Almond ET/Yield Production Function

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Problem and its Significance:

Water is a critical resource for Californian agriculture and much of California suffers from periodic shortages and persistent threats of reduced allocations. Water is also the primary means of delivery of nitrogen and the primary driver for nitrogen loss. One of the major challenges faced by irrigated agriculture is to optimize the use of water with respect to production (i.e., more "crop per drop"). It is well known in almonds and most other crops that production increases with increasing water availability up to a point, but for almonds a relation between water availability and crop production, the "Water Production Function" (WPF), has not been established. It has long been assumed that production will be maximized by applying water to match orchard evapotranspiration (ETc), but we do not know the shape of this relation, and the shape of the relation is an important basis for determining the optimum irrigation approach. It is imperative that the almond industry have the best available information on the relation of almond tree yield to different levels of irrigation in mature orchards.

Objective:

- Develop a water production function (WPF) for almonds grown in California that will relate potential yield to water applied, accounting for the site-specific effects of orchard cover, soils, varieties, and physiological level of stress experienced by the tree.

Results and Discussion:

- As in previous years, even though the seasonal pattern of ETc was similar at each site (dashed lines in Fig. 1), the initiation of irrigation at each site depended on winter rainfall and soil conditions, with irrigation starting sooner at the Kern site, later at Tehama, and intermediate at Merced (Fig. 1).
- At each site, the differences in applied water lead to clear differences in SWP throughout the season (Fig. 2), and the ranking of the seasonal average SWP was identical to the treatment ranking at all sites (Table1).
- Kernel yields in this third year of treatments generally ranked in treatment order (Table 1), but it is surprising that in this year, as well as in previous years, yields do not exhibit a clearer statistical effect, even though Kernel weight and canopy development (PAR) do (Table 1).

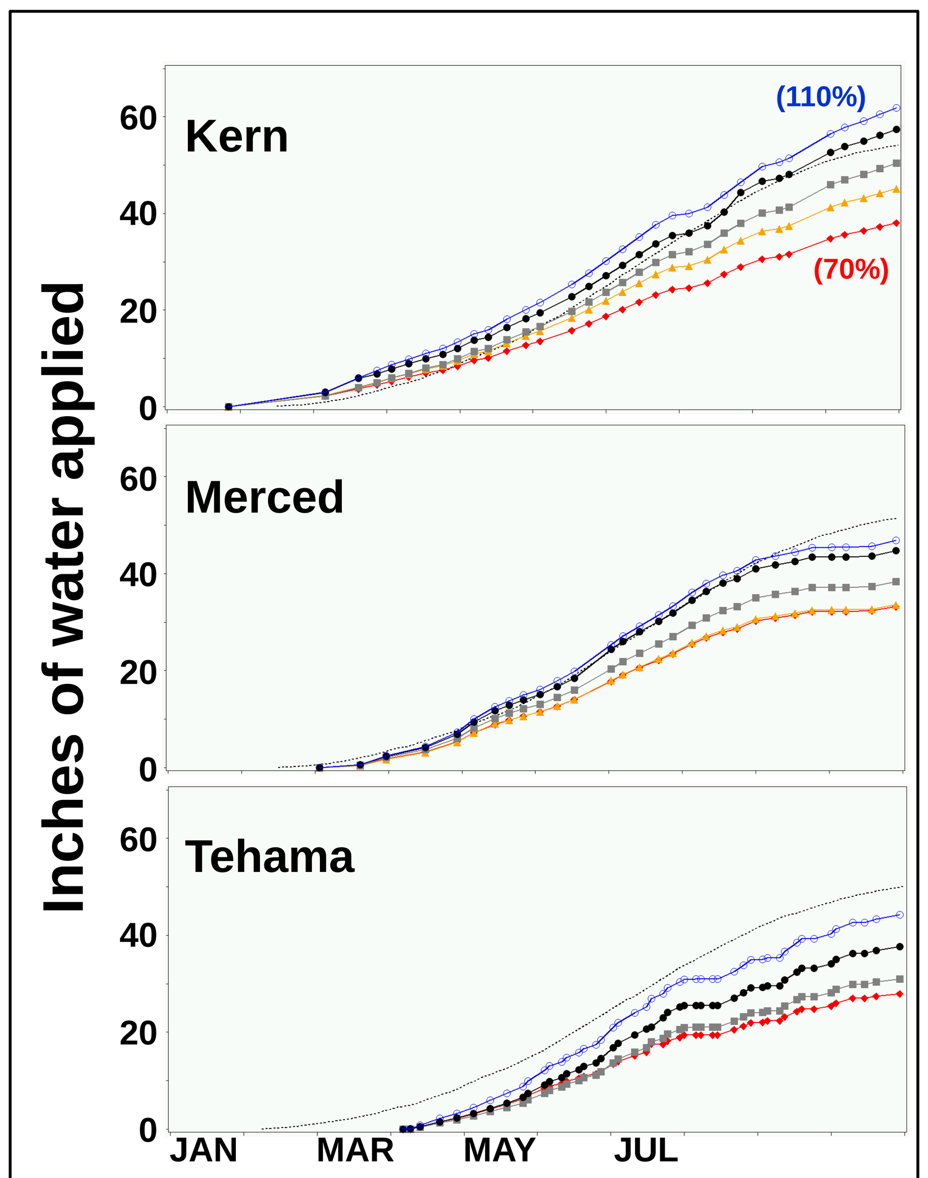

Figure 1. Seasonal pattern in cumulative applied water at each site. Only the 110% (blue) and 70% (red) treatments are indicated for clarity, with the others being 100% (black), 90% (yellow), and 80% (grey). The predicted water demand (ETc) for almonds at each site is indicated by the dashed line.

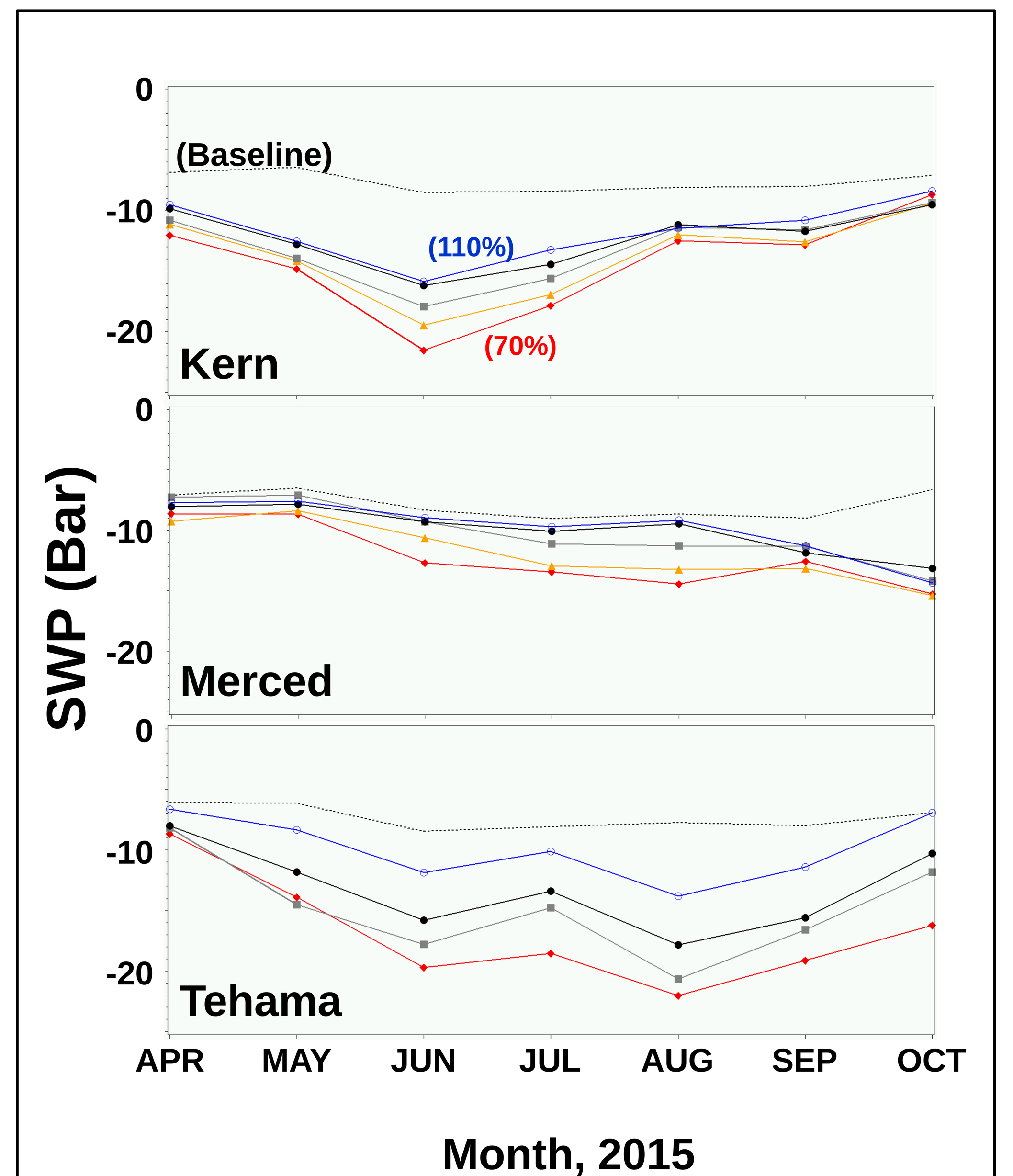

Figure 2. Monthly average stem water potential (SWP) values for each treatment at each study site, with symbols as in Fig. 1. Also shown for reference is the fully irrigated (non-stressed) baseline SWP for each month and site.

Table 1. Orchard yields, Kernel weight, % light interception, and average seasonal tree SWP (April - September) for the different sites and irrigation treatments (70 – 110 %ET) in 2015. All means are ranked in numerical order (means which appear to be identical are due to rounding), but means followed by the same letter are not significantly different. An absence of letters also indicates that there was no significant treatment effect.

Site	Kernel Yield (lbs./ac)		Kernel weight (g)		PAR (%)		SWP (bar)	
	Treatment	Mean	Treatment	Mean	Treatment	Mean	Treatment	Mean
Kern	110	2,770a	100	1.08a	110	76a	110	-12a
	100	2,410b	110	1.04ab	100	75ab	100	-13ab
	80	2,370b	90	1.03b	90	73abc	90	-14abc
	90	2,350b	80	1.02b	80	72bc	80	-14bc
	70	2,140b	70	0.92c	70	72c	70	-15c
Merced	100	2,410	110	1.23	110	70.5a	110	-9a
	110	2,220	90	1.22	100	70.2a	100	-9a
	90	2,080	80	1.19	90	65.8ab	90	-10ab
	80	1,820	100	1.17	70	64.2b	80	-11bc
	70	1,750	70	1.14	80	63.9b	70	-12c
Tehama	116	2,440	116	1.23a	116	71.2a	116	-11a
	86	2,380	100	1.16ab	86	66.3b	100	-14b
	100	2,230	86	1.11bc	100	66.1b	86	-16bc
	74	2,170	74	1.05c	74	65.5b	74	-18c

- Yields over time have been relatively stable at the Tehama site, but have exhibited annual fluctuations at the other sites (Fig. 3).
- Pre-treatment (2012) yields were not statistically different, but numerical pre-treatment differences did occur (Fig. 3, 2012), indicating that a trend analysis of yields may be needed.

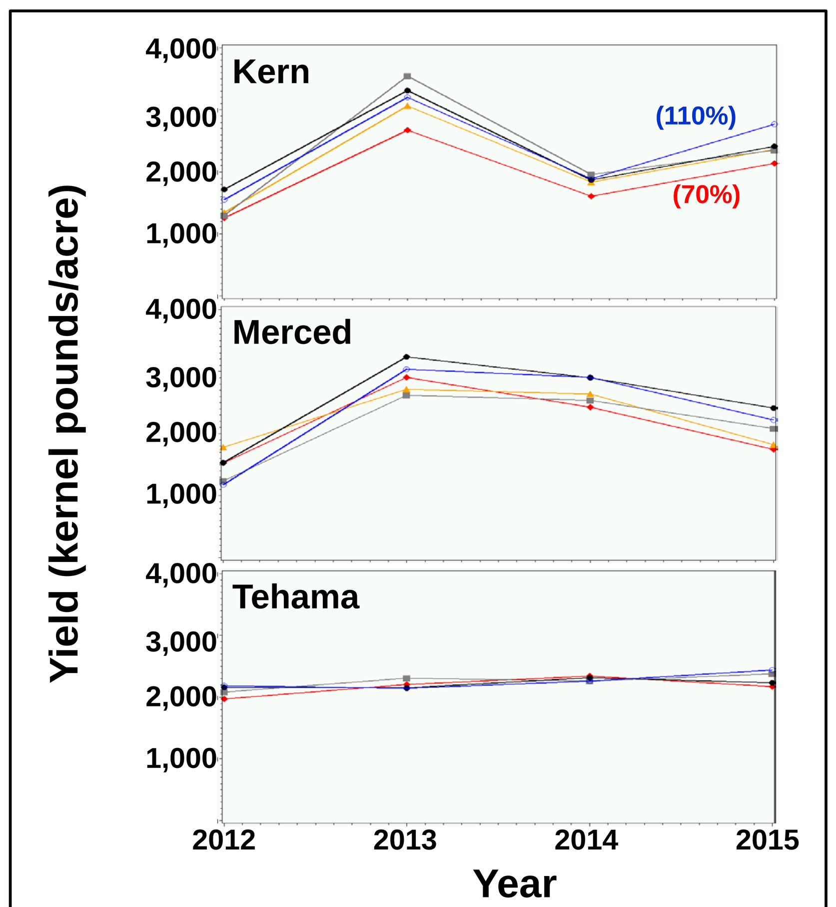

Figure 3. Average yields beginning prior to any irrigation treatment (2012) and for the 3 years of treatment imposition (2013 – 2015). Symbols as in Fig. 1.

- By adjusting treatment yields for the average orchard yield each year, a clear trend for each treatment over time could be detected at some sites (e.g., Merced, Fig. 4).
- The slope of this trend adjusts for pre-treatment effects, as well as year effects.
- This analysis was performed for each site for yield and for the factors related to yield (PAR, kernel weight).

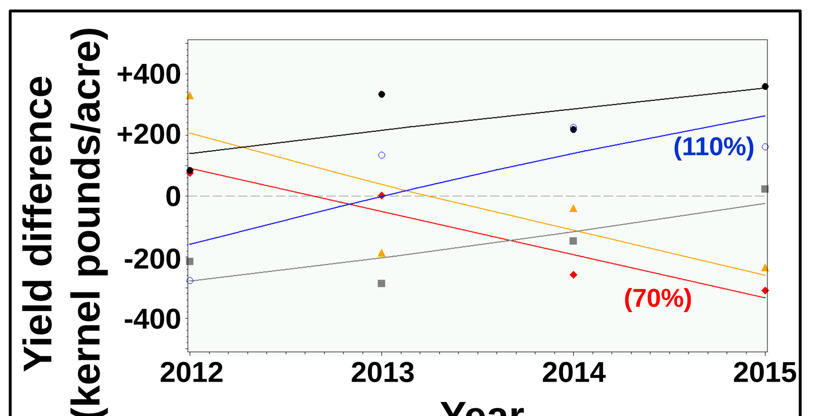

Figure 4. Example of a yield trend analysis using Merced yields. Each point is the difference in yield between the treatment (same symbols as in Fig. 1) and the mean yield for that year. An upward slope indicates a trend of relative increase over time compared to the other treatments, and a downward slope indicates a trend of decrease.

- In all cases where trends were detected (Fig. 5), increasing levels of irrigation were associated with increases in yield, PAR, and kernel weight, as expected.
- Yield showed a high sensitivity to irrigation level at the Merced site, but was flat at the Tehama site and only showed a slight increasing trend at Kern (Fig. 5, Yield).
- Canopy development showed some sensitivity to irrigation level at Merced and Tehama, but not Kern (Fig. 5, PAR).
- Kernel weight showed a small but similar level of sensitivity to irrigation at all sites (Fig 5, Kernel weight).
- These results suggest that the yield response to irrigation level (i.e. the water production function) may be site specific.

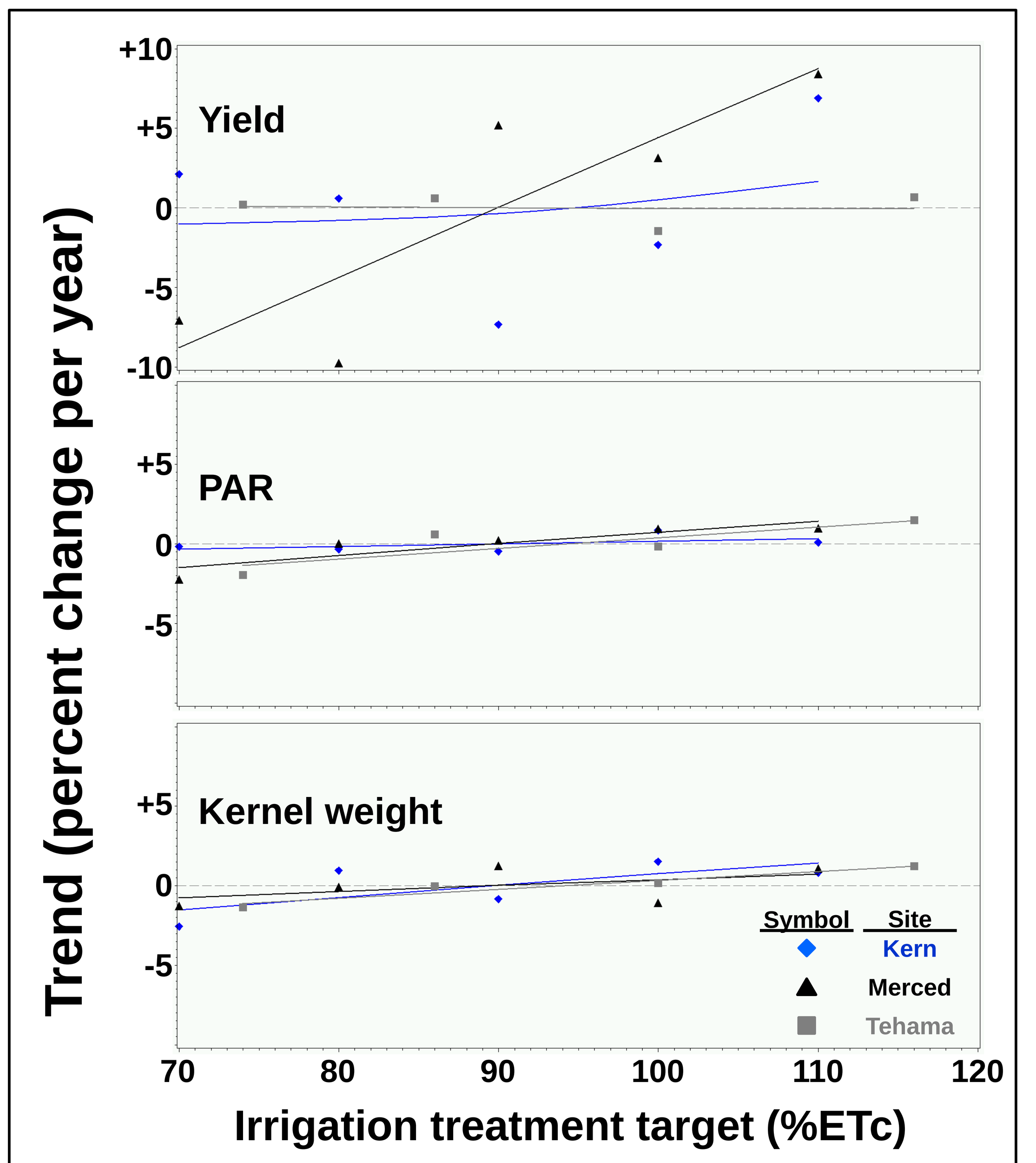

Figure 5. Trend analysis for Yield, PAR, and Kernel weight for the first 4 years of this project. For simplicity, irrigation is expressed as the treatment target value at each site. Lines with a steeper slope indicate which factors and locations exhibit more response to irrigation.

Conclusions:

There are many factors that influence almond orchard yield, and it appears that each of these factors may have it's own independent response to irrigation. While the orchards in this study have consistently exhibited good yields (2,000 - 3,000 kernel pounds per acre range), none have consistently achieved the maximal level of 50 pounds per % PAR found in other studies, and possible reason(s) for this are under investigation. Probably the most important result to date is that different sites may show different responses to irrigation, at least when irrigation is expressed as a percent of ETc. Where there is a response to irrigation, the trend analysis used thus far has suggested a more-or-less linear increase in yield, kernel weight, and PAR with increasing irrigation, but all of these factors will reach a stable value over time for each orchard, and it is only this stable value that can be validly used for an almond water production function.