# Potential of Whole Orchard Recycling to Improve Soil Health and Water Use Efficiency of Almond Orchards

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## Background

- High commodity prices and costly irrigation water have incentivized orchard turnover and planting of Almond across the Central Valley.
- Closing of power plants and burning restrictions have left growers with few solutions to dispose of tree residues.

**Woodchipping and soil incorporation**

- Whole orchard recycling (WOR), where whole trees are ground and returned to the soil provides an opportunity to recycle biomass while sequestering carbon, retaining nutrients and water, and improving soil health.
- However, long-term benefits of orchard recycling (input of ~ 60 T/h of Carbon) for soil health in Almond orchards remain unclear.
- Healthy soils can provide key benefits to growers such as improvements in irrigation water use efficiency, tree water status and resilience to water shortages.
- This is especially relevant to maintain Almond production in California semi-arid climate (270 mm rainfall on average), where soils are low in organic matter and production relies on increasingly costly fertilization and irrigation.

**Can whole orchard recycling (WOR) improve soil health? Does that benefit water storage, use efficiency of irrigation water and resilience to water shortages?**

## Objectives

- To evaluate the **long-term impacts** of WOR on soil health parameters (physical, chemical, and biological).
- To quantify shifts in tree-soil water relations, including **water use efficiency** and tree water status.
- To examine the potential of WOR to build up **soil carbon storage.**

## Methods

- The trial was established in 2008 at the University of California Kearney Agricultural Research and Extension Center (Parlier, CA) on a sandy loam.
- Half of a 20-year old stone fruit orchard was recycled using land clearing equipment (grind treatment) and the other half was burned (burn treatment). Orchard was replanted with 3 almond varieties (Nonpareil, Butte, and Carmel) in a complete randomized block design.
- In 2017, a deficit irrigation trial was implemented for 28 days from 6/5 to hull split (7/3) on the Nonpareil variety (Fig.1)
  - **Regular irrigation (100% ET)**
  - **Deficit irrigation (80% ET)**

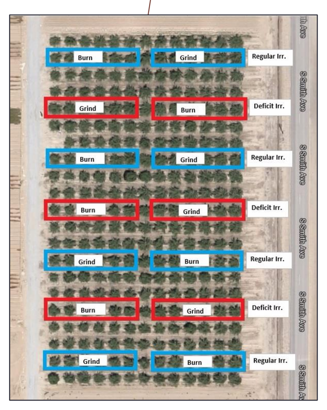
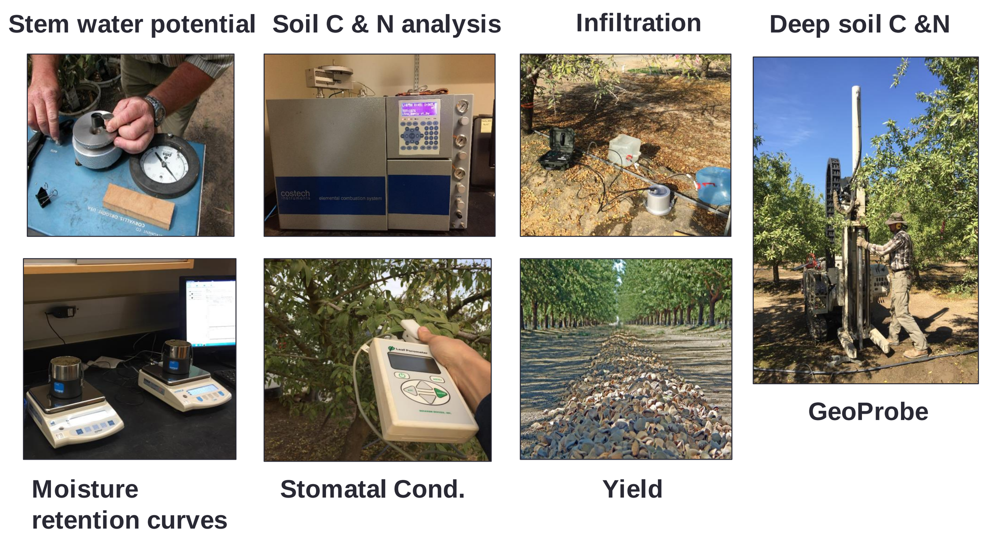


Figure 1. Plot layout and treatments.

**Removing orchard using land clearing equipment (Iron wolf)**

### Measurements

- Soil samples were taken in spring of 2017 to measure soil health parameters (Physical, Chemical, Biological).
- Samples were collected from the berms in between two trees to a depth of 0-15 cm.
- Data were analyzed using Proc Mixed (SAS). Significant differences when $P \leq 0.05$.




## WOR increases long term soil C content and aggregation

- As expected, grind plots had more total C and N, organic C, labile C, and organic matter content compared to the burn treatment (Table 1).

Table 1. Soil chemical properties (0-15 cm).

| Soil test results | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Total C | Org. C | OM | Total N | Labile C (mg/kg) | K (mg/L) | EC | pH |
| | ………………%………………. | | | | | | ds/m | |
| Grind | 0.79 | 0.88 | 1.52 | 0.07 | 250 | 11.06 | 0.57 | 6.94 |
| Burn | 0.55 | 0.62 | 1.07 | 0.06 | 153 | 11.68 | 0.58 | 7.02 |
| p Value | 0.001 | 0.001 | 0.001 | 0.05 | 0.04 | 0.39 | 0.45 | 0.39 |
| | Mg (meq/L) | Ca (meq/L) | Na (meq/L) | Zn (ppm) | Cu (ppm) | Mn (ppm) | Fe (ppm) | B (mg/L) |
| Grind | 1.46 | 3.02 | 0.89 | 9.69 | 9.25 | 9.03 | 33.23 | 0.3 |
| Burn | 1.43 | 3.05 | 0.72 | 9.64 | 9.26 | 6.79 | 28.01 | 0.31 |
| p Value | 0.47 | 0.48 | 0.03 | 0.47 | 0.5 | 0.01 | 0.11 | 0.4 |

*P* values ≤ *0.05* indicate significant difference between the treatments

- + 14.6 T/ha C stored in the grind plots across the soil profile compared to the burn; + 58% TC (0-30 cm) in the grind, 9 years after incorporation (Fig. 2).

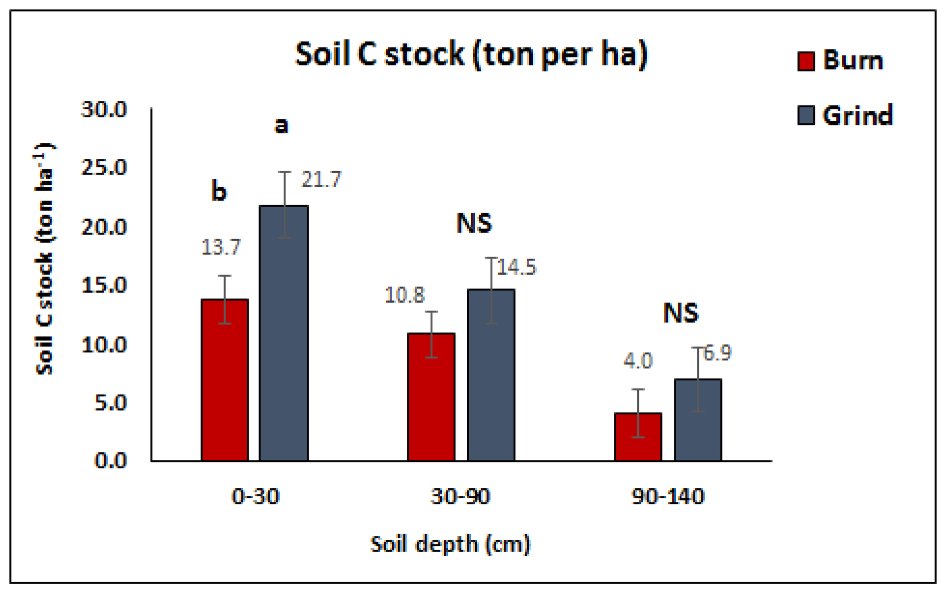



Figure 2. Total carbon stored in the grind and burn soil at different soil depths. Different letters indicate significant difference between the treatments ($P \leq 0.05$). NS, no significant difference.

- 14% greater C storage in large macroaggregates and 34% greater N content in the silt and clay fractions of the grind treatment (Fig. 3).

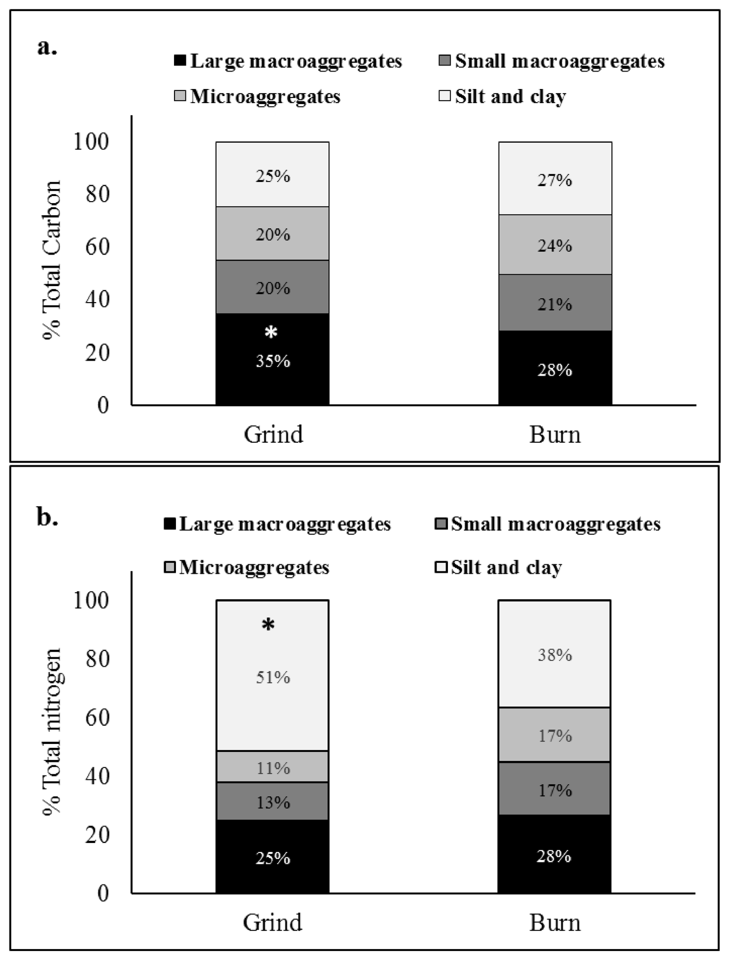



Figure 3. Total carbon and nitrogen content in different soil aggregate sizes (a and b, respectively), * Significant difference at $P \leq 0.05$.

- WOR improved wet aggregate stability (+19%) compared to the burn treatment (Fig. 4).

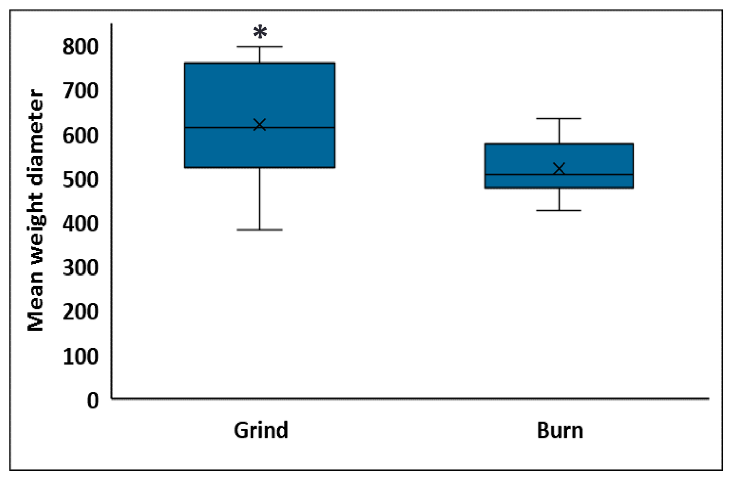



Figure 4. Mean weight diameter in the grind and burn treatments. *Significant difference at $P \leq 0.05$.

## WOR increases, infiltration, water retention, and soil biological activity

- Higher infiltration rate in the grind treatment compared to burn (a). 32% greater moisture retention at field capacity in the grind plots (b) (Fig.5).

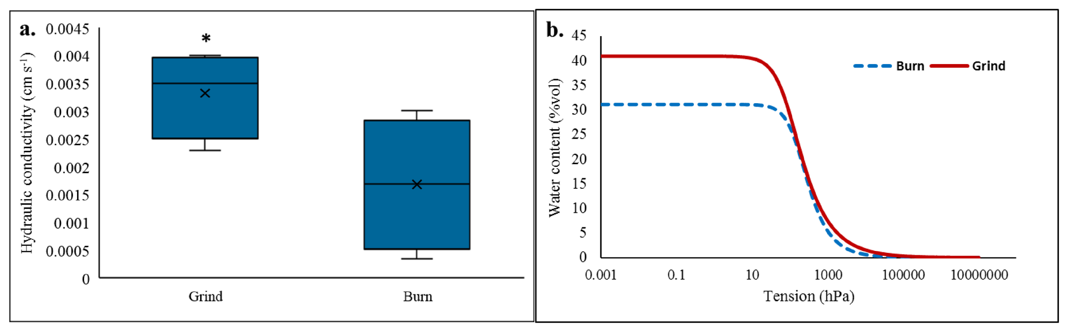


Figure 5. Infiltration rate, measured as hydraulic conductivity (a), and water retention curves (b) in the grind and burn treatments. *Significant difference at $P \leq 0.05$.

- WOR increased soil microbial biomass, + 46% and + 14% (MBC and MBN, respectively) (Fig. 6).

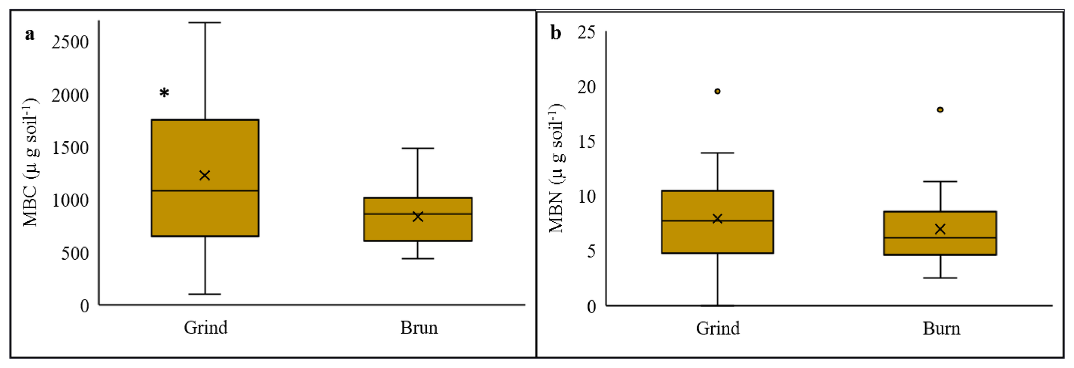


Figure 6. Microbial biomass carbon (a) and nitrogen (b) in the grind and burn treatments. *Significant difference at $P \leq 0.05$.

- Higher activity of carbon and nitrogen cycling enzymes in the grind plots (Fig. 7).

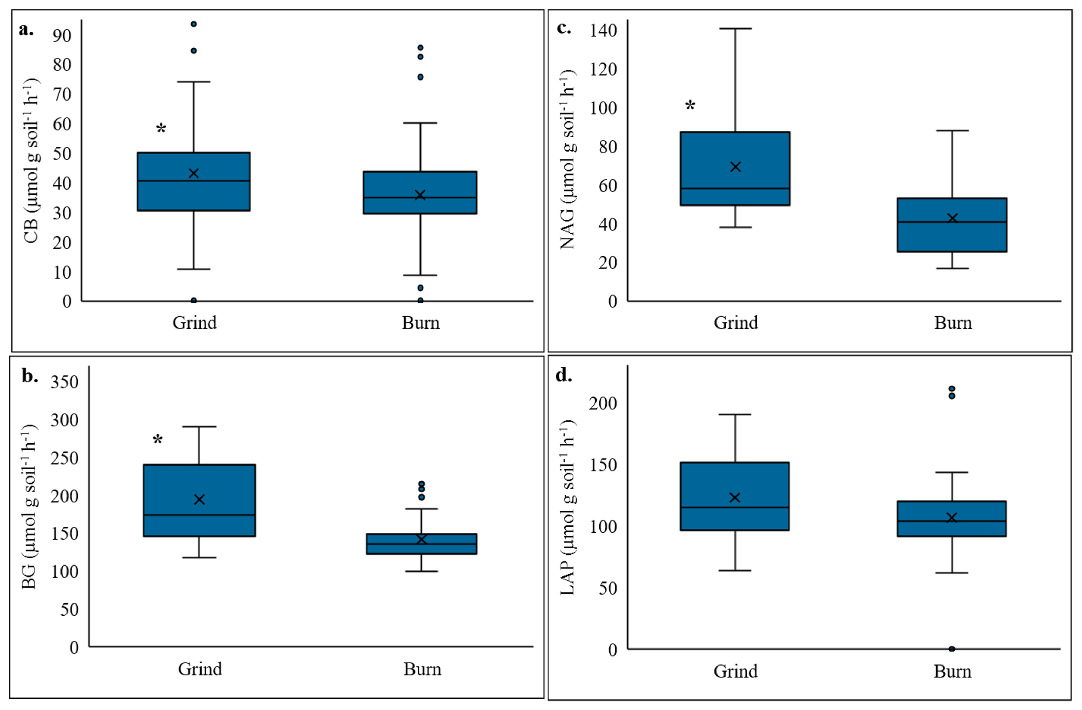


Figure 7. Soil enzyme activity in the grind and burn plots. *Significant difference at $P \leq 0.05$.

## WOR improves tree water status

- Higher stomatal conductance (+ 9.7%) in the grind treatment under both irrigation scenarios (Fig. 8).

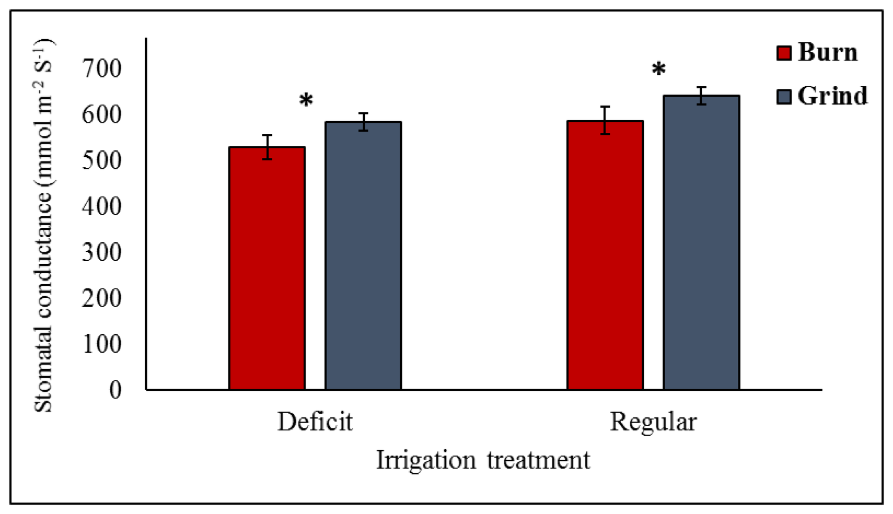



Figure 8. Effect of WOR and irrigation treatments on stomatal conductance. *Significant difference at $P \leq 0.05$.

- Less negative stem water potential in the grind plots on the most stressed day and a week after regular irrigation was resumed (Fig. 9).

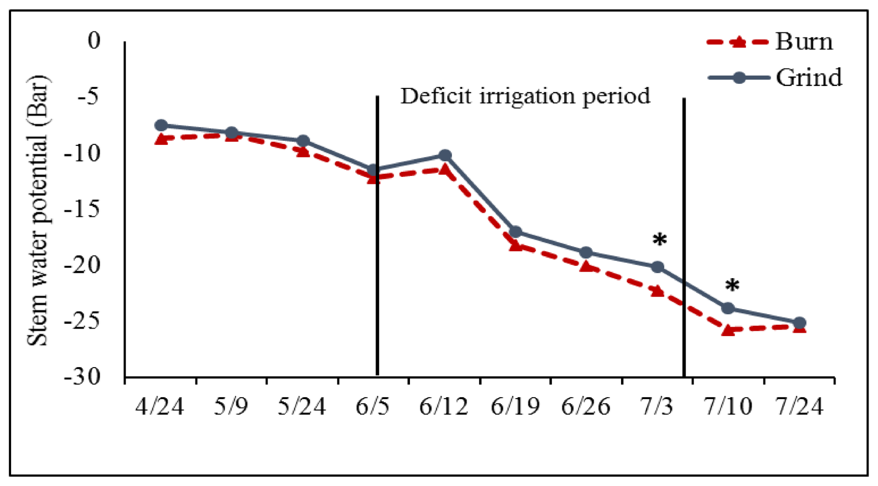
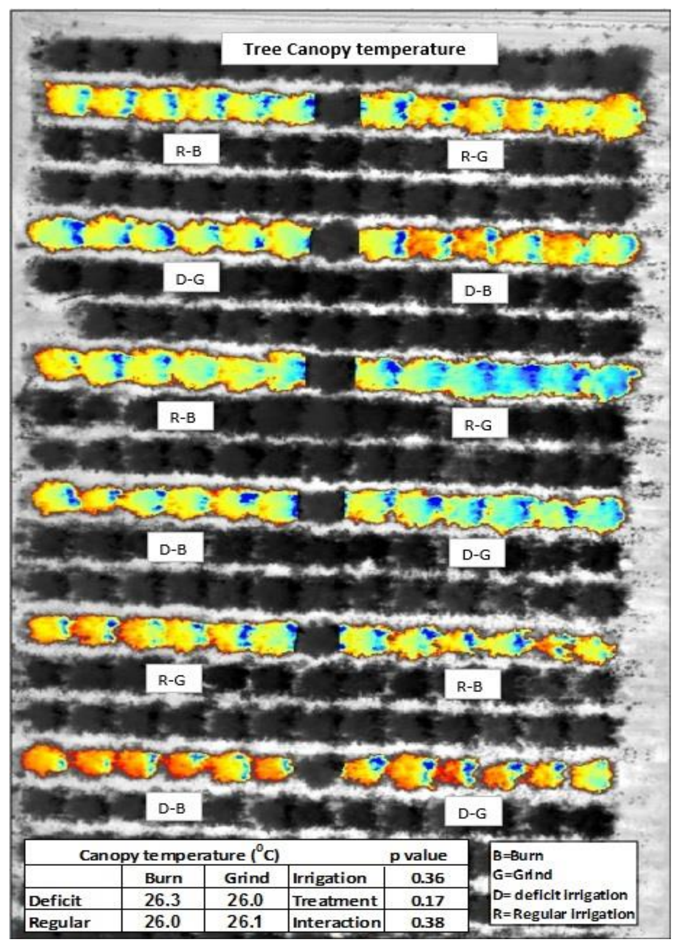



Figure 9. Stomatal conductance in the grind and burn treatments. *Significant difference at $P \leq 0.05$.

- We did not detect any significant effects of WOR on tree canopy temperature.




## WOR increases yield and water use efficiency

### Yield

- Yield benefits of the grind treatment under both regular and deficit irrigation treatments. Benefits were up to 20% in regular irrigation (Fig. 10).

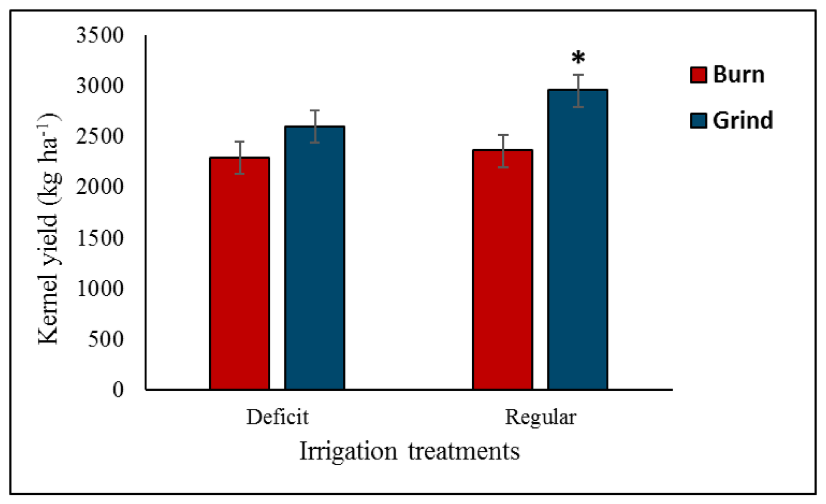
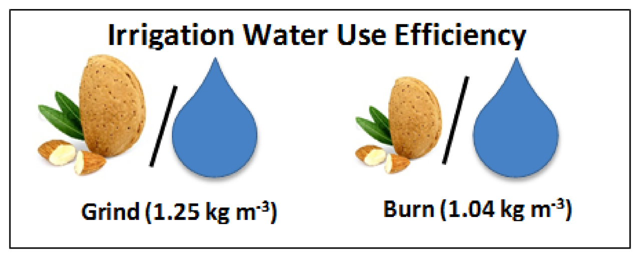



Figure 10. Kernel yield at WOR and irrigation treatments. *Significant difference at $P \leq 0.05$ between grind and burn within irrigation treatments.

### Irrigation water use efficiency (IWUE)




- 20% higher IWUE in the grind plots

## Conclusions and next steps…

- Overall soil health indicators (physical, chemical, and biological) were improved in the grind plots, 9 years after incorporation compared to open field burning.
- The C-rich residues and abundant fungi likely formed and stabilized macroaggregates which, coupled with increased SOC, and improved soil hydraulic properties.
- This study is part of a wider project monitoring the impacts of WOR and the different methods involved in sustainability. Analysis of shifts in multiple other ecosystem services will clarify the potential to improve sustainability of Almond production in California.
- Studying long term and short term effects of whole orchard recycling on soil nitrogen retention (ongoing).
- In a soil column experiment using 15N labeled fertilizer, we will measure processes involved in soil N availability and retention such as gross N mineralization, immobilization, and leaching.

## Acknowledgements

This project is funded by the Almond Board of California and California Department of Food and Agriculture. Thanks to members of the Gaudin and Browne labs. Support from the Department of Plant Sciences, UC Cooperative Extension, and Kearney Agricultural Research and Extension Centers are highly appreciated.

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