California Almond Water Footprint

Julian Fulton[1], Michael Norton[2], and Fraser Shilling[2], 1 – Department of Environmental Studies, California State University, Sacramento; 2 -- Department of Environmental Science and Policy, University of California Davis

Contacts
Julian Fulton (julianfulton@csus.com)
Fraser Shilling (fmshilling@ucdavis.edu)

Objectives

- Calculate an accurate water footprint for California almonds, using the most recent statewide data and where possible, local or regional research products to inform data-use, such as actual crop evapotranspiration values.
- Compare almond water footprint to economic benefits gained from almond production and sales.
- Carry out a more detailed analysis of the water footprint of almonds compared to food value components and total food value.
- Analyze the effects of variation in evapo-transpiration rates (ETo and ETc) geographically, temporally, by variety, and with physiological status.
- Compare the water footprint to other types of footprint (e.g., ecological, energy/carbon) and life cycle analysis in order to identify production and management actions that could contribute to reducing water impacts and increasing efficiency.

Background

The domestic and international media have recently started focusing on the water footprint of California almonds and have related the water footprint to water use and the drought. The water footprint is an index of the complete use of and impacts to water systems. It is the sum of water impacts from production of a good or service used by people. It is typically expressed per unit production, per region, or per capita. It goes beyond consideration of water use (e.g., from irrigation) and according to the International Standards Organization is similar to the life cycle analysis approach. Besides the problem of perception that California almonds have a large water footprint, there is the additional problem that the water footprint estimate quoted in the press is not accurate. It is likely that the California-almond water footprint is smaller than estimated and is gradually improving over time. Finally, the many nutritional and economic benefits that almond production and almonds provide are lost in a water footprint calculation that reports volume of water per unit weight of almonds. Almond production provides a large economic and employment benefit to California. Almonds are also replete with protein, healthy fats, fiber, vitamins and micronutrients. There is no requirement that water footprint be only expressed in terms of volume per unit weight. Other denominators, such as economic benefit, protein (g), or total food benefit are likely to provide a better representation of the benefits of almonds relative to the water footprint.

Discussion

Almond water footprints show a great deal of variability around the state based on yield, ETo rates, and recently updated crop coefficients (Kc). While current estimates of an average almond water footprint may be only slightly revised by this research, we find almonds to have economic and health productivity advantages over other crops commonly grown in the region. Further, we see potential for management actions that reduce water footprints synergistically with greenhouse gas and other ecological footprint indicators.

Estimating an accurate water footprint for almonds

$$Water\ Footprint = \frac{Consumptive\ Water\ Use}{Yield}$$

Blue Water refers to applied surface and ground water that is utilized in orchard production.

Green Water refers to rainwater and residual soil moisture that is utilized in orchard production.

Grey Water refers to contamination and is expressed as the volume of water needed to assimilate non-utilized nutrients and other pollutants to governing standards.

Average (10-year) values for California are:
[Notes]

$$Blue\ water = \frac{4.3\ acre{-}feet/acre}{1.2\ tons_{kernels}/acre} \times \frac{1\ ton}{2{,}000\ lbs} \times \frac{325{,}851\ gallons}{1\ acre{-}feet} = 610\ \frac{gallons}{lb_{kernels}} \qquad [1]$$

$$Green\ water = \frac{0.6\ acre{-}feet/acre}{1.2\ tons_{kernels}/acre} \times \frac{1\ ton}{2{,}000\ lbs} \times \frac{325{,}851\ gallons}{1\ acre{-}feet} = 87\ \frac{gallons}{lb_{kernels}} \qquad [2]$$

$$Grey\ water = \frac{3.2\ acre\ {-}feet/acre}{1.2\ tons_{kernels}/acre} \times \frac{1\ ton}{2{,}000\ lbs} \times \frac{325{,}851\ gallons}{1\ acre{-}feet} = 464\ \frac{gallons}{lb_{kernels}} \qquad [3]$$

Co-product credits: hulls used as feed for livestock and shells and other woody biomass used for energy production help offset the water footprint of almonds:

Assuming hulls offset corn silage at a 1:1 ratio,

$$\frac{1.5\ tons_{hulls}}{1\ ton_{kernels}} \times \frac{0.1\ acre{-}feet}{1\ ton_{corn\ silage}} \times \frac{1\ ton}{2{,}000\ lbs} \times \frac{325{,}851\ gallons}{1\ acre{-}feet} = 25\ \frac{gallons}{lb_{kernels}} \qquad [4]$$

Assuming shells and woody biomass are used to produce electricity,

$$\frac{0.76\ kWh_{electricity}}{1\ lb_{kernels}} \times \frac{0.7\ gallons}{1\ kWh_{electricity}} = 0.5\ \frac{gallons}{lb_{kernels}} \qquad [5]$$

Notes:

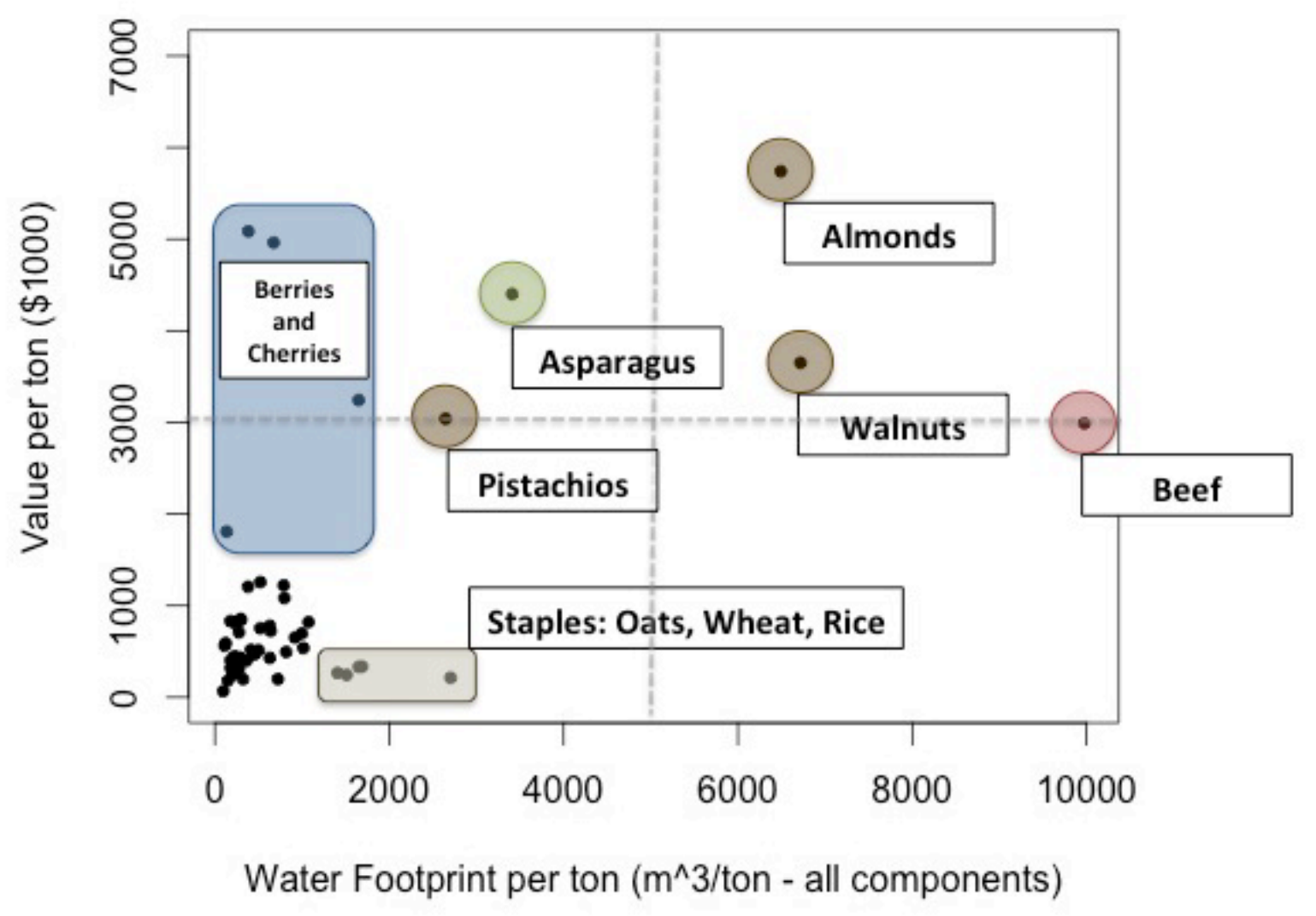
[1/2] Average evapotranspiration of applied water (blue) and effective precipitation (green) values are taken from Cal-SIMETAW (Orang et al, 2013) and weighted by almond acreage per county.

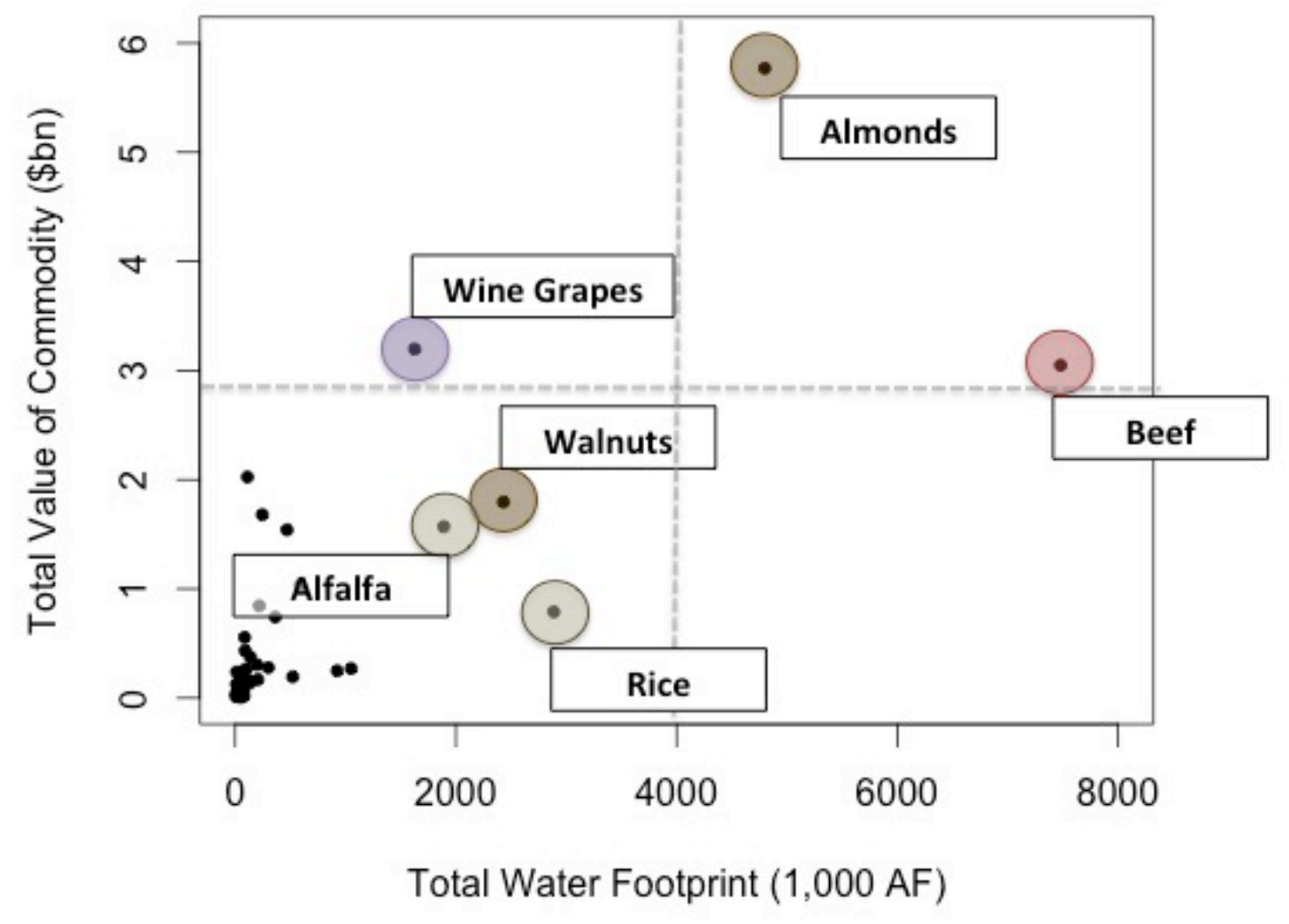
[3] Based on average nitrogen application rate of 250 lb/acre and 35% leaching-runoff coefficient (Brown, 2015). State maximum contaminant level is 10mg-N/l (SWRCP, 2010).

[4] Hull-to-kernel ratio is from Kendall et al (2015). Corn silage water footprint value is from Fulton et al (2012).

[5] Electricity generation per kernel is from Kendall et al (2015). Electricity water footprint is from Fulton et al (2015).

Inter-Crop Comparison of WF & Value

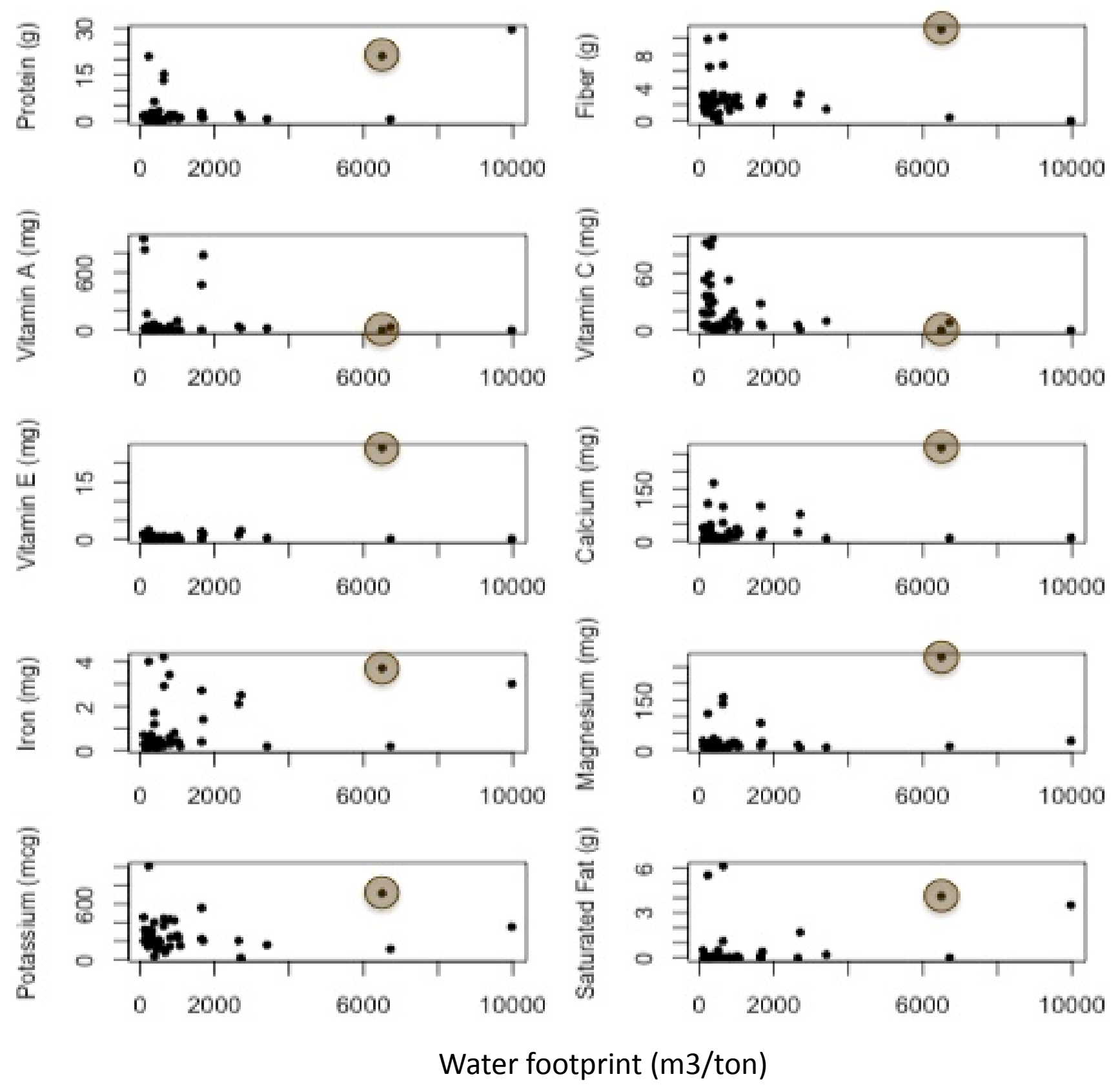




We compared WF with the sales value and total value (for CA) as a way of comparing among crops/foods.

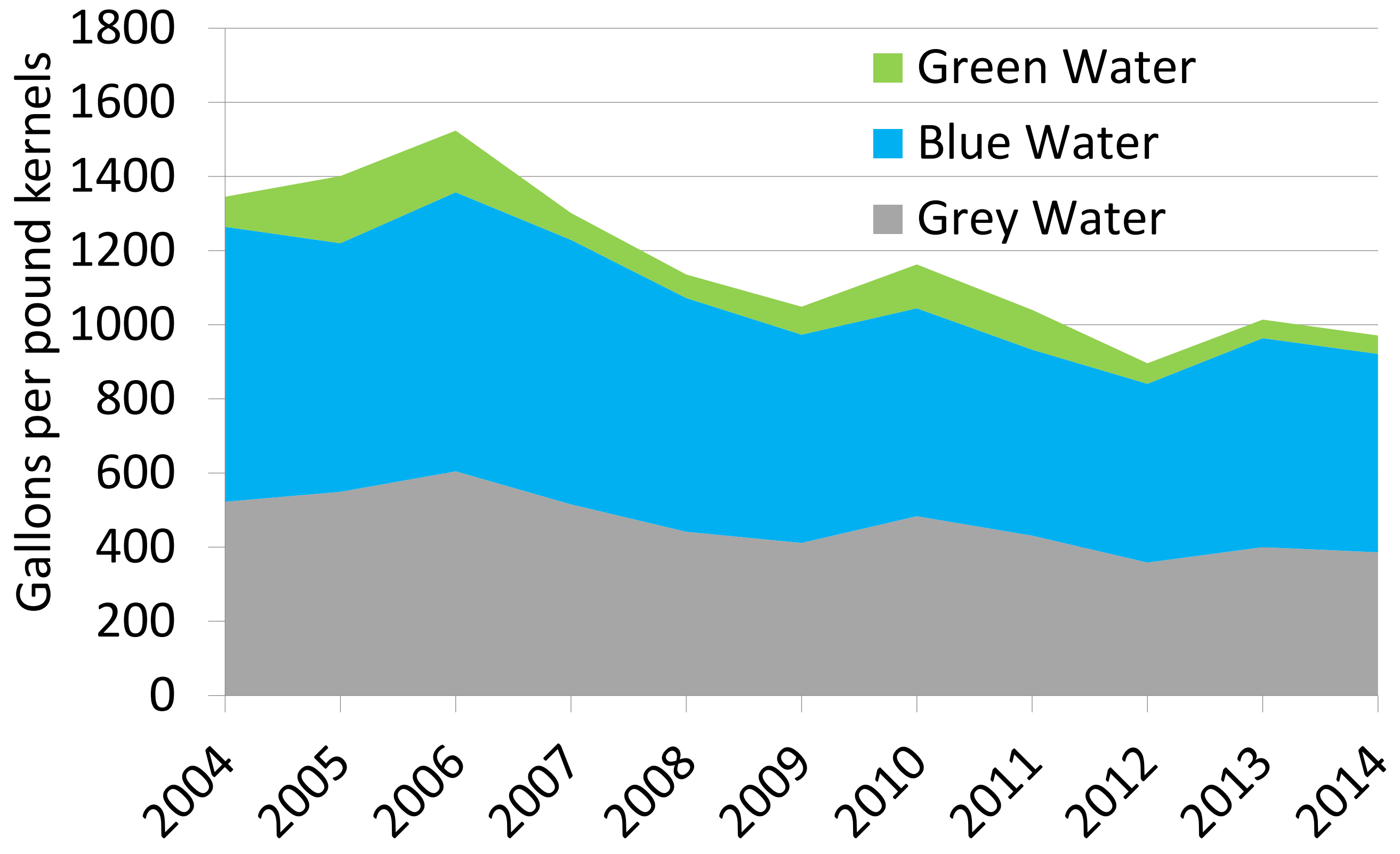
Inter-Crop Comparison of WF & Nutrients

We compared WF with the amounts of specific nutrients available in various common foods. Almonds consistently had the highest or among the highest nutrient concentrations (amount/100 g).

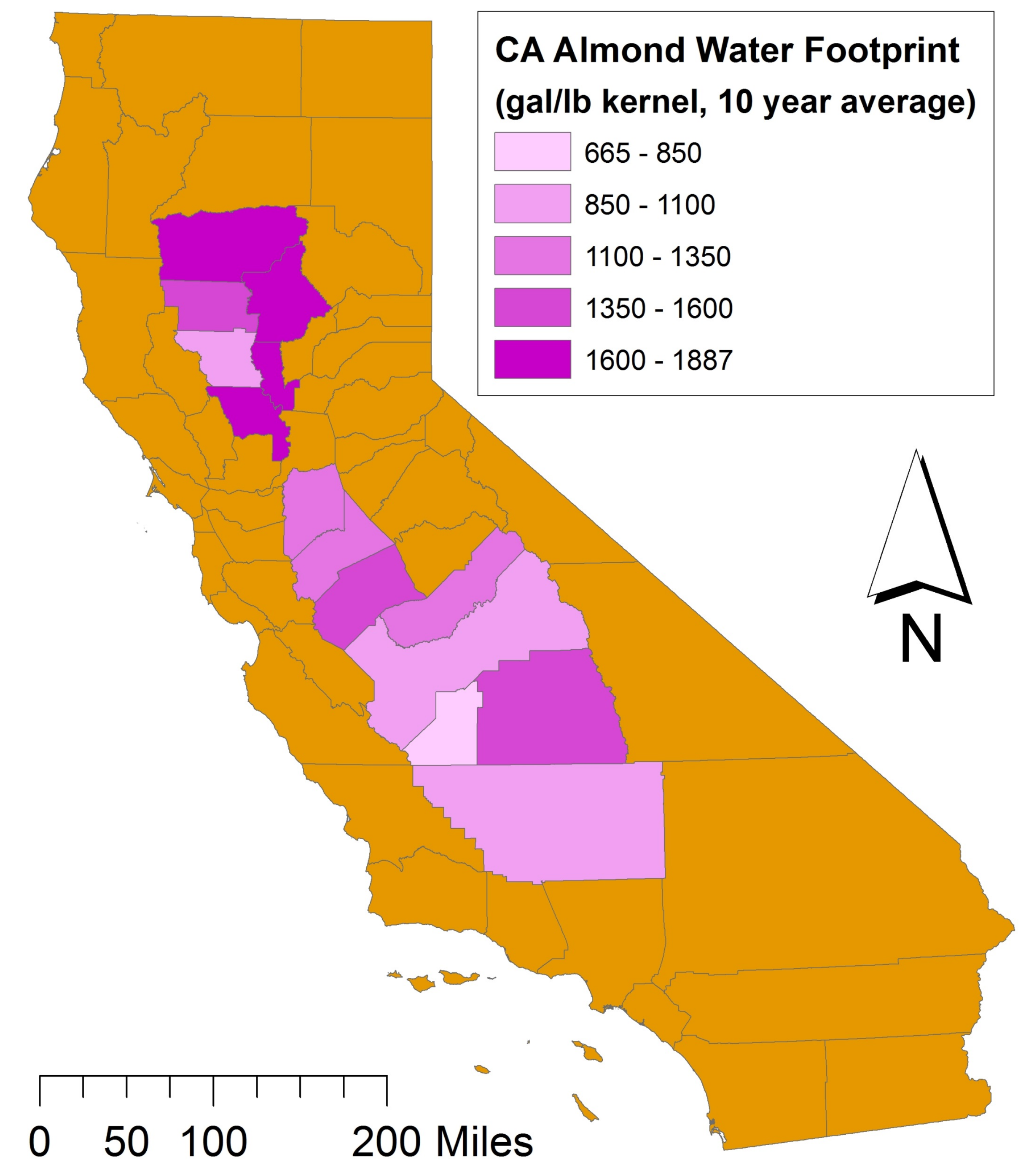


Variability in the water footprint for almonds

We calculated the WF for each year (between 2004 and 2014) and for each almond-producing county. We found that the WF was steadily declining and varied from N to S within the Great Valley.



Inter-annual variation in the water footprint of California almonds



Regional variation in the water footprint of California almonds

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