be affixed to the two wind-machine towers (Figures 1 through 4).

In addition, a meteorological sensors tower was fabricated and installed in the lemon field to incorporate weather data with the LAS data (Figure 5).

Results

Mounting LAS systems on towers above the crop was an unorthodox application of the LAS, and after installation the instrument did not perform according to the manufacture's specifications. This presented significant challenges to our data collection. It was eventually returned to the vendor for repairs. A spare unit was installed in its place until the original unit purchased for this project was repaired, but our ability to collect data was significantly impacted. We are collecting data and are optimistic it will ultimately work as envisioned.

An example of energy fluxes obtained from the LAS unit is shown in figure 6, where red symbols indicate LAS-derived H fluxes, blue symbols indicate net radiation, and green symbols indicate latent heat flux (LE). The LAS observes and integrates infrared scintillations to 60-second time steps. Daily evapotranspiration estimates (ET x 100 mm, black circles) were computed by summing daytime fluxes and illustrate a transition in water use from 2.5 mm/d to less than 1.0 mm/d, representing overall field conditions. The LAS results did not give us sufficiently complete data for good ETc estimation, but as a result of the work done with this seed money from the ACRC we have obtained funding from the Yuma Mesa Irrigation District to continue ETc work with lemons. We will augment our LAS methods with ECV and sap flow instrumentation to gain more complete ETc data as we move forward.

Literature

Erie, L. J., O. F. French., D. A. Bucks, and K. Harris. 1982. Consumptive use of water by major crops in the southwestern United States. United States Department of Agriculture Research Bulletin Number 29.

Rogers, J.S. and L. H. Allen. 1985. Evapotranspiration from a humid region developing citrus grown with grass cover. Trans. ASAE 26:6 1178.

Rashid, M. T., and M. Salim. Consumptive use of water for citrus. Pakistan J. Ag. Sci.. 10:248-253.

Wright. 2000. Irrigating Citrus Trees. ag.arizona.edu/pubs/crops/az1151.pdf

Figure 1. Installation of an adjustable mechanism platform

Figure 2. Sighting of LAS transmitters and receivers

Figure 3. Installation of instruments and data loggers to wind machine towers

Figure 4. Transmitter affixed to tower

Figure 5. Meteorological tower setup

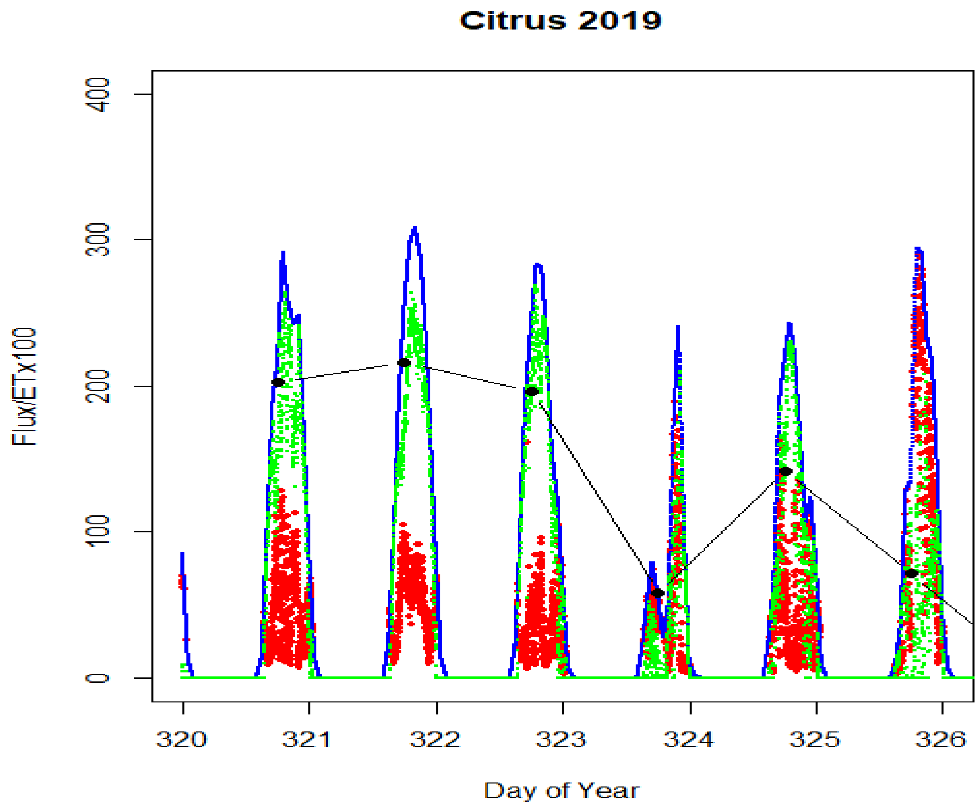

Figure 6. ET and energy flux values derived from the LAS. Red symbols denote daytime LAS sensible heat fluxes at 60-s intervals. Summed LE fluxes yield daily ET estimates (black symbols).