Evaluating the Effectiveness of Surface Renewal and other Technologies to Determine Almond Tree Water Use and Stress

Project No.: **HORT28.McElrone/Bambach**

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A. Summary

Surface Renewal (SR) technology is now patented and being provided to growers as a commercial product, however, it has yet to be evaluated against weighing lysimetry and other stress indicators under field conditions for almonds. We continued to evaluate the following research question: How effective is SR as a cost-effective irrigation management tool that provides growers with information about both the amount and timing of irrigation events for almond orchards? We found that tree water use measured with SR correlates well with other measurements from a weighing lysimeter and eddy covariance methods, but the magnitude of measurements differs. A stress index determined from SR was also well correlated with other stress proxies like stem water potentials. We also successfully developed a new method to measure ET based on canopy temperature measurements.

B. Objectives *(300 words max.)*

We addressed the following specific objectives: 1) Evaluate the effectiveness of the new stand-alone SR method to accurately quantify almond orchard ET; 2) Compare stress indices from SR with several other methods to determine how effective they are for almonds; 3) Continue efforts to develop IRT based measurements of ET using SR principles.

C. Annual Results and Discussion

We continued our ongoing efforts with collaborators to validate the new SR technique for measuring almond ET, and compared our estimates with those from weighing lysimetry (with Ken Shackel) and eddy covariance. We evaluated how well SR works when radiation and ground heat flux are measured directly versus modelled. We also tested how effectively the SR technique works for detecting water stress compared to other methods like water potential measurements, leaf gas exchange and crop water stress indicators derived from measurements of canopy temperature (with Infrared Radiometers- IRT).

Our flux footprint analysis and station location and instrumentation was improved in the 2018 season, and we continued measurements to gather a full season of data in 2019. We now have adequate to make a sufficient evaluation of the effectiveness of SR for

use in almond orchards. We also evaluated IRT sensors to estimate ET and will continue these efforts based on promising results. We began comparing our results with those of satellite based ET approaches for all years of the study, and established a new tower at Nickel's Ranch (with Tom Buckley) to compare output with sapflow output. We are preparing multiple peer-reviewed manuscripts to be submitted in 2020, which will include comparison with other techniques collected by collaborators. See details in figures at the end of the report.

Growers require information on how much, when and where to irrigate. ET estimates can provide data on the quantity of water lost via ET from crop surfaces. Based on the results from the new approach presented here, IRT sensors provide an opportunity to determine ET at the single plant resolution, but also estimates of stress based on changes in canopy temperature with adequate resolution to account for infield variability. Such data would also be particularly useful for ground-truthing remotely sensing based estimates of ET from energy balance approaches.

D. Outreach Activities

Presented at the Almond Conference 2020 in Sacramento in December 2019. Session: How Much and When to Irrigate ~200 attendees

E. Materials and Methods *(500 word max.)*:

Objective 1: A research grade surface renewal station along with an Eddy Covariance system was established in an almond orchard located at the Kearney Agricultural Center. The station is equipped similarly to commercial units. We measured net radiation and ground heat flux directly, and also model net radiation and set daily G to zero to obtain ET estimates to assure commercial sensors perform equally well to research systems. ET estimates obtained from both types of surface renewal station were compared to ET estimates recorded by the weighing lysimeter and eddy covariance located in the orchard. **Objective 2:** Midday values of leaf and stem water potential (Ψ_{LEAF} and Ψ_{STEM}) were measured with a pressure bomb on weekly or biweekly basis using sun-exposed leaves in the block. Applied water quantity and irrigation frequency were recorded. We compared the ET_C and stress indicators from SR with those obtained using IRT sensors. This will be done using a research quality Apogee IRT connected to a datalogger. **Objective 3:** Until now, SR has used air temperature measured by fine wire thermocouple temperature sensors. We are worked with IRT sensors and mathematical methods to measure ET on individual trees. We implemented this research over almond canopies in our study.

F. Publications that emerged from this work

Manuscripts in preparation

Bambach, Parry, Shackel, McElrone (in prep). An alternative method to estimate atmosphere-canopy fluxes from semi-high frequency canopy infrared temperature. Target Journal- *Agricfultural and Forest Meterology*

Bambach, McElrone, Shackel et al. (in prep). Comparison of almond tree evapotranspiration and stress measured with surface renewal, eddy covariance and weighing lysimetry. Target Journal- *Irrigation Science*

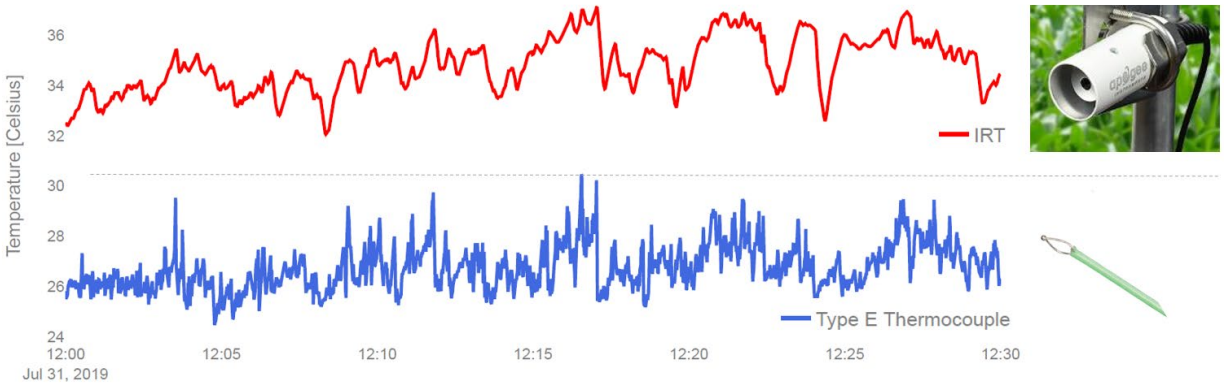

Figure 1: Raw temperature traces from IRT (top-red) aimed at the plant canopy, and fine wire thermocouple (bottom in blue) located above the canopy. Ramp like structures in the fine wire thermocouple data that represent energy exchange between the canopy and air coincide with ramps in the canopy temperature.

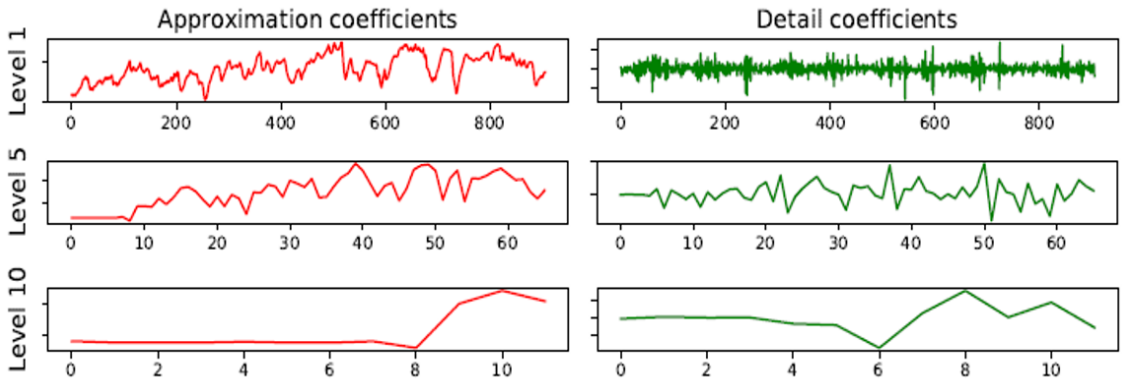

Figure 2: Wavelet analysis conducted on the same IRT raw canopy temperature traces from Fig 1. using PyWavelets- an open source wavelet transform software for Python. This analysis identifies the ramp like structures from the IRT canopy temperature data that coincide with sensible heat flux ramps.

Flux tower in experimental almond orchard containing a mature tree in a weighing lysimeter

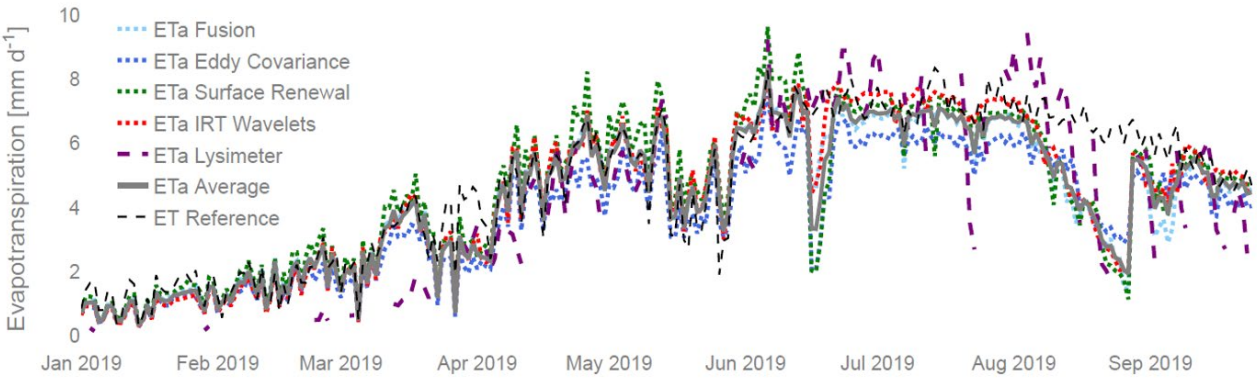

Figure 3: Tree evapotranspiration (ET) estimates from a variety of methods measured in an experimental almond orchard in Parlier, CA. A single almond tree is growing in a weighing lysimeter contained within this orchard to measure ET directly. A flux tower was used on site to estimate ET using eddy covariance and surface renewal using a footprint to represent the entire orchard, and the combination of these two techniques was used for a Fusion ET estimate. IRT sensors aimed at the lysimeter tree were used to calculate H. These values were also compared with reference ET calculated from a California Irrigation Management Information System station located at the Kearney Ag Center.

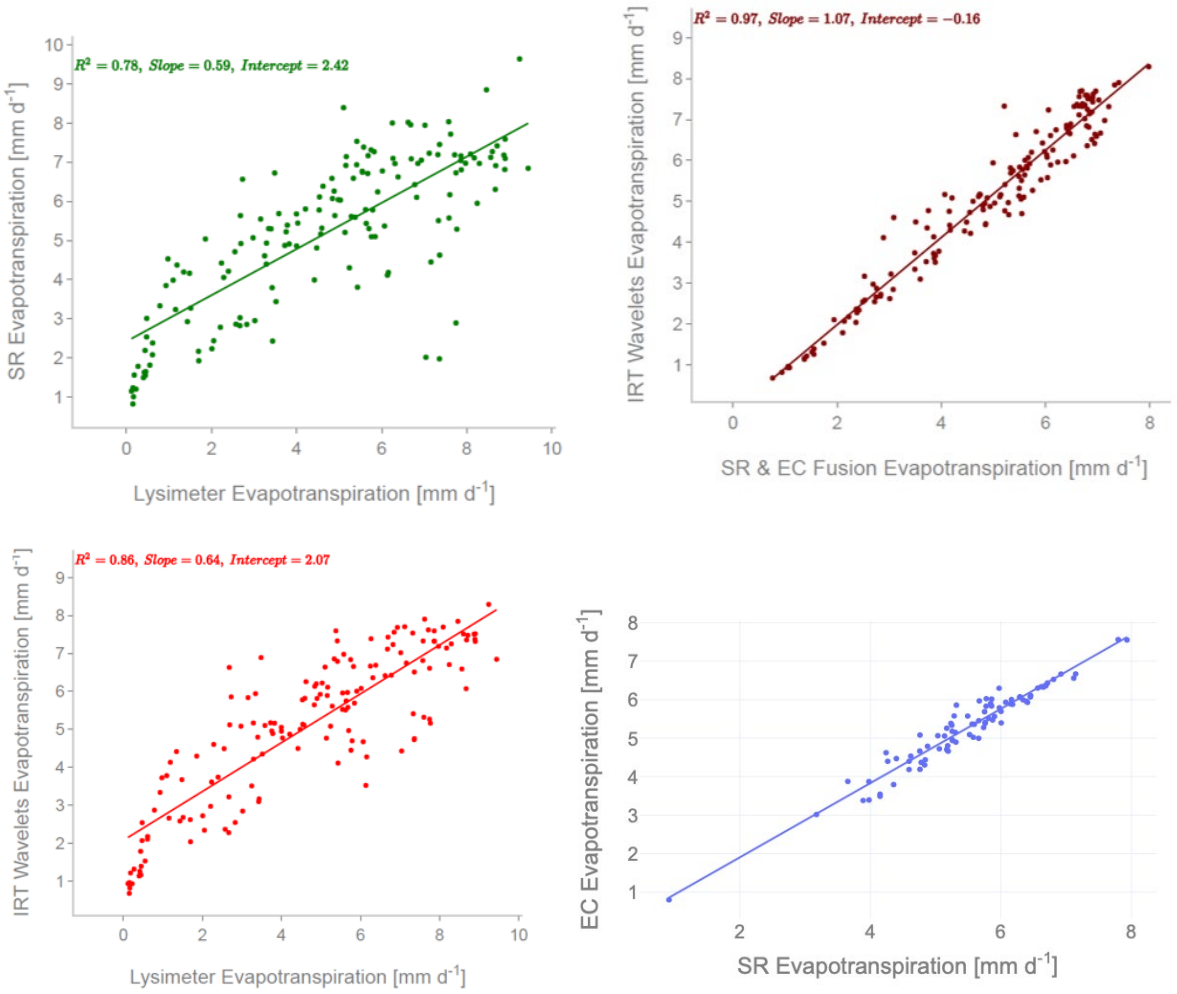

Figure 4: Regression analyses comparing ET estimates from several of the techniques presented in Fig. 3 for the 2019 growing season. A similar relationship was found between SR and the lysimeter for the 2018 growing season (i.e. the slope was 0.59 in 2018, too).

Figure 6: New Flux tower installation at Nickels Ranch, where collaborator Tom Buckley is conducting sap flow measurements on trees in an experimental orchard.