Improving the (Net) Almond Water Footprint

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Objectives

In this project, we investigated how the water footprint approach could relate to sustainability reporting that growers are already participating in. We also describe the potential impacts of regulation and climate change on future water availability for almond production. We estimated the almond-specific groundwater and surface water requirements for DAU-county units throughout the production area. We then described the impacts that future groundwater availability and reduced Sierra Nevada snowpack could have on future production

1) Match water footprint and LCA/water to existing sustainability reporting carried out by ABC.
2) Associate water footprint with types and sources of water.
3) Investigate geographic variation of current and potential future water availability as it relates to water footprint
4) Describe trade-offs and benefits between water footprint and conservation activities (Phase 2).
5) Compare California almond water footprint to other regions globally and asses overall industry water savings gained through trade (Phase 2).

Background

California grows about 80% of the world's almonds produced in any given year (USDA-FAS, 2015). Almonds are also the top economic-value export crop for California farms, accounting for 25 percent of California's farm exports in 2014 (AIC, 2015), as well as accounting for a total contribution of $21.5b to California's economy in 2014 (Sumner et al. 2015).

Almonds are known for their nutritional value, providing a dense supply of protein, fats, fiber, and micro-nutrients (Chen, Lapsley, and Blumberg 2006). Balancing the environmental impacts (e.g., from water use) of food production with nutritional benefits of foods is increasingly discussed in the press and can occur at the scale of governments and individuals. Successful crops and foods are likely to be those that demonstrate contributions to tasty and healthy diets, economic benefits at the scale of production and consumption, and are demonstrably less-damaging to grow than other foods that provide similar benefits. In the previous project, we showed that almonds had among the highest nutritional benefits among crops.

Because of its water footprint, almond production may also be vulnerable to predictable changes in water availability and quality. Future groundwater use may be vulnerable to regulation under the Sustainable Groundwater Management Act (SGMA). Implementation of the act began with identification of groundwater basins with significant changes in elevation indicating over-drafting. Under the auspices of SGMA, groundwater users must coordinate their activities in relation to groundwater basins. For many groundwater basins in the Central Valley, almond production is one of the largest single users.

Almond production may also be vulnerable to climate change effects on surface water availability. Although a separate discussion of ground and surface water is somewhat artificial, they are managed and diverted in different ways, and both are used in almond production. Climate change is expected to result in a reduction in snow pack in the Sierra Nevada, increases in rain on snow events, and increases in plant evaporative water demand.

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.

Methods

Crop Applied Water Requirements

Irrigated crops' applied water (AW) requirements were obtained from Cropscape database. Almond applied water requirement is needed to calculate separately, as in the database, almond was calculated with pistachios together. Almond orchard age was based on the CropIQ map of almond production areas, commissioned by the Almond Board. We used the almond age to estimate the yield. AW, ET or EP data were from the Cropscape database.

Relationship between blue water footprint and source of water

Almond evapotranspiration (ETc) was calculated using the irrigation calculator (built by Almond Board of California) based on almond trees' age and planted area at the DAU_County level (this unit results from an intersection of DAUs and Counties). The process was as follow, 1) Intersect almond orchard boundary with DAU_County boundary, information about almond orchards, including its planted area and the year of plantation, was obtained; 2) Water demand for almonds at the Dau_County scale was calculated using the irrigation calculator functions derived from three sites in California (North, Mid and South Central Valley), with the almond age and area information. Almond applied water could be estimated by using the proportion of almond ETc to the sum of almond and pistachios ETc and multiplying it with the total applied water of almond & pistachios (data from Cropscape).

$$AW_{almond} = AW_{almond\&pistachios} * (ETc_{almond}/ETc_{almond\&pistachios})$$

Surface Water Use

Surface water use data was obtained from water reports to the State Water Resources Control Board, including information about water diversion points and water rights reporting data for 2015. For water diversion points, points without coordinates and duplicated points with the same application ID number were deleted. For water reporting data, the largest and more unrealistic values (> 2 times the water right value) were removed, after conversation with SWRCB staff about accuracy in reporting. Surface water use for crops was summed for each DAU_County area.

Groundwater Use

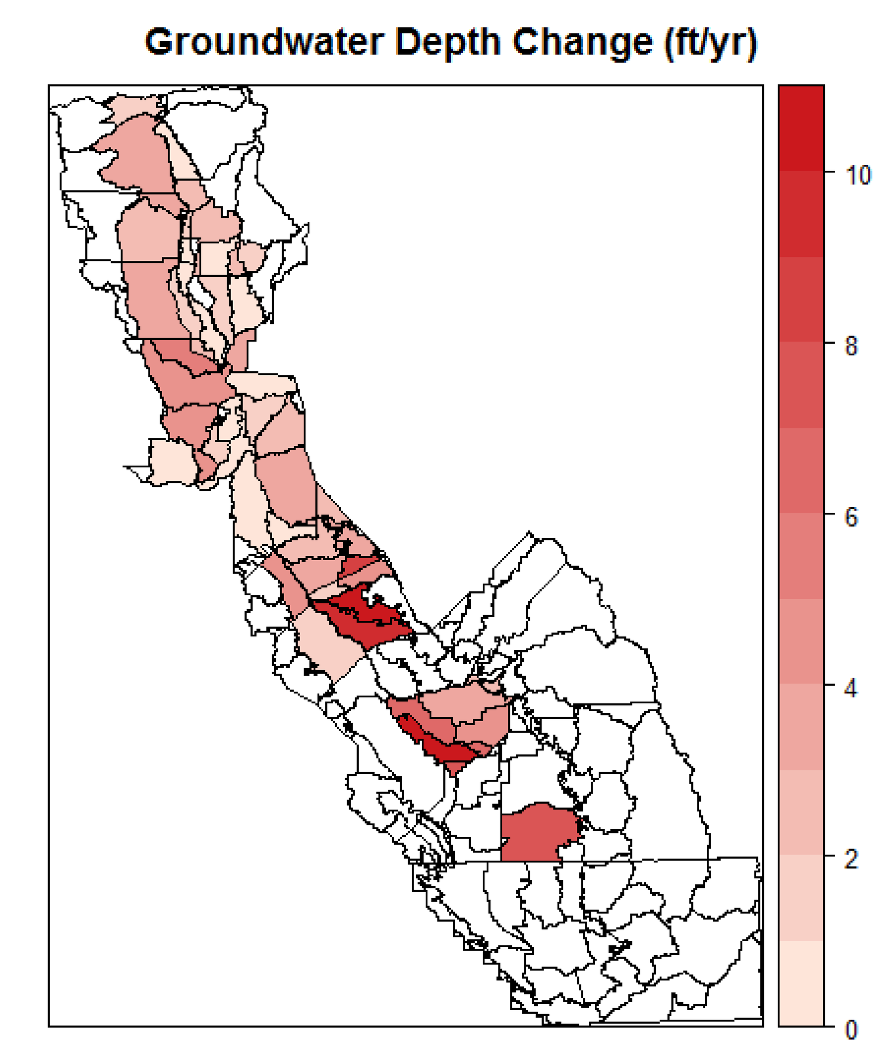
Groundwater use was calculated by subtracting the estimated surface water diverted and used from the total applied water requirement for all the irrigated crops, per DAU_County. Almond groundwater demand was estimated by multiplying the total groundwater need with the proportion of almond (Almond AW divided by all irrigated crop's AW). 1) Using almond ETc, we calculated the proportion of almond using the sum ETc of almond and pistachio; 2) We used this proportion multiplied by the total AW (almond and pistachio) to get almond applied water use value; 3) We estimated groundwater need (Demand (total applied water of all crops)-Supply (total surface water)); 5) Groundwater used for almond production was calculated (total groundwater need* proportion of almond applied water demand)

Groundwater Depth Change

Data for depth below ground surface were downloaded from the DWR Groundwater Information Center website. Data for depth from 2011 spring to 2015 spring was used to obtain the annual groundwater change. For each year, depth measurements for the earliest date were used. For each well, the annual change of depth was obtained using a linear regression model. The change of depth among all wells was averaged for each DAU_County.

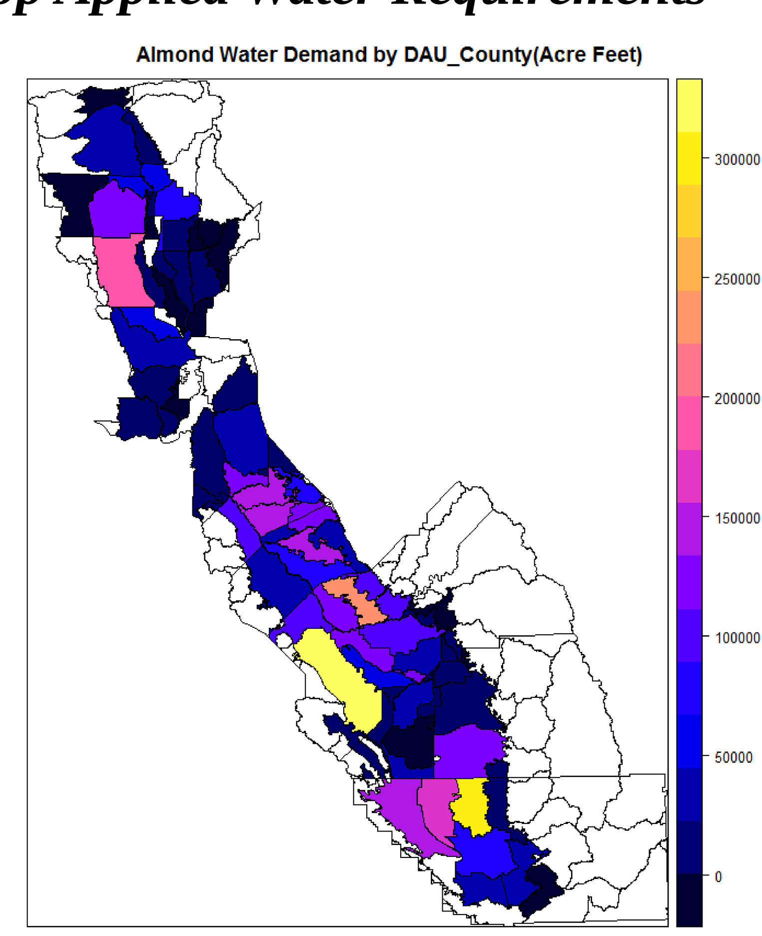
Geographic variation of current and potential future water availability as it relates to water footprint

We compared locations of depleted groundwater to areas of almond production to identify the location and degree of threat to production from groundwater depletion and potential future regulation.

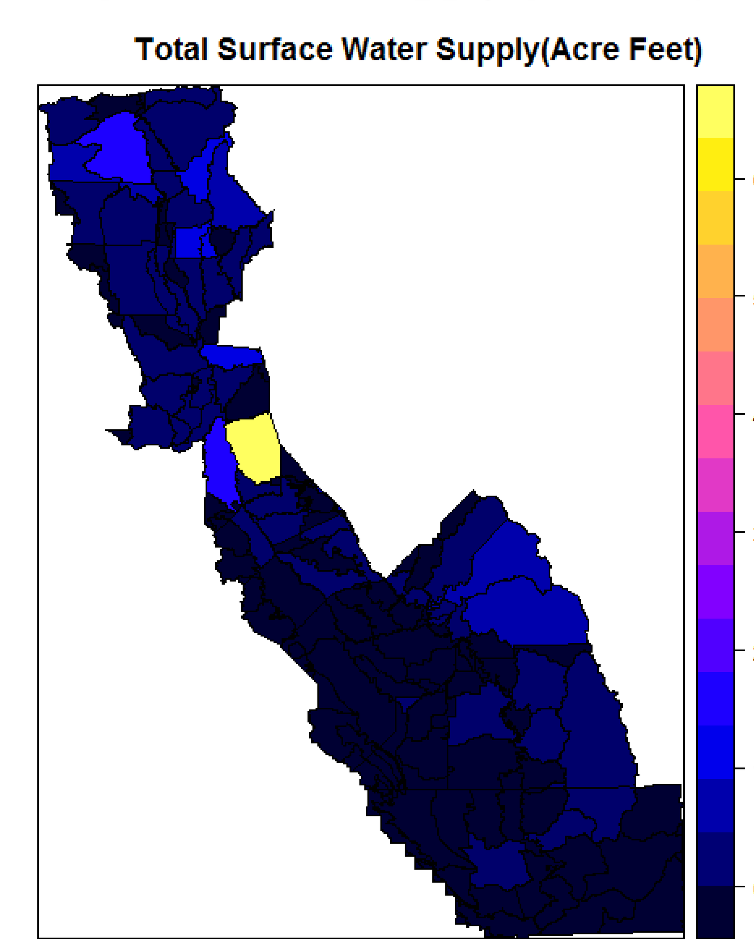


Relationship between water footprint and source of water

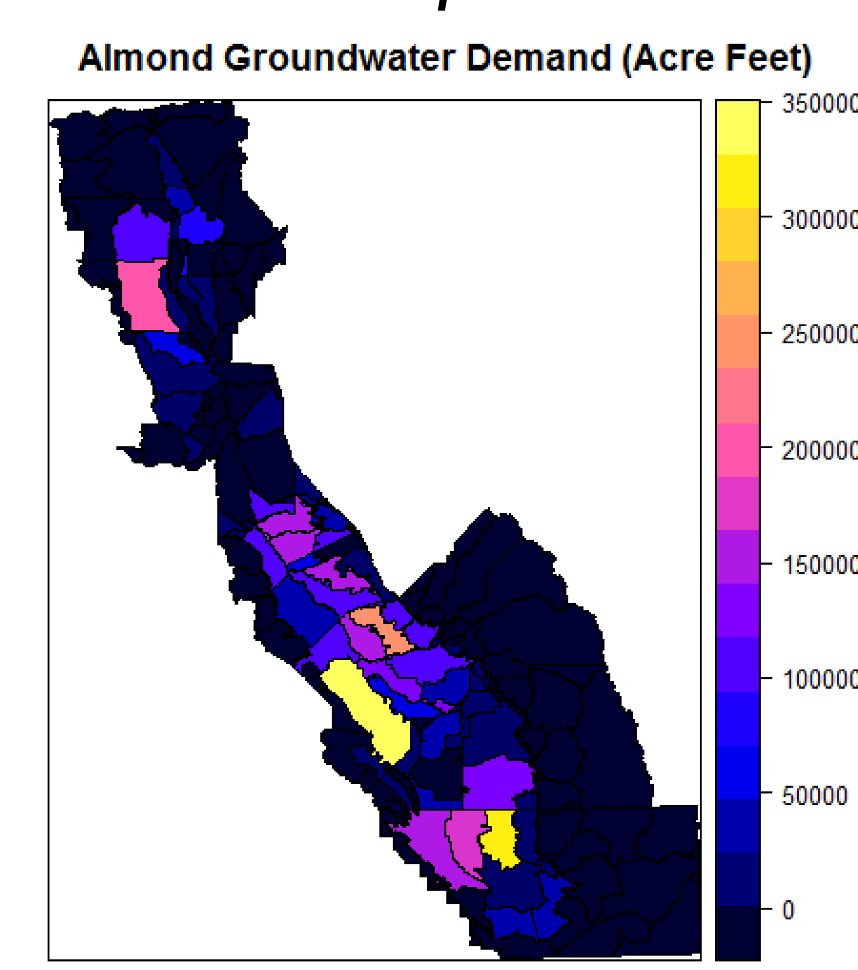
Crop Applied Water Requirements



Surface Water Supply for Irrigation



Groundwater Use for Almond Production



Synergistic Improvements in Almond Water and Carbon Footprints

Understanding the intersection of the California Almond Sustainability Program (CASP) with environmental assessment methods in the scientific field of industrial ecology, namely water footprint assessment (WFA) and life cycle assessment (LCA) can be beneficial to the Almond Board of California (ABC) because WFA and LCA offer methods to consistently assess how environmental impacts change over time and at different scales, from individual orchards to the entire almond industry. As CASP documents (and drives) changes in grower practices, WFA and LCA assessments can provide indication of changes in resulting environmental impacts.

Irrigation Source and Nutrient Management: to the extent that blue WF can be reduced through efficient irrigation management, energy use and associated GHG emissions can be reduced. This is especially true as supplementary irrigation applications might need to be sourced from higher marginal energy- and GHG-intensive supplies, such as deeper groundwater or more distant surface water. More distant surface water supplies, in turn, entail more evaporative losses in their delivery thus marginally increasing blue WF.

Irrigation Technology: the lowest GHG emissions values are found in microsprinkler systems fed by diesel pumps delivering surface water. Higher-pressure systems usually have higher energy costs with associated GHG emissions. Precision irrigation technologies such as subsurface drip irrigation have the potential to reduce evaporative losses almost completely, thus reducing the blue water footprint to levels nearer to actual plant water demand, or even below this level with the practice of regulated deficit irrigation.

Biomass fate: grower practices found to reduce energy use and GHG emission (LCA) indicators generally include keeping as much orchard biomass (byproducts, prunings, and dead trees) within the local farm operation. Practices include open burning, mulching, solid-fuel energy generation, and gasification energy generation with or without by-product (biochar) sequestration in orchard soils. These practices also reduce WF through increasing water and nutrient retention and reducing evaporative losses.