Two Years of Sap Flow for Evapotranspiration Characterization in Riparian Vegetation

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Abstract

To close the water budget in irrigated agricultural fields on flood plains with riparian corridors, it is necessary to understand groundwater usage, including usage by dominant phreatophytes, particularly when primary source of water for irrigation is groundwater abstraction. We report results of phreatophyte vegetation sap flow data along a riparian corridor, which is part of a larger watershed located along the Pacific coast in Santa Cruz County, CA. Four trees were instrumented with sap flow sensors. In addition to diurnal fluctuations, sap flow data show seasonal variation, with summer maxima & winter minima and transitional fall & spring periods. The data are useful for tracking inter-annual fluctuations.

Study Objectives

1. Measure sap flow of four phreatophytes with thermal dissipation probes for two years [1].
2. Extrapolate sap flow measurements from the study area across the entire riparian forest using sampled tree sapwood area and used to estimate forest evapotranspiration (ET).
3. Continuously monitor groundwater fluctuations with pressure transducers in piezometers within the riparian forest and adjacent agricultural land for two years.
4. Model response of unconfined aquifer and aquitard to sap flow and ET using model of [2] to include water table kinematics.

Field Site

- Swanton Pacific Ranch in Santa Cruz County, CA, along Pacific coast. Canopy dominated by:
  1. Red alder (*Alnus rubra*)
  2. Arroyo willow (*Salix lasiolepis*)
  3. Pacific willow (*Salix lasiandra* var. *lasiandra*)
- Riparian corridor borders Scotts Creek
- Three-layered subsurface aquifer system [4]
- Phreatophyte roots in unconfined aquifer and underlying aquitard
- Geology: Unconsolidated sediment underlain with fractured shale

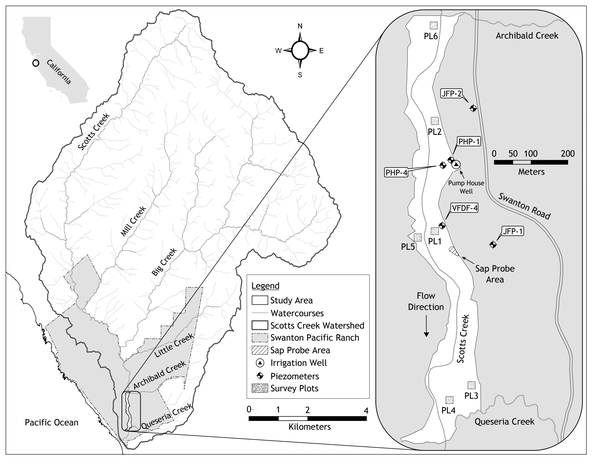

Figure 5: Study site showing riparian corridor, instrumented trees along Scotts Creek, & piezometers.

Materials & Methods

Four trees were instrumented for sap flow measurements and sampled at 15 minute intervals for two years.

- 30-mm thermal dissipation probes (Dynamax)
- CR1000X data logger with AM16/32 relay multiplexer (Campbell Scientific)
- PT2X pressure transducer (INW/Seametrics)

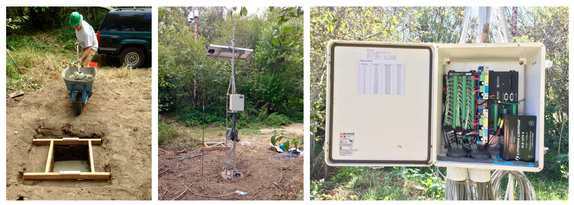

Figure 6: Field installation of data-logging station.

During 2 years of continuous monitoring, tree healing occurred with wood growing over the probes. Groundwater fluctuations were monitored continuously in piezometers installed in aquitard and overlying unconfined aquifer.

Figure 7: Sap flow sensors at start and end of study, and piezometer with transducer in riparian corridor.

Observations

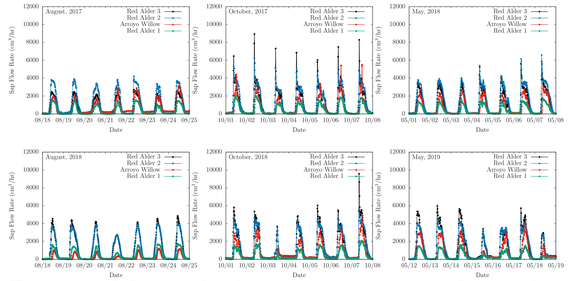

Figure 1: Weekly & diurnal sap flow over 2-y period.

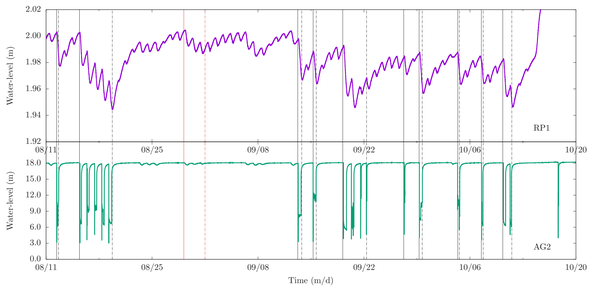

Figure 2: Aquitard groundwater fluctuations (2017) [4].

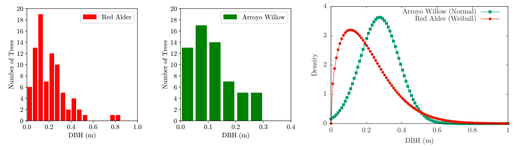

Figure 3: Empirical and theoretical DBH distributions.

ET and sap flow-induced diurnal fluctuations in groundwater levels in thin shallow near-surface unconfined aquifer and underlying aquitard instrumented with transducers for continuous high-frequency water-level monitoring. Responses to

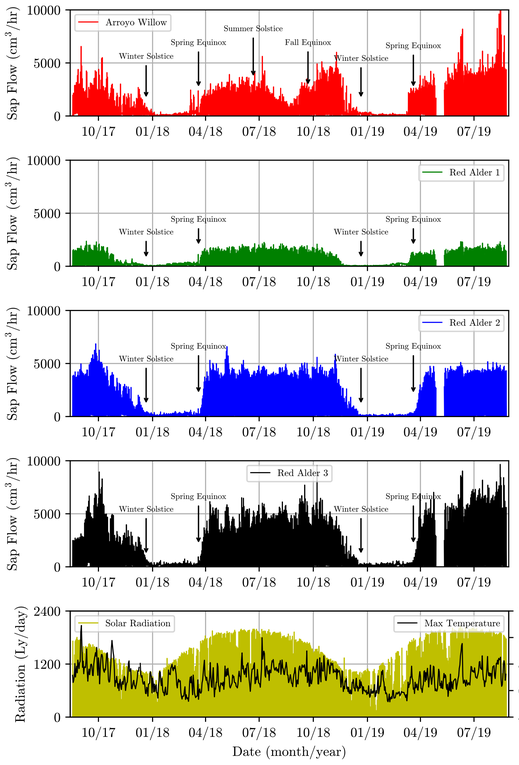

Figure 4: Seasonal sap flow data, solar radiation, and maximum daily temperature data over study period.

ET and pumping clearly observable in long-term data. Sap flow data are projected across entire riparian forest using sampled tree sapwood area and used to estimate forest ET. Sap flow strongly correlated with solar radiation at seasonal scale.

Conclusions

The ET is used in a groundwater flow model to predict observed groundwater fluctuations and usage by riparian vegetation. Groundwater fluctuations mimic sap flow and ET. Groundwater fluctuations at the site are predicted by model of [2]. For a well characterized aquifer, groundwater fluctuations may be used to predict the causal ET, which allows for closure of groundwater balance across riparian corridor. Long-term high-frequency data more reliable indicator of aquifer-aquitard-stream-ET connectivity and inter-flow than traditional short-term aquifer tests.

References

[1] Granier, A., 1987. *Evaluation of transpiration in a Douglas-fir stand by means of sap flow measurements*. Tree Physiology 3 (4), 309–320.

[2] Malama, B., Johnson, B., 2010. *Analytical modeling of saturated zone head response to evapotranspiration and river-stage fluctuations*. Journal of Hydrology 382 (1-4), 1–9.

[3] Moore, G. W., et al., 2010. *Structural and compositional controls on transpiration in 40-and 450-year-old riparian forests in western Oregon, USA*. Tree Physiology 24 (5), 481–491.

[4] Pritchard-Peterson, D., 2018. *Field investigation of stream-aquifer interactions: a case study in coastal California*. Master's Thesis, California Polytechnic State University.

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