# Leaf Monitoring System for Continuous Measurement of Plant Water Status to Assist with Irrigation Management of Specialty Crops

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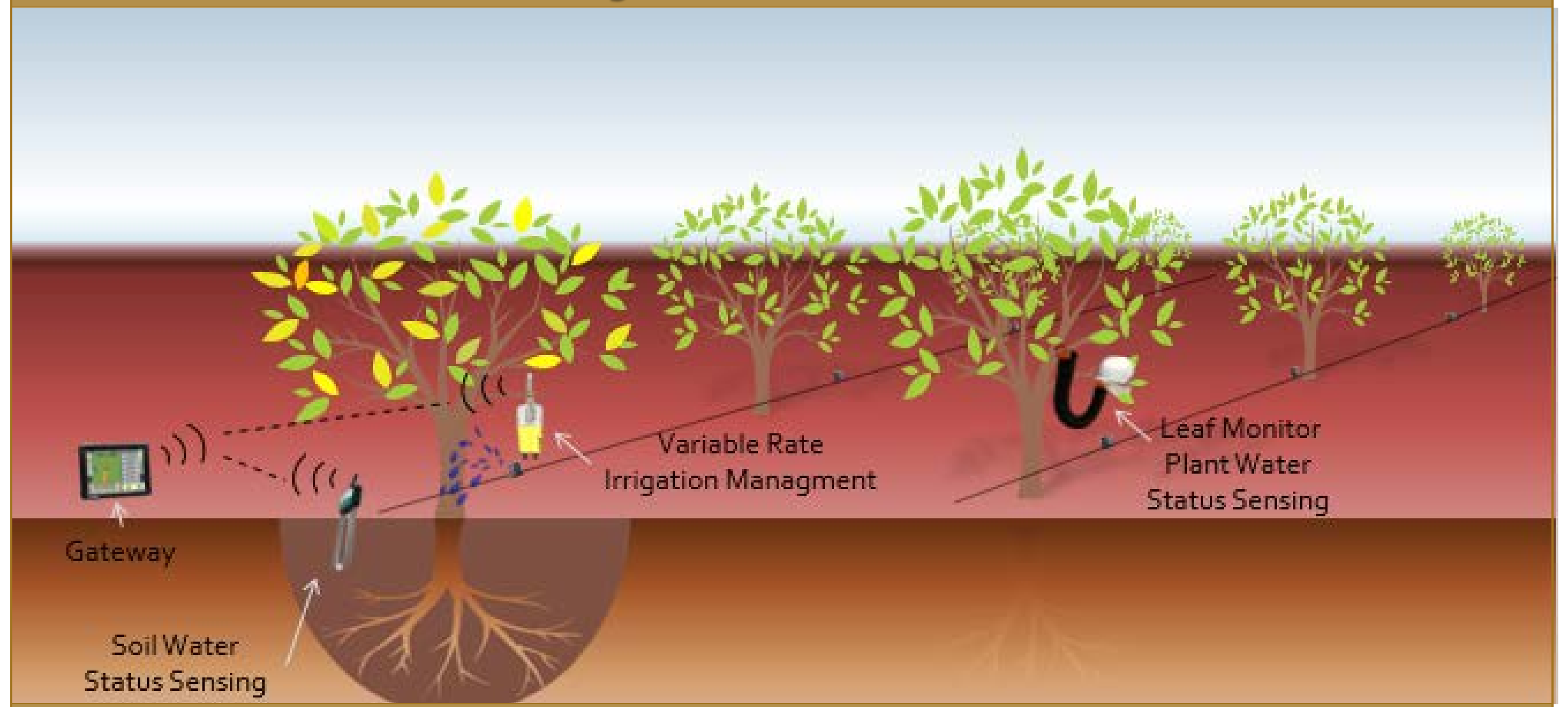
california almonds Almond Board of California — cdfa California Department of Food & Agriculture — E&J Gallo Winery

## Project Overview



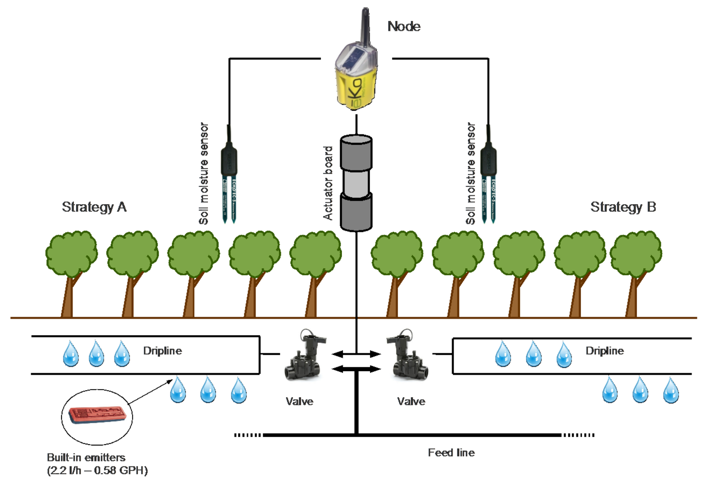

## Objectives

1. Monitor plant water status by measuring leaf temperature and microclimatic variables using a continuous sensing system interfaced to a wireless mesh network.
2. Develop irrigation management zones based on soil and plant characteristics.
3. Implement a variable rate, plant water stress based irrigation management scheme that accounts for spatio-temporal variability in orchards.

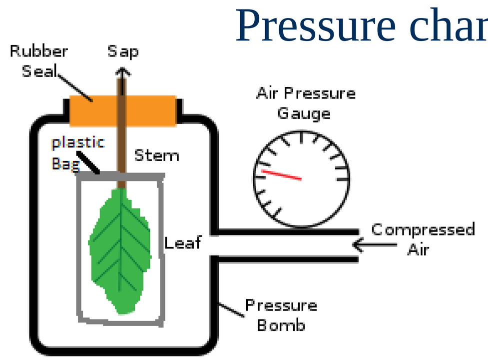
## Background

**Introduction:** Common practice is to irrigate on fixed days of the week in response to evapotranspiration (ET) estimates or soil moisture content. The current water demand in California's Central Valley necessitates the development of precision irrigation practices based on crop needs. It is therefore very important to develop convenient techniques to measure plant water status.

**Plant Water Status:** This measurement indicates the current stress level in the plant. Studies have shown that measurement of plant water status (PWS) provides the key information necessary to implement efficient irrigation management schemes in orchards. A pressure chamber is often used to measure PWS. However, this technique is labor intensive, tedious and time-consuming. To address these issues, a continuous leaf monitoring system was developed to predict plant water stress based on leaf temperature and relevant microclimatic variables (i.e. ambient temperature, relative humidity, photosynthetically active radiation (PAR) and wind speed).

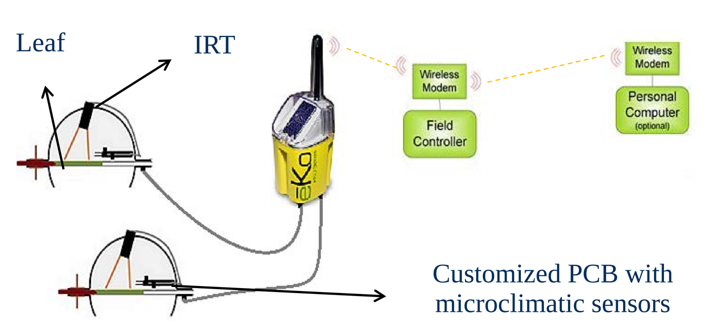


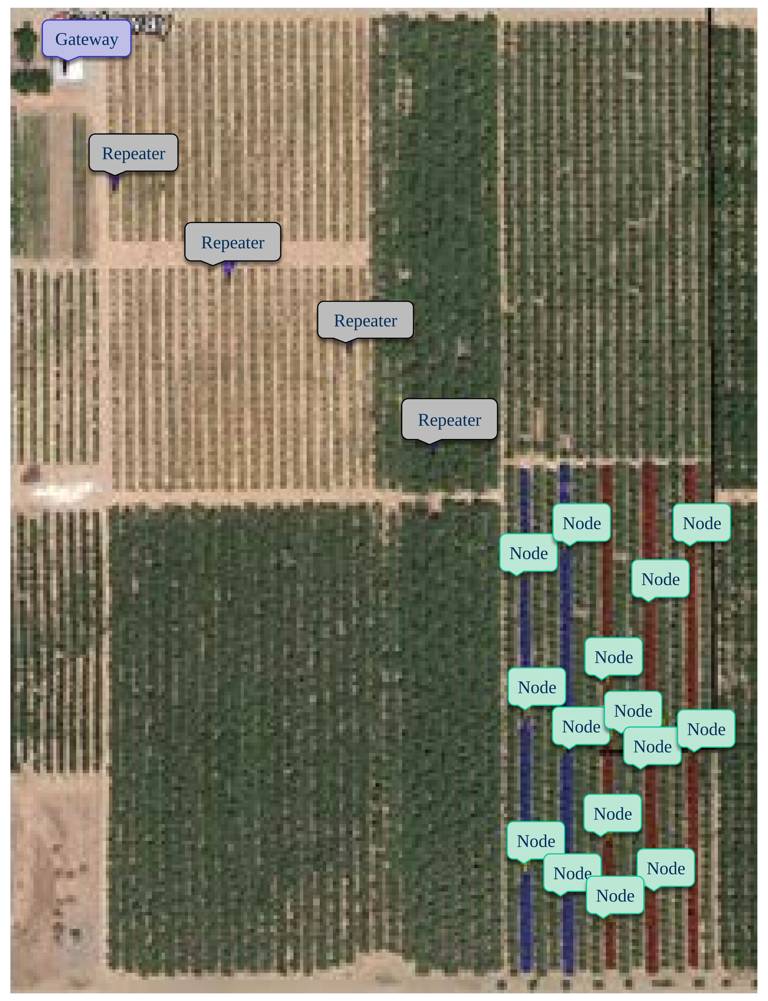

Pressure chamber



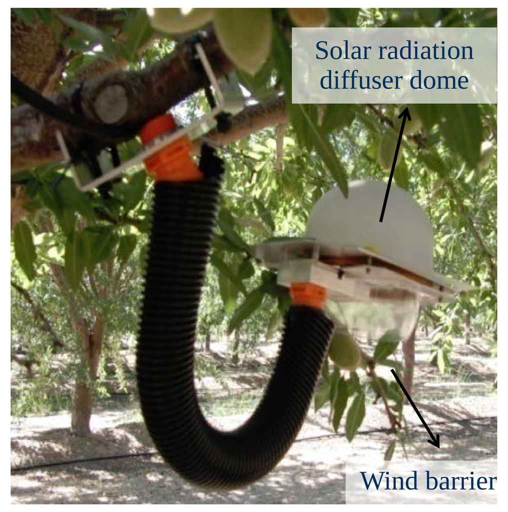

## Methods

**Wireless Mesh Network:** We have deployed 14 such leaf monitors and interfaced them to a wireless mesh network so that data could be uploaded to the internet through a gateway computer and accessed through the web. The system also included a controller capable of actuating latching solenoid valves to manage precision irrigation of an almond orchard, located in Nickels Soil Laboratory, Arbuckle, CA.



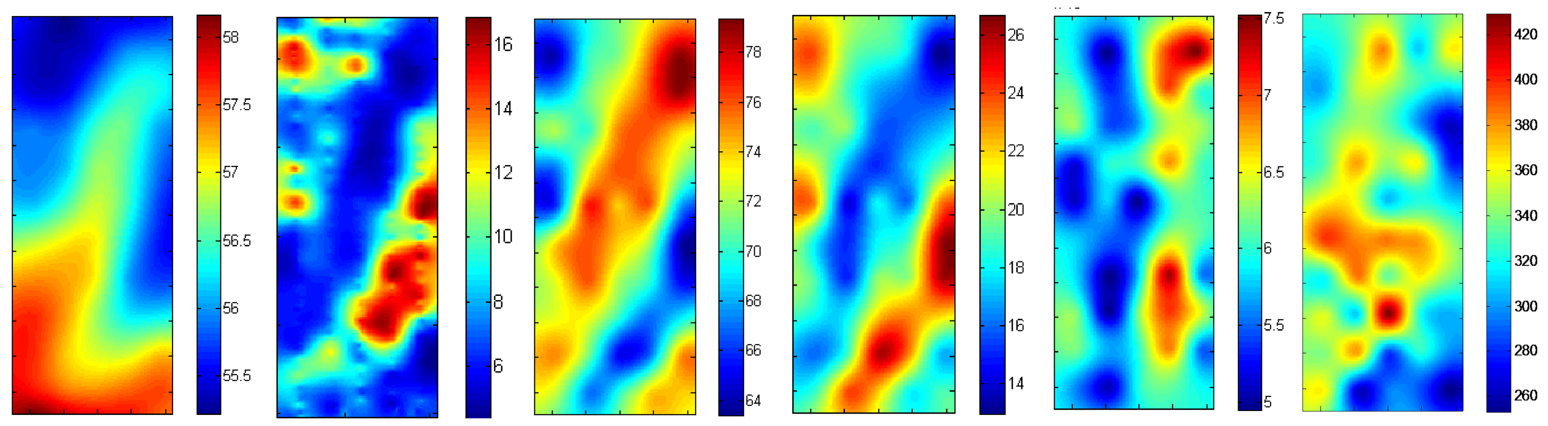








**Plant water status:** Leaf monitor data were used to calculate daily crop water stress index (CWSI). Estimated CWSI were used to perform stress based irrigation management to maintain the stress values within a reasonable range.

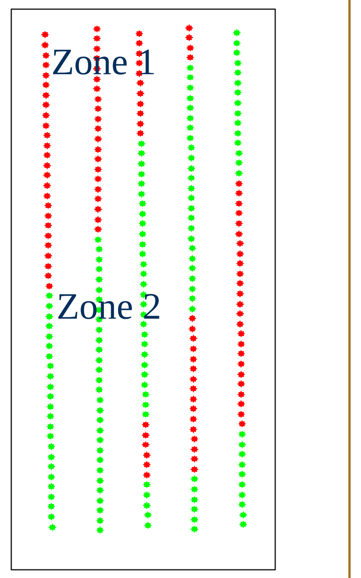
**Management Zones:** Two management zones were created based on plant and soil characteristics using unsupervised fussy classification. The soil characteristics considered were digital elevation, shallow EC, sand, silt content, soil texture, and electrical conductivity, whereas the plant characteristics were represented by canopy light interception and canopy temperature. Each management zone was divided into two treatments. The position of each node was carefully chosen by analyzing stem water potential maps created on three different occasions.



Digital Elevation — Shallow EC — Sand — Silt Content — Leaf Temperature — Canopy Cover

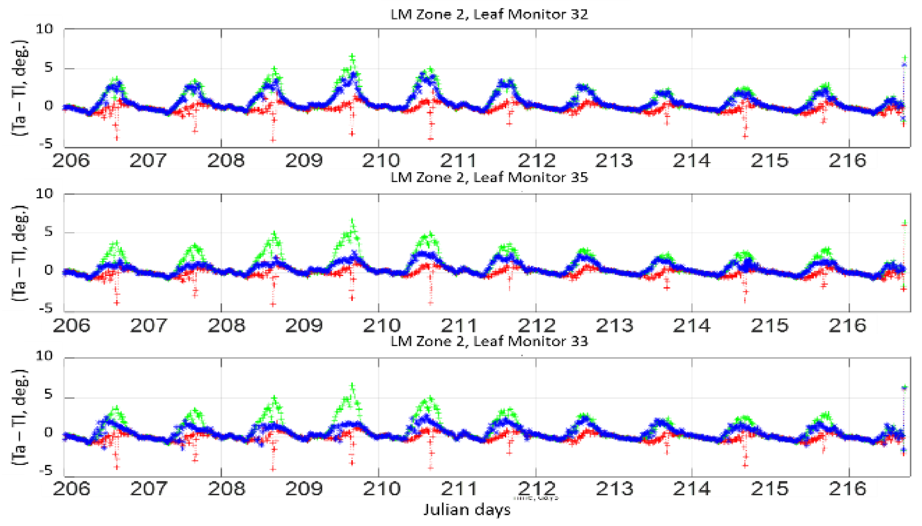
## Results

**Zoning:** As can be seen from the figure to the right, soil characteristics had a greater contribution in the classification than plant characteristics. Among the soil characteristics considered, digital elevation was the feature that contributed the most.

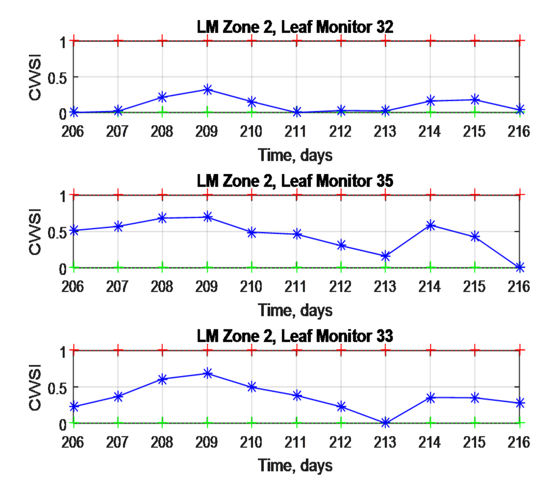



**Stress Index:** When the average CWSI values for a zone exceeded the maximum allowable stress (i.e. CWSI value of 0.3), irrigation was implemented at a defined percentage of ET. The percentage of ET was adjusted over time until stress became manageable.

Temperature difference

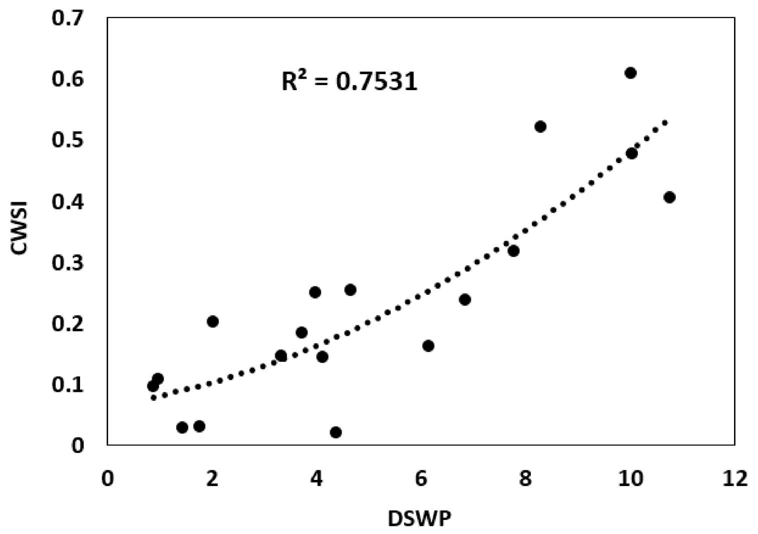



CWSI




**Leaf Monitor:** When a tree transpires, its stomata open and a lower temperature is observed on each leaf's surface compared to the air. For a well-watered tree (green curves), this temperature difference is high; for a simulated dry tree* (red curves), this difference is low. The behavior of the temperature difference for each monitored tree (blue curves) was observed with respect to that of a well-watered tree and a simulated dry tree.

**Stress Relationships:** Each treatment was represented by three leaf monitors in each zone. CWSI and DSWP were found to be strongly correlated, with a second order relationship. The coefficient of multiple determination was 0.75, evaluated from the average values for each treatment of each management zone.




## Conclusions

By monitoring leaf temperature and microclimatic variables with leaf monitors, variable rate irrigation was implemented according to the crop stress level of each management zone. Preliminary results indicated that zone #1 required about 70% water compared to grower treatment and zone #2 required about 90% water compared to grower treatment.

*a leaf with stomata closed (- due to antiperspirant application or a broken stem)

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