Technical appendix

2.1. Soil stratigraphy

In November 2015, three soil cores were taken down to 13 ft with a Geoprobe push-drill system (Geoprobe Systems, Salina, KS). Cores were opened within 48 hours after coring to take sediment samples for soil texture analysis and to describe stratigraphy. Cores were sampled based on stratigraphy as determined by changes in color or texture. Redoximorphic features were noted throughout the cores. Samples were tested for carbonates using 0.5M HCl. A modified pipette method was used to analyze texture whereby 0.18 oz of soil were placed in 1.69 oz centrifuge tubes with 1.35 oz of 0.5% sodium phosphate and shaken overnight (Soil Survey Laboratory Methods Manual, 1992). After shaking samples overnight, they were hand shaken before a 0.08 oz aliquot was taken 11 seconds (sand fraction) and 1 hour and 51 minutes (clay fraction), respectively and placed in a pre-weighed tin. Tins were oven dried at 221 °F overnight and reweighed the next day. Silt fractions were calculated by subtracting the sand and clay fraction from 1.

The soil stratigraphy at the Delhi site consisted of varieties of sand in the recharge treatment and increasingly finer materials (silt loam and silt) in the control (Supplementary Fig. 1). At Modesto, a lower percentage of clay was found in the recharge treatment than in the control in the surface soil profile at 0-3.3 ft. A clay-rich layer was located at 4.3 ft depth in the recharge treatment and at 3.3 ft depth in the control (Supplementary Fig. 2).

2.2. Root zone hydrology and water percolation

Volumetric water content (VWC) was measured at each site and within each treatment at two randomly selected trees at 0.5, 1.5 and 3.3 ft depths using Decagon GS-1 and GS-3 sensors (Decagon Devices, Pullman, WA). Water for groundwater recharge was provided by the land owner or local water district, who reported total application amounts per event. Using the applied water amounts and VWC data, a water balance model based on the Thornthwaite-Mather procedure (Dahlke et al., 2018; Steenhuis and Van Der Molen, 1986) was set up for each site to estimate the fraction of applied water going to deep percolation (i.e., groundwater recharge) versus to evapotranspiration and to storage in pore space. The model was applied only to the root zone (upper 2 ft), where most evapotranspiration demand takes place.

Attenuation of applied water in the deeper soil profile (transmission zone, 2 to 5 ft) was modeled with a one-dimensional vertical flow model capable of simulating saturated and unsaturated flow. More detailed information on the soil water balance model can be found in (Dahlke et al., 2018).

Rootzone residence time was estimated as the time duration the soil maintained a volumetric water content equal to or exceeding field capacity. Using the observed VWC data the soils at both field sites reached field capacity when removal from water from the soil profile due to gravity slowed down and the tails of the VWC data after rainfall or flooding events flatten out. These values correspond to 0.15 in^3/in^3 for Delhi and 0.3 in^3/in^3 for Modesto.

2.3. Midday stem water potential

Changes in water status of single trees with groundwater recharge were determined by stem water potential (Ψ_{stem}) measurements using the pressure bomb method (Scholander et al., 1965). Measurements were made on shaded leaves close to the stem except in winter, when twigs were used. Each leaf or twig was covered with a plastic bag inside an aluminum foil exterior envelope for an hour prior to sampling. After equilibrium was reached, a razor blade was used to cut the petiole of an encased leaf or the base of an encased twig. The bagged sample was then inserted into a Scholander pressure chamber (3000 series, Soil Moisture Equipment Corp., Santa Barbara, CA, USA).

2.4. In situ root observation and root image analysis

The minirhizotron technique was applied for *in situ* root observation. One minirhizotron tube was installed beside each sample tree with an insertion angle of 60º which could reach to 2 ft soil depth, with five trees in each treatment block and ten trees at each field site. Root images were collected approximately every three weeks from January 2016 to October 2017, using CID-600 In-Situ Root Imager (CID Bio-Science, Camas, WA, USA). Each tube yielded four root images per time of measurement. The size of each window was 19.6 cm wide and 21.5 cm long. Root images were imported and analyzed using Rootfly software (Clemson University, USA). Images were digitally enhanced when needed (generally brighten and increase contrast) and sorted by tube, then processed by depth for the whole series of observation dates. This allowed for checking root appearance and disappearance through time. Roots were manually traced for length and diameter and appearance and disappearance dates were marked as “birth” and “death”. All data were then exported into an Excel spreadsheet, double checked for outliers and mistakes, and total lengths of new root appearance (birth) and root disappearance (death) within each period (three months interval) were calculated.

2.5. Canopy light interception and yield

Photosynthetically active radiation (PAR) below the canopy (PAR_b) of both sides of trees was measured in each replicate treatment during the growing season in 2016 and 2017 using digital photography. A GoPro Hero HD2 digital camera (GoPro Inc., San Mateo, CA, USA) mounted at a height of 1.4 m above the orchard floor on a Kawasaki Mule utility vehicle was used for capturing images of the canopy shadow. Full sun PAR (PAR_a) was recorded simultaneously at the end of each row. All the images were collected at solar noon ± 1 h. Digital images were then processed to calculate the area of canopy shadow using the open source software GIMP 2.8 (The GIMP Development Team 2013, http://www.gimp.org/). Details in the design of the novel digital photographic technique and image processing are described in (Zarate-Valdez et al., 2015). Fraction PAR (fPAR) intercepted by the canopy was calculated with the formula as below:

$$fPAR = \frac{PAR_b}{PAR_a}$$

Yield was measured at harvest in 2015 (pre-treatment), and in 2016 and 2017 by utilizing commercial nut harvesting carts with built-in weigh bars and electronic scales. Subsamples were collected and cracked out by hand to determine almond kernel weight and quality parameters.

2.6. Data analysis

Data were analyzed separately by location. A t-test was used to determine the differences between the means (stem water potential, root growth, canopy light interception and yield) of the two groups of almond trees (under no recharge (control) and recharge treatment, respectively) at a significance level of $\alpha = 0.05$. The t-test effectively tests the null hypothesis that the means of tree physiological responses for each group of trees are not significantly different from each other. A p-value < 0.05 would allow rejection of the null hypothesis and indicates a significant difference in a particular response between the groups of trees.

References

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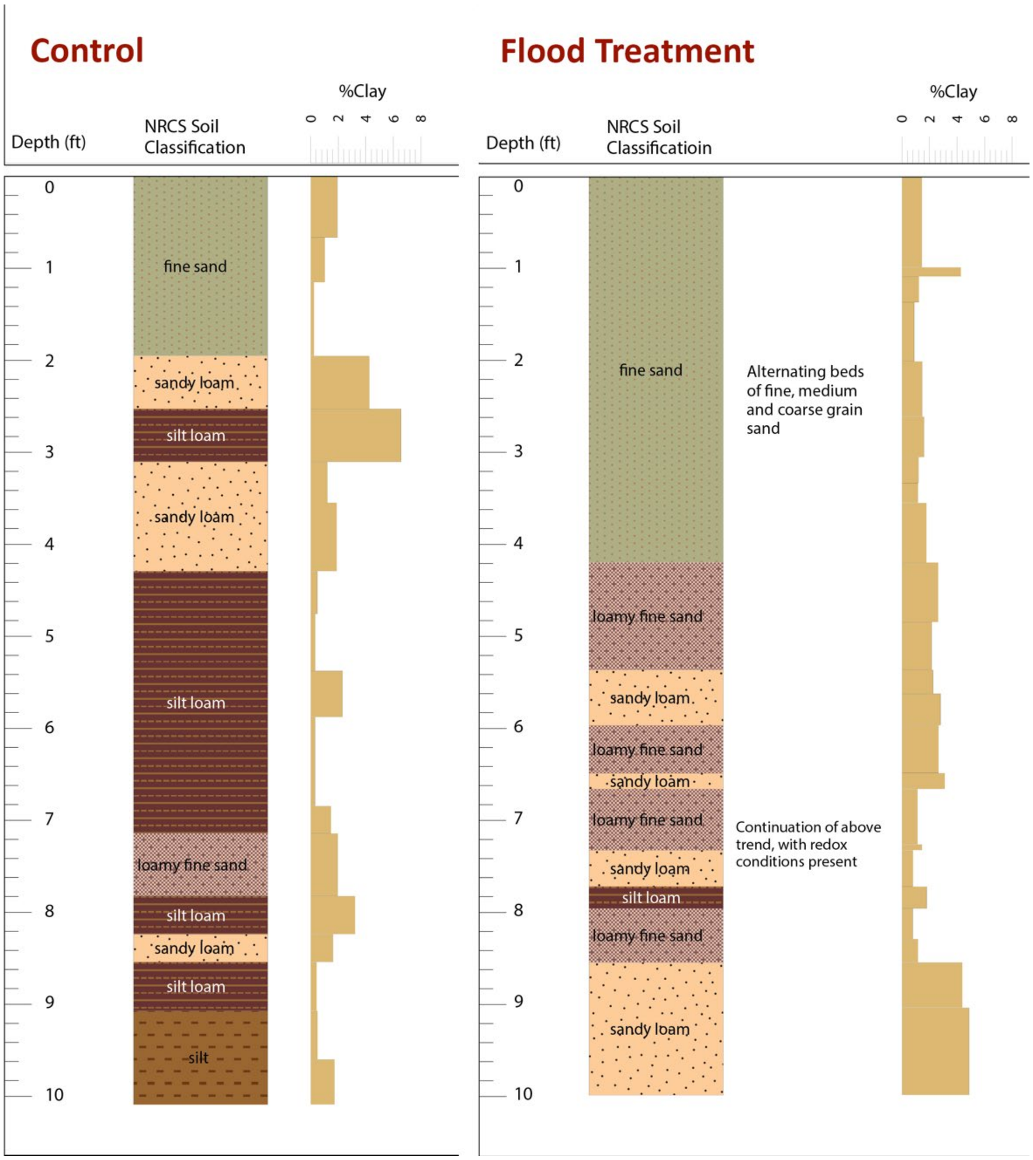
Figure captions

Supplementary Figure 1. Soil stratigraphy and percent clay content in the control and recharge treatments at the Delhi site.

Supplementary Figure 2. Soil stratigraphy and percent clay content in the control and recharge treatments at the Modesto site.

Supplementary Figure 1



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Supplementary Figure 2