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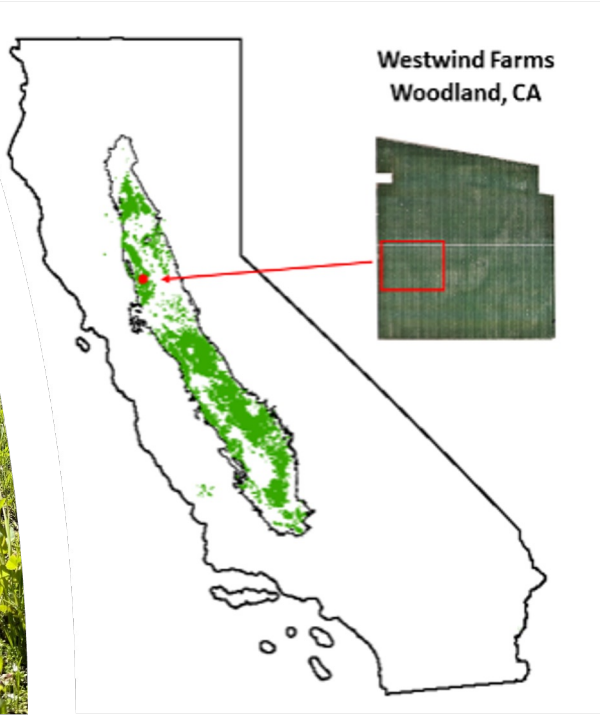


Almond hulls and shells as potassium rich organic matter amendments

Sydney L. Cho, Ellie M. Andrews, Patrick H. Brown, and Sat Darshan S. Khalsa – UC Davis

Quick summary

Benefits of almond hulls & shells

Potassium (K)	Water	Soil
Hull & shell layer released K rapidly as water was applied	Amended catch frame soil had higher water infiltration rate and reduced soil surface evaporation compared to control soil	After year 2, amended catch frame soils had increased soil bacteria, fungi, and beneficial subgroups (saprophytes and arbuscular mycorrhizal fungi)
Hulls & shells decomposed by half after year 1, and by 90% after year 2	Upper 0-10 cm of the soil had significantly higher soil moisture and more moderate temperatures than control soil	Higher Total C and N in microaggregate and macroaggregate soil fractions in the amended catch frame soils compared to the control

- **Reference costs of K**
  - Almonds have a high K demand: 75 lbs K/1000 lbs kernel produced (Muhammad et al., 2015)
  - For a 3000 lbs kernel/acre:
    - 270 lbs K_2O
    - 80% SOP $ 0.60 lb
    - 20% KTS $ 4.54 gal

→ **Grand total of $211/acre**

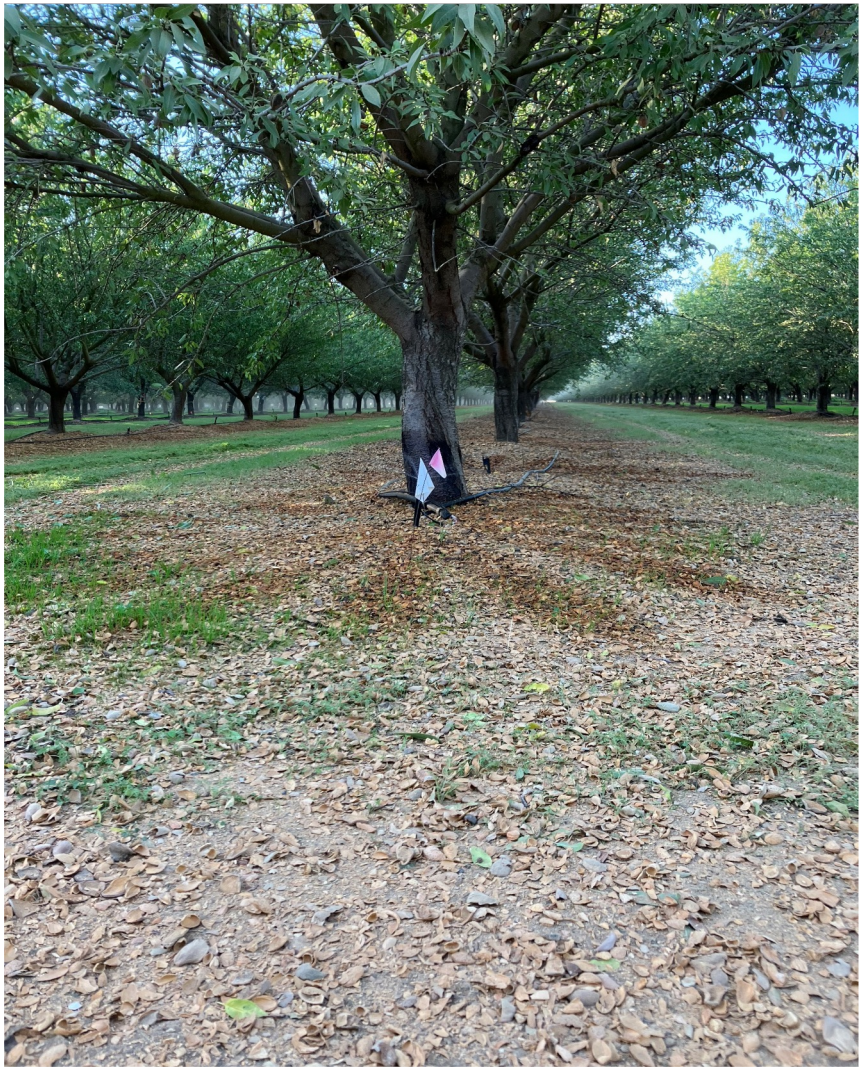
Introduction

California Almond Systems

Potassium Cycling

Water Dynamics

Soil Health



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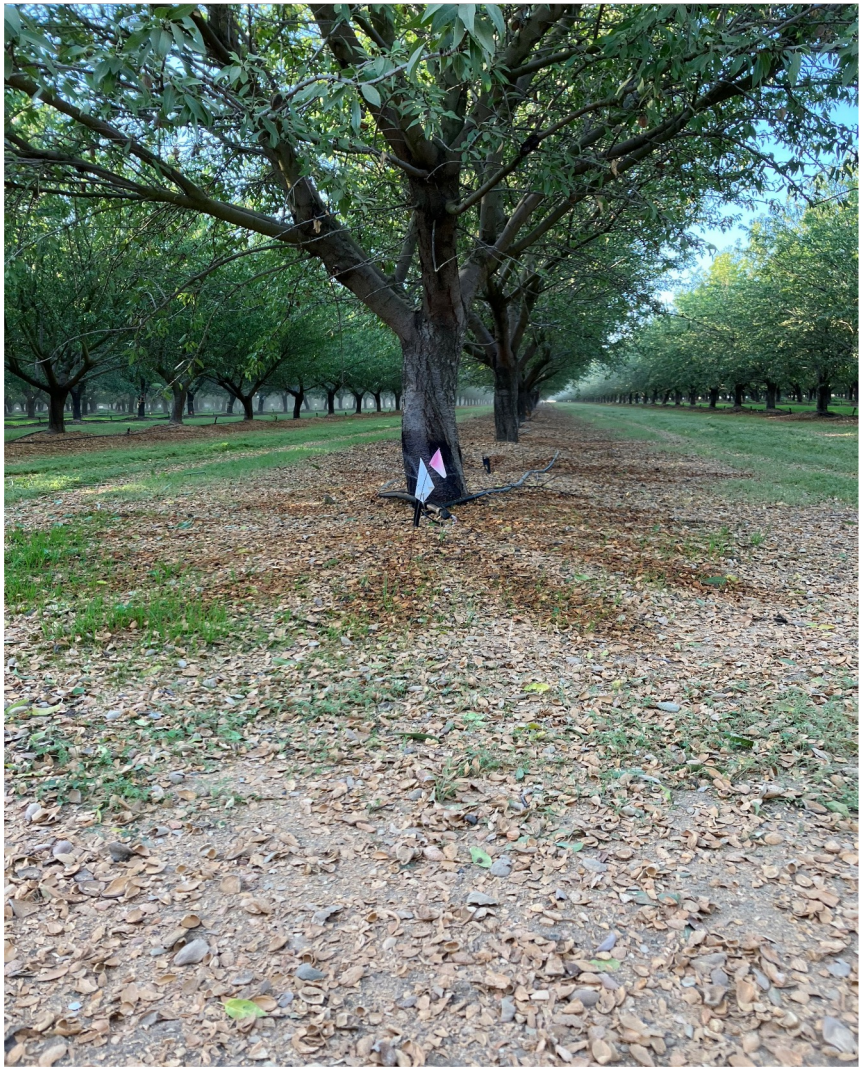
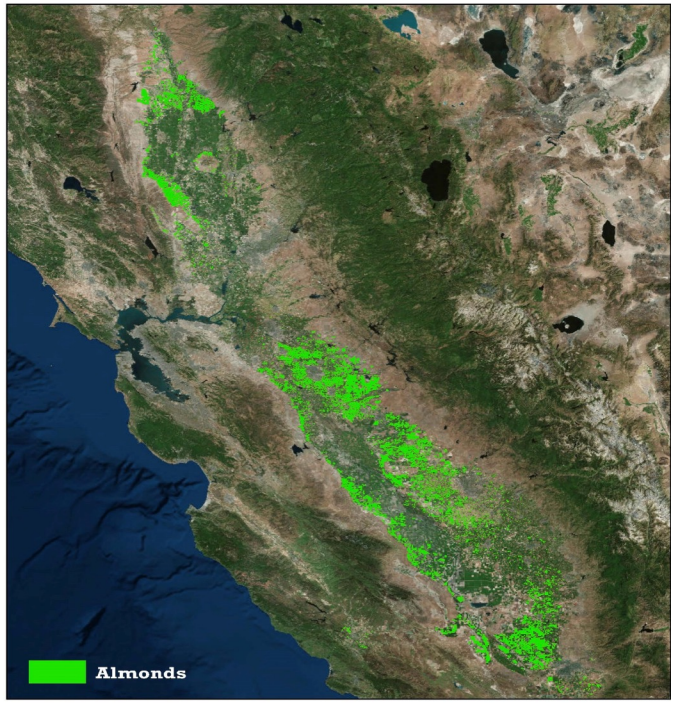


Background

- 1.64 million acres of almonds in CA in 2021 (USDA NASS)
- Need a sustainable use for billions of pounds of almond hulls & shells
- Recycling hulls & shells as organic matter amendments may improve soil and plant functions in almond orchards

Almond hulls & shells at almond processing facility in Winters, CA



2023 almond acreage, Almond Board of CA, Land IQ

Harvest approaches

On-ground harvest

Shake trees, crop falls onto ground

Sweep crop into windrows in alleyway

Off-ground harvest

Shake trees, catch frame funnels crop into alley

Undisturbed topsoil in tree rows

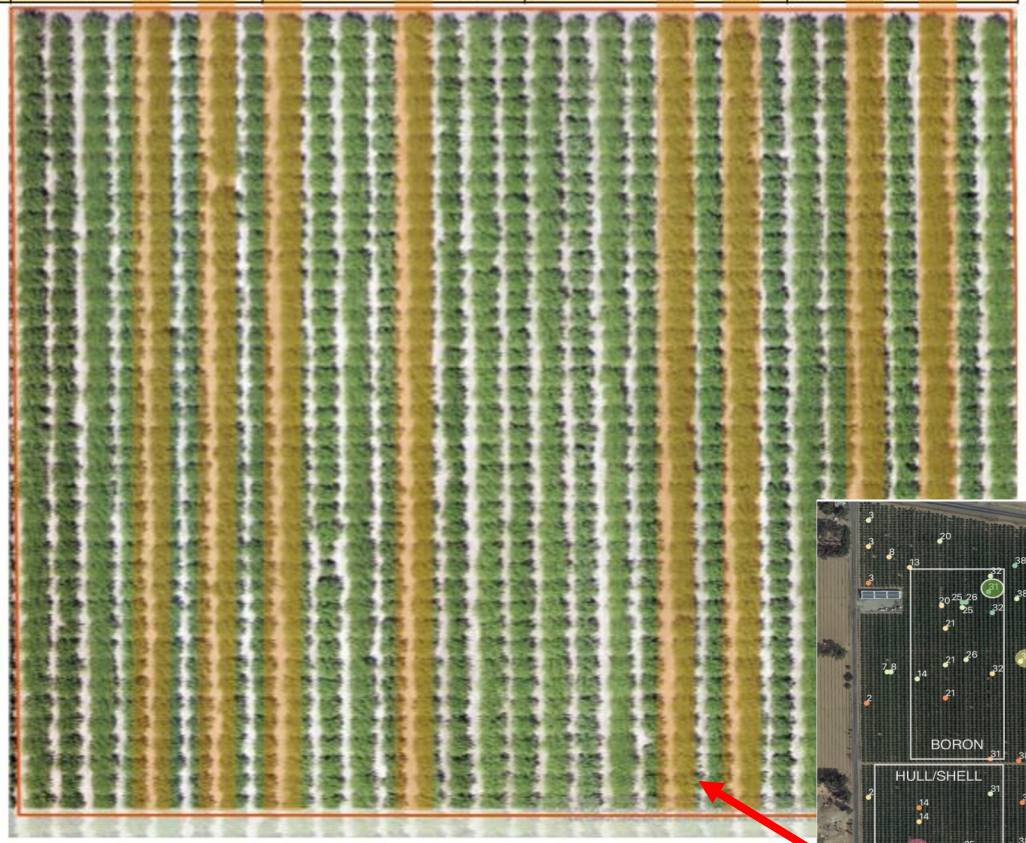
Sustainability goals

- Currently, laying nuts in windrows
- Future goals: remove hulls in the field and/or dry off-site to allow for zero soil disturbance

Woodland, CA – Hull & Shell Trial

Block	1				2				3				4			
Treatment	T2	T1	T4	T3	T3	T2	T4	T1	T1	T2	T3	T4	T2	T3	T4	T1
Row #	3	5	7	9	11	13	15	17	19	21	23	25	27	29	31	33

N



Westwind Farms

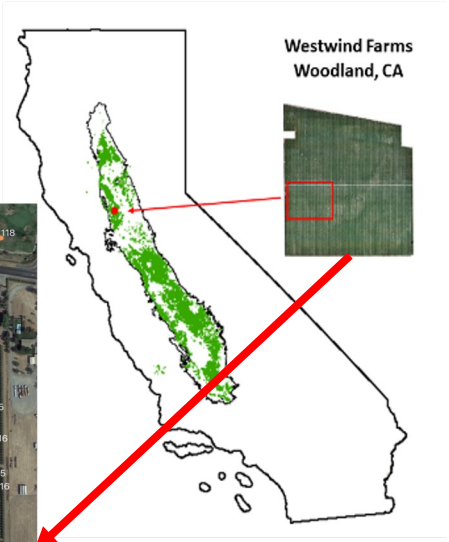
Hull & Shell Treatments

T1: no amendment, on-ground harvest

T2: no amendment, catch-frame harvest

T3: 8 tons/ac amendment, on-ground harvest

T4: 8 tons/ac amendment, catch-frame harvest



Research Questions

(1) How does soil fertility, physical properties, and microbial community composition under almond hulls & shells shift with on and off-ground harvest in the tree row after two years of treatment application?

(2) How do yearly fall applied almond hulls & shells impact nutrient status and short-term decomposition in the following Winter and Spring?

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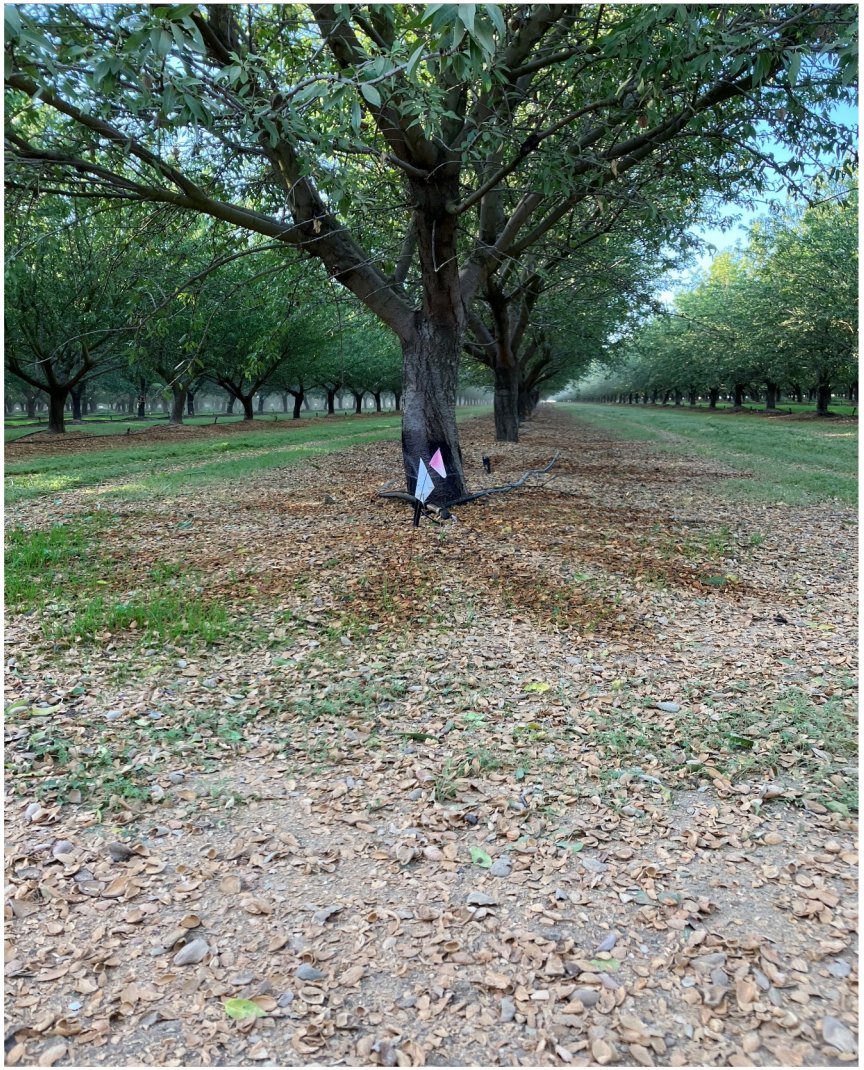
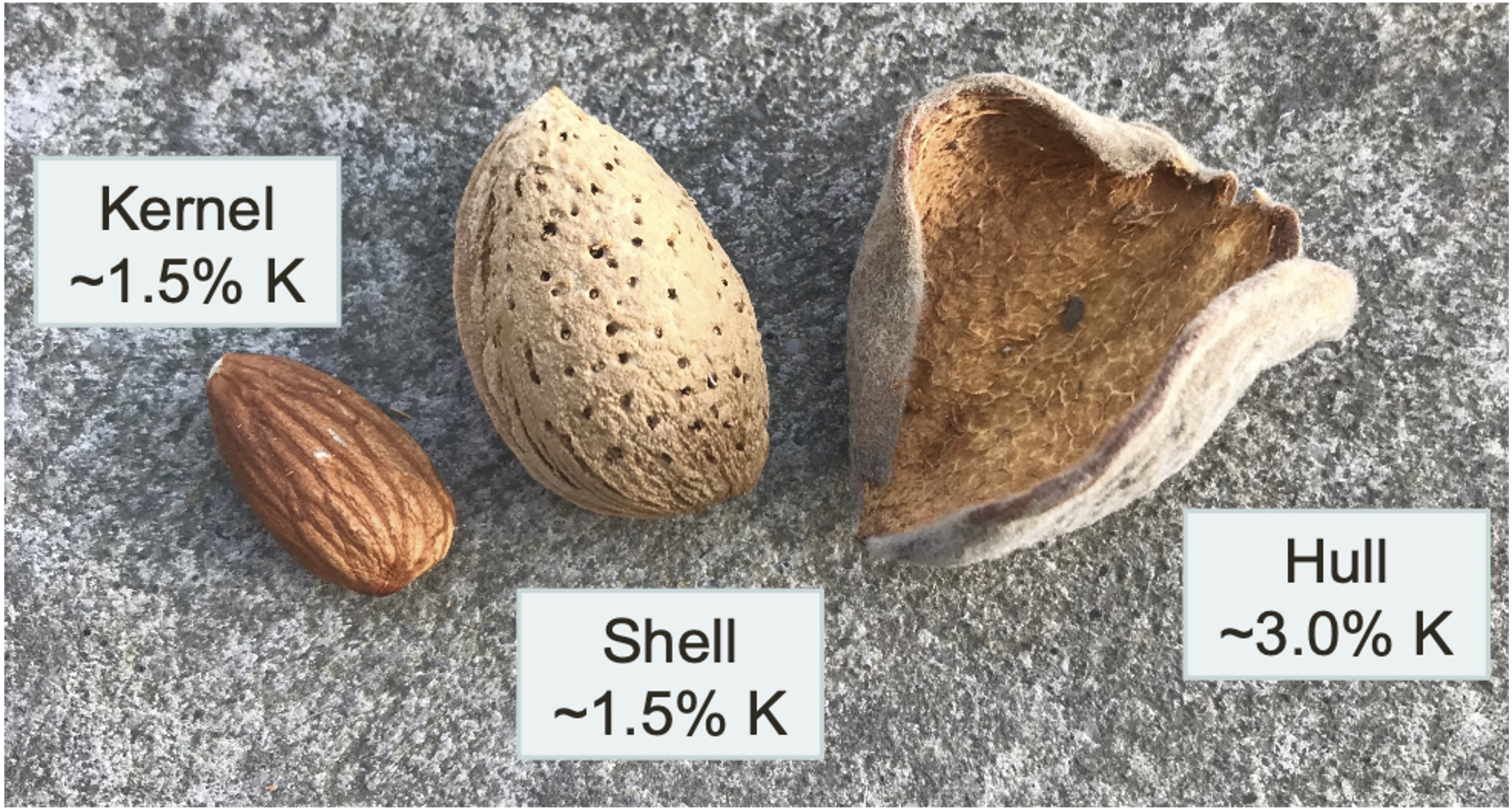


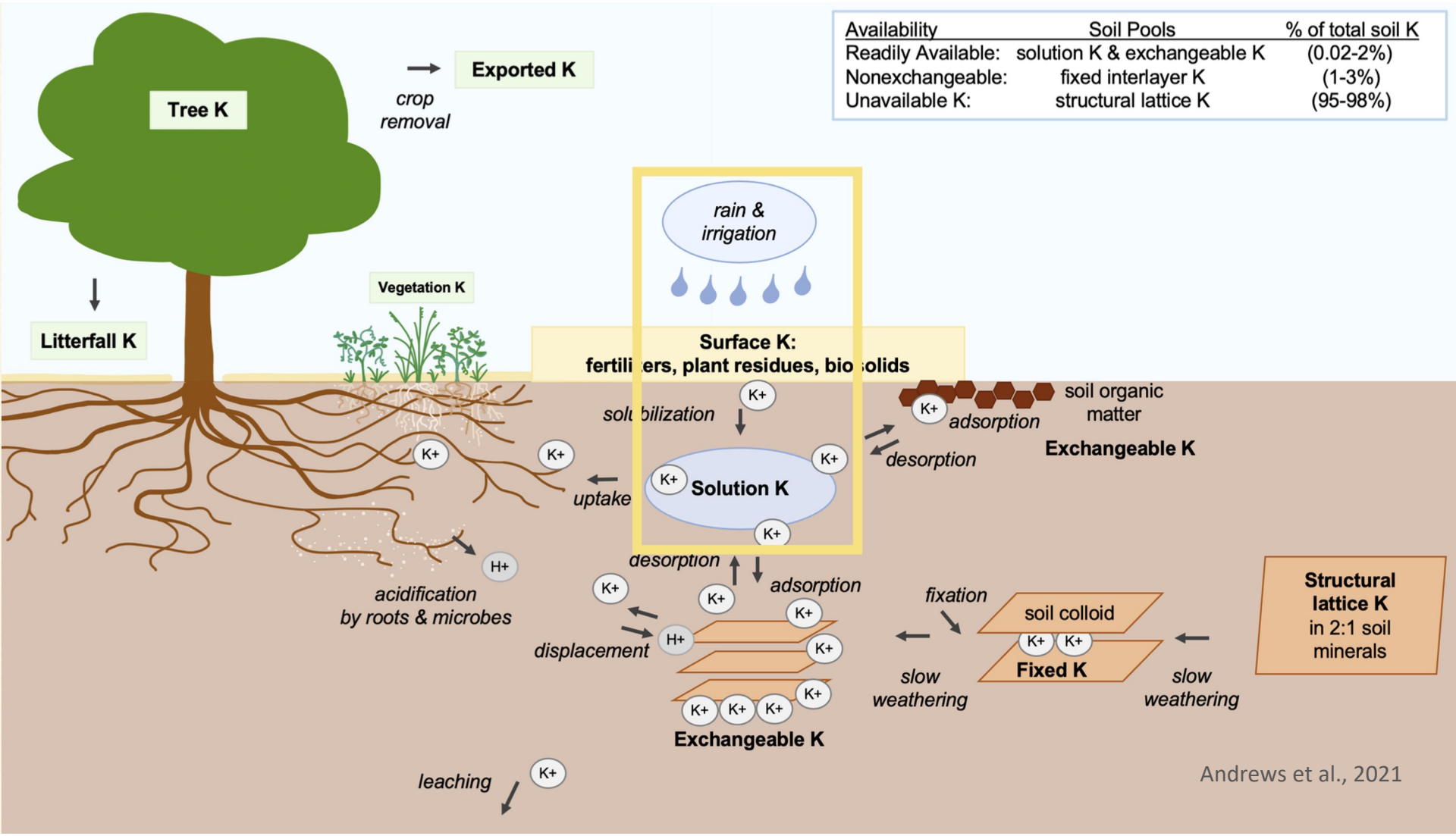
Almond fruit parts



Andrews et al., 2021

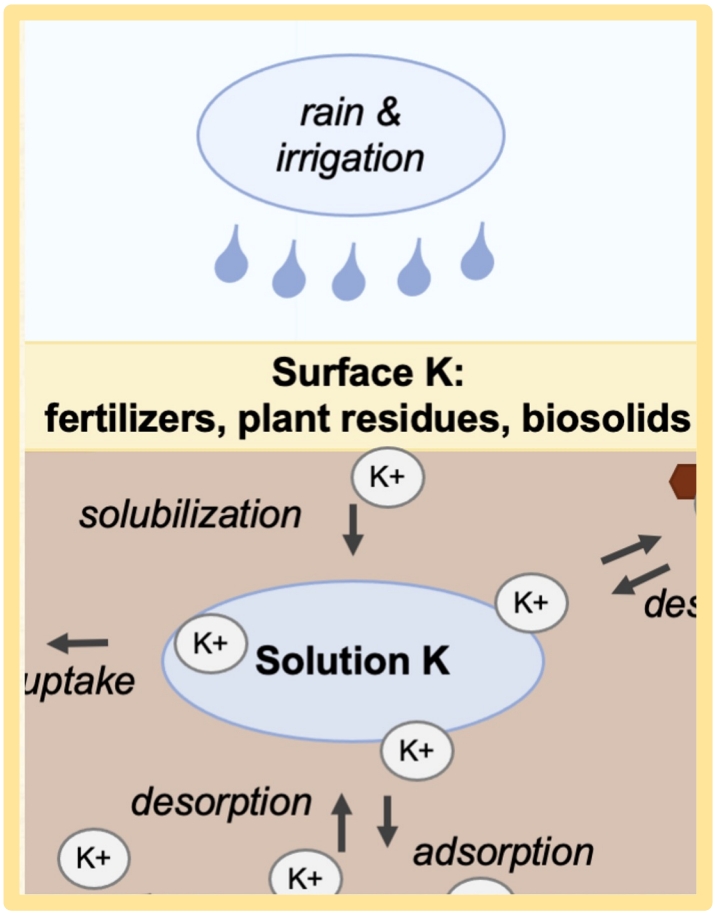
- 90% of whole tree annual K uptake from 3 fruit tissues
- 68% whole tree annual K uptake from hulls & shells

Potassium cycling



Andrews et al., 2021

Water drives K solubilization



Andrews et al., 2021

- K release from amendments
  - Driven by water
  - Not initially limited by decomposition of C:N
- Occurs faster than other nutrients
- Provides K+

K contributions from hulls & shells

Material	Composition	C:N ratio	%K
Almond hull & shell mix	25% hulls, 75% shells	63:1	1.89

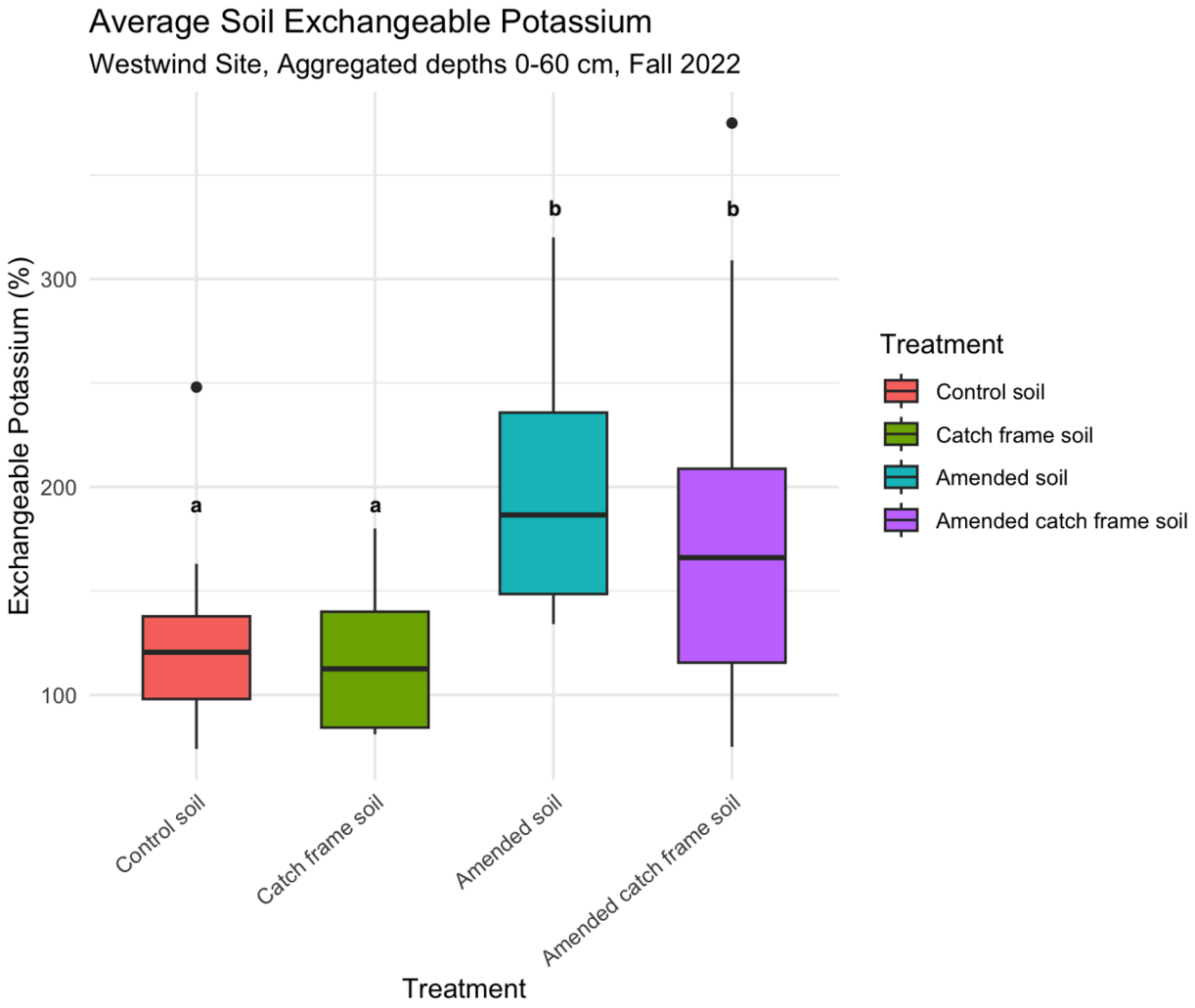
Almond hull & shell material applied on 10/7/22

- **K contributions from 8 tons/ac of fresh almond hulls & shells were 446.5 kg/ha (398.6 lb/ac)**
- Almonds have a high K demand: 75 lbs K/1000 lbs kernel produced (Muhammad et al., 2015)
- For a 3000 lbs kernel/acre:
  - 270 lbs K_2O
  - 80% SOP $ 0.60 lb
  - 20% KTS $ 4.54 gal
  - **Grand total of $211/acre**

Amended soil with hulls and shells

Bare soil

Soil exchangeable potassium (XK)



- XK in amended soil ~200 ppm and in amended catch frame soil ~180 ppm
- XK in soil ranges from 100-150 ppm
- Maintaining the amendment with off-ground harvest may improve soil XK overtime and replace some/all of K crop demand

Amended soils indicate significantly higher XK readily available for the plants

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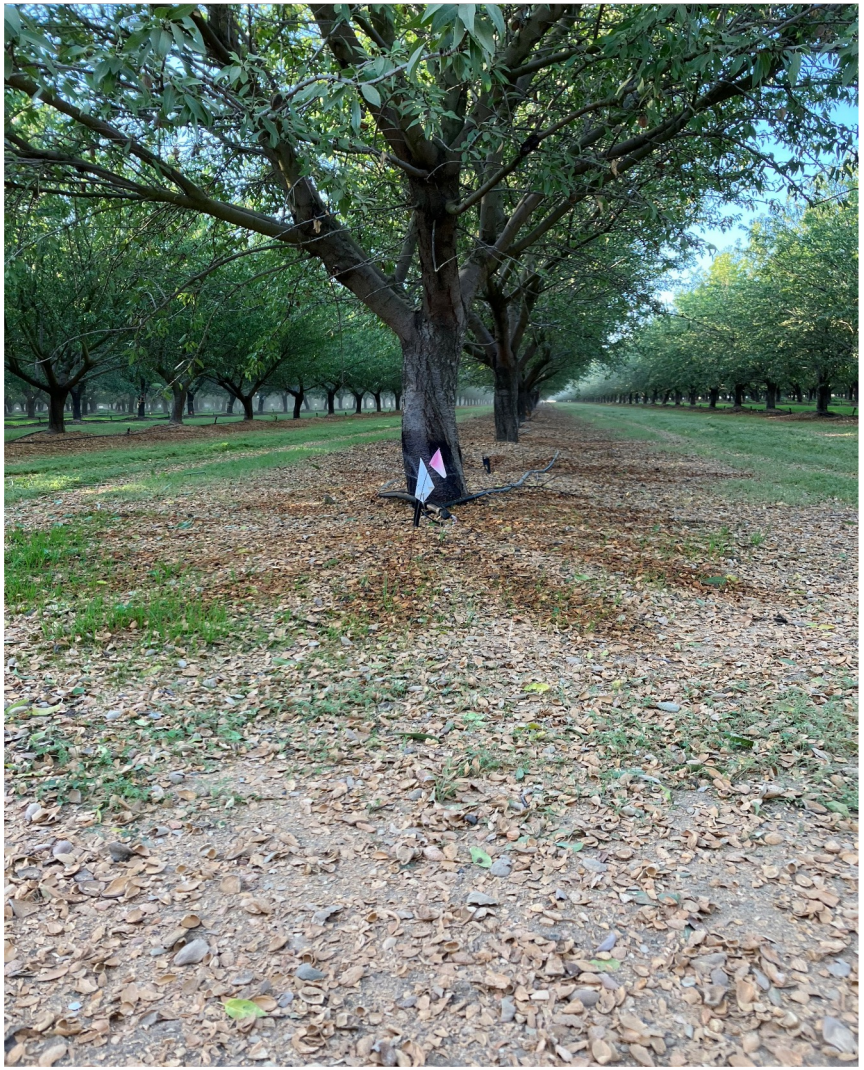
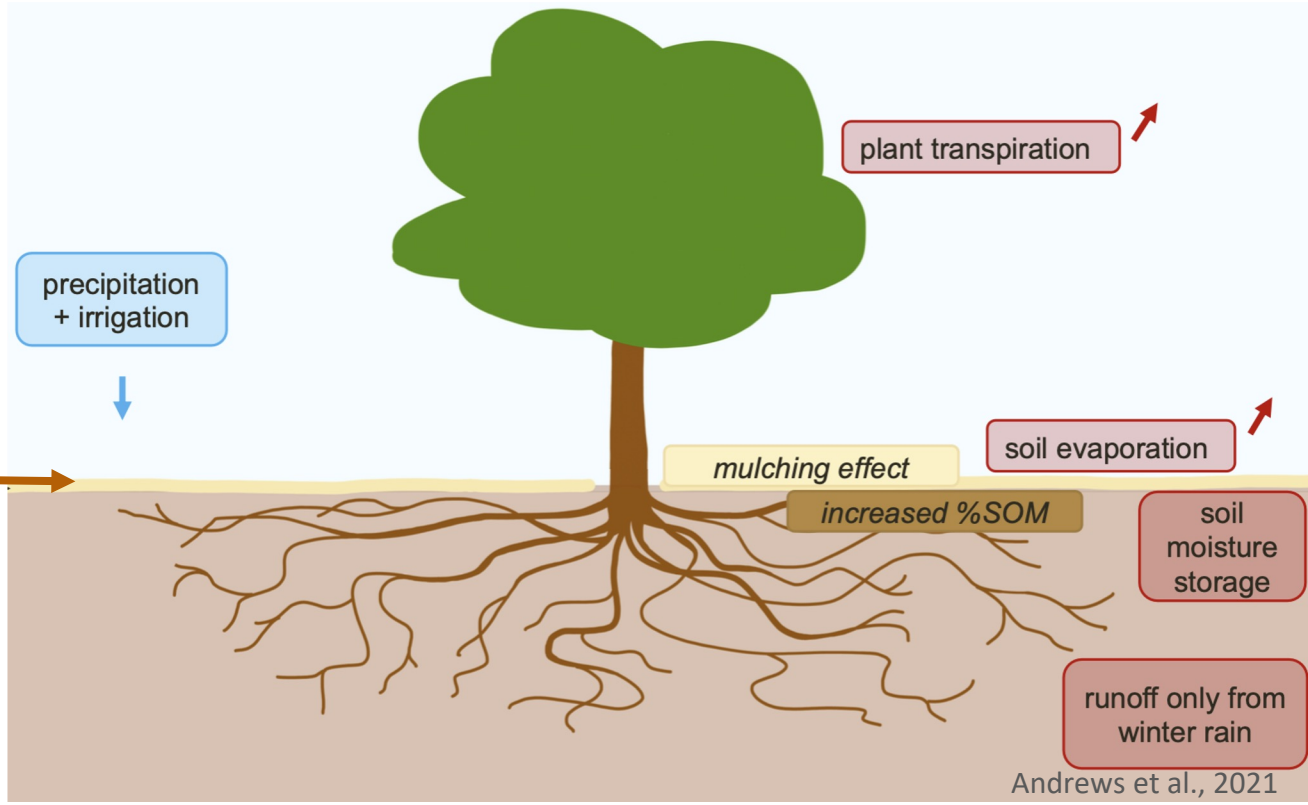
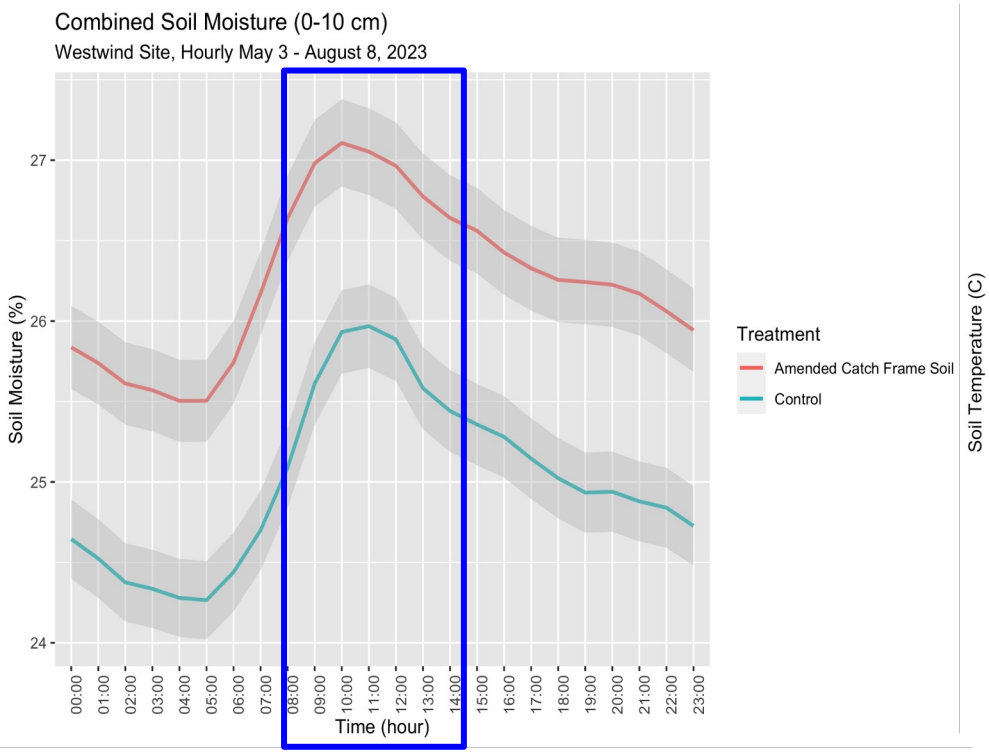


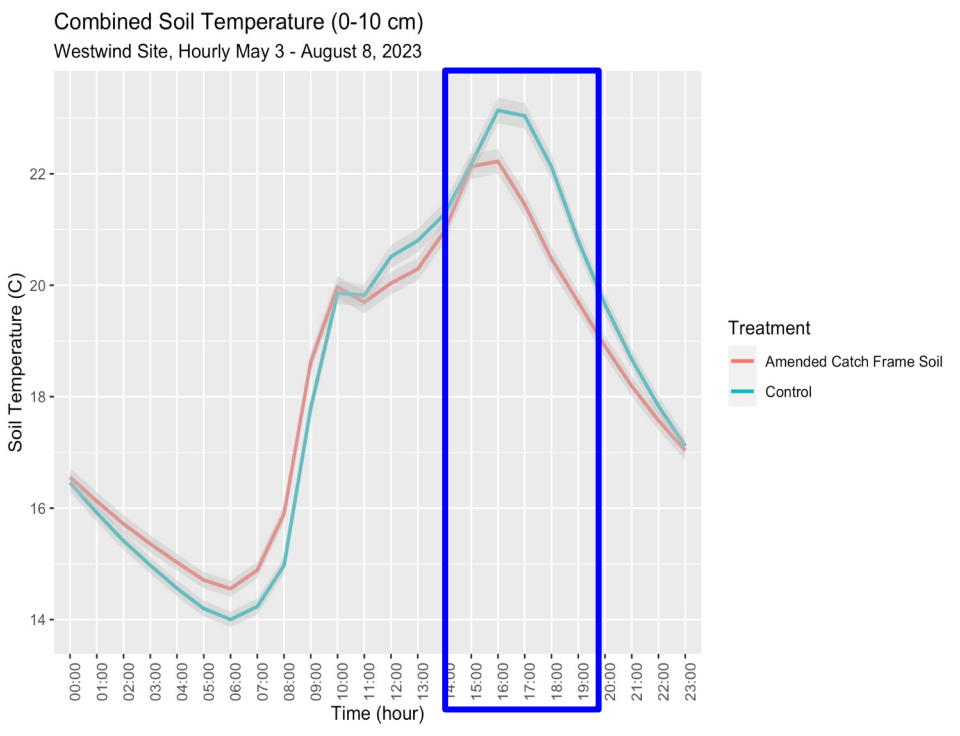
Potential mulching effects



Amended soil moisture & temperature

Water Dynamics

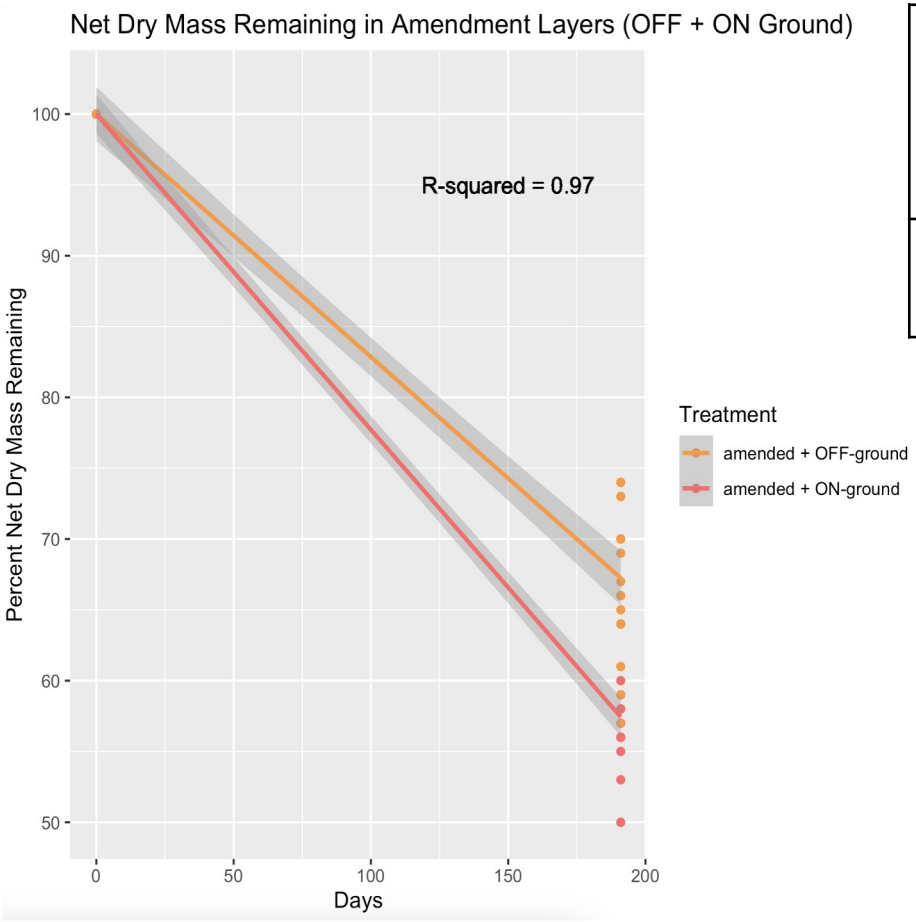




Significantly higher % soil moisture during peak heat hours in the amended catch frame soil

More moderated temperature during peak heat hours in the amended catch frame soil

Short term decomposition



Treatment	C:N Ratio	Site	Time Length (Days)	Total Water Applied (inches)	Avg. % Net Mass Remaining
Hull/Shell Mix	49:1	Westwind	192	38.37	62%

~ 35-70% of total K was released within the first 3 inches of water

Almond hull and shell amendment was approximately 60% decomposed over 6 months

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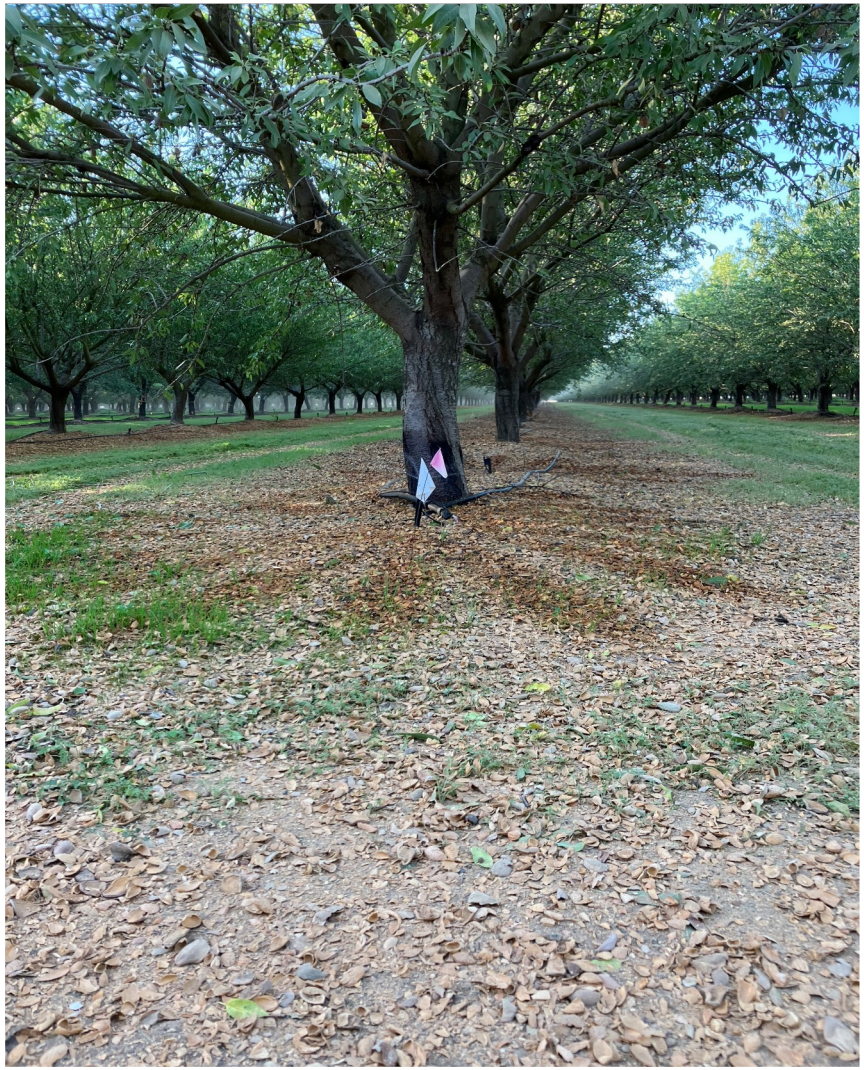
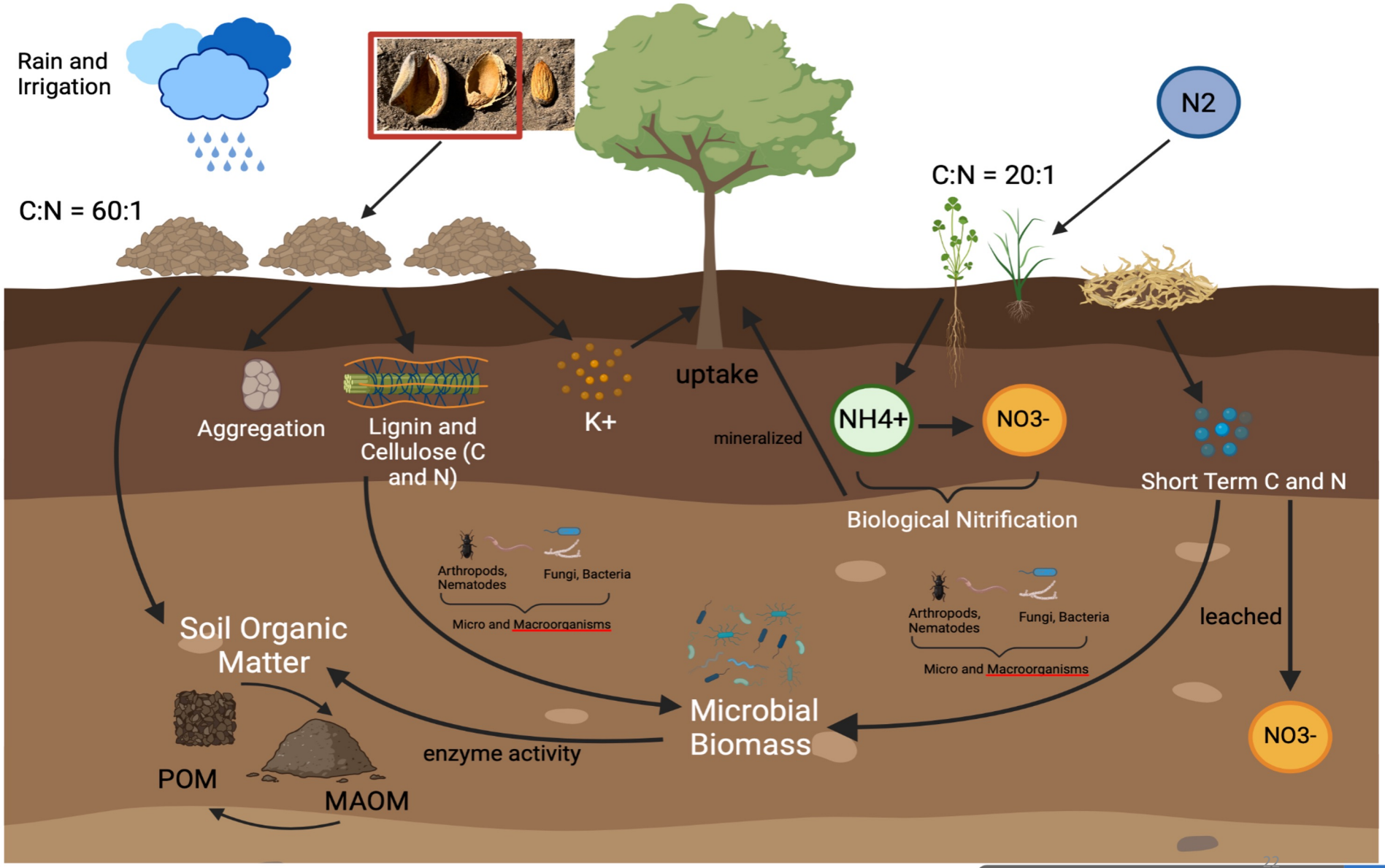


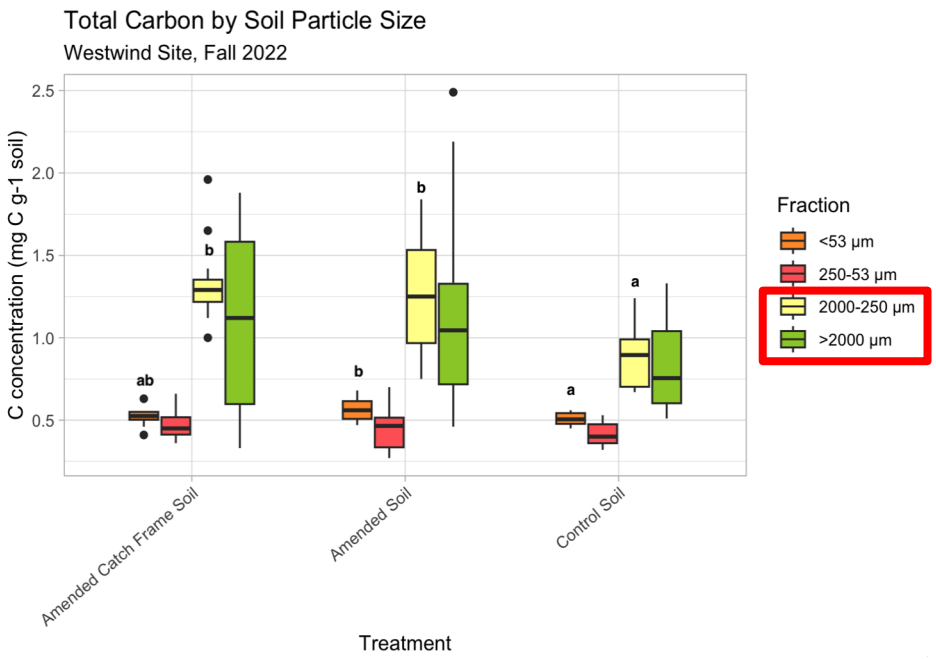
Defining soil health

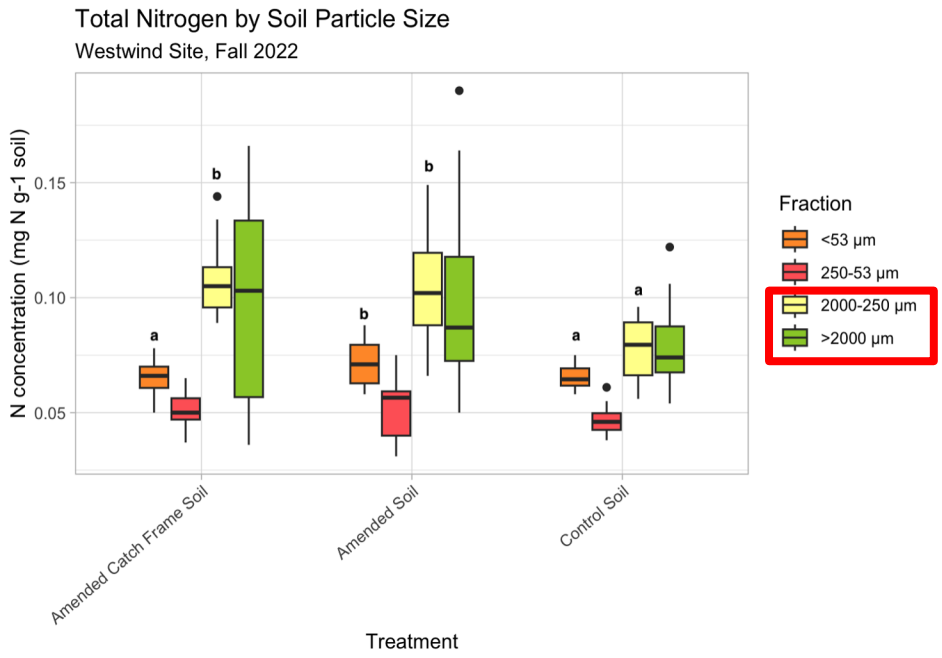
- The continued capacity of soil to function as a vital living ecosystem that sustains plants, animals, and humans (NRCS)
- Choose indicators based on prioritized soil functions:
  - Physical: aggregate stability, OM stabilization
  - Chemical: CEC, % SOM, pH
  - Biological: microbial biomass, community, & function

Potential mechanisms in the soil from surface applied amendments



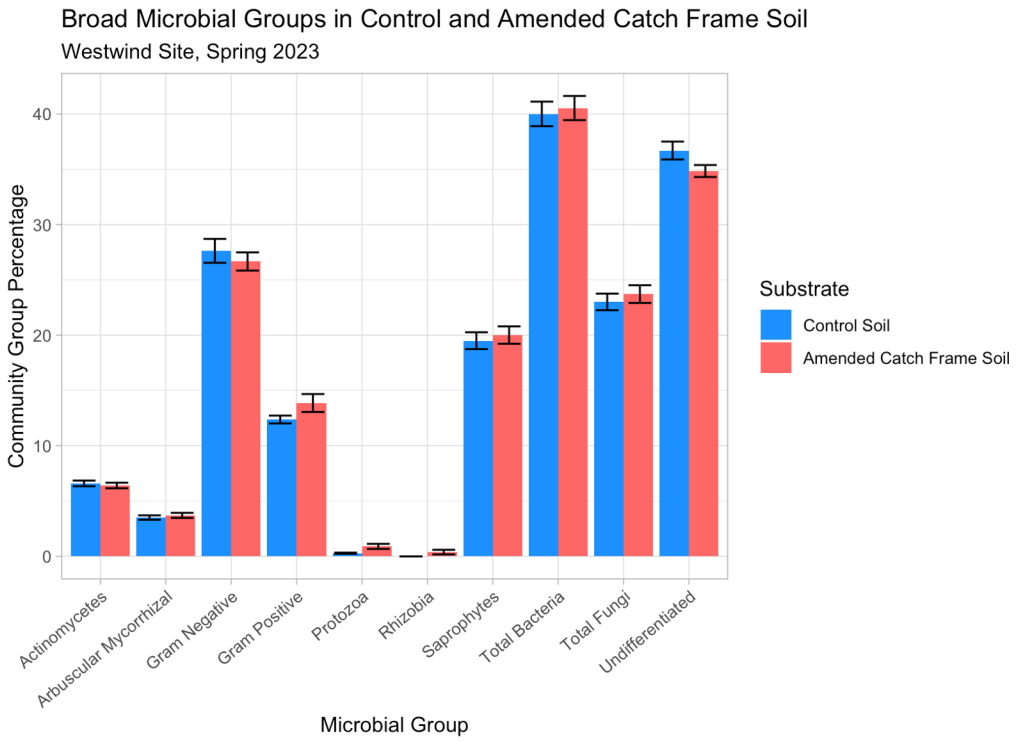
Total soil C & N partitioned by aggregates

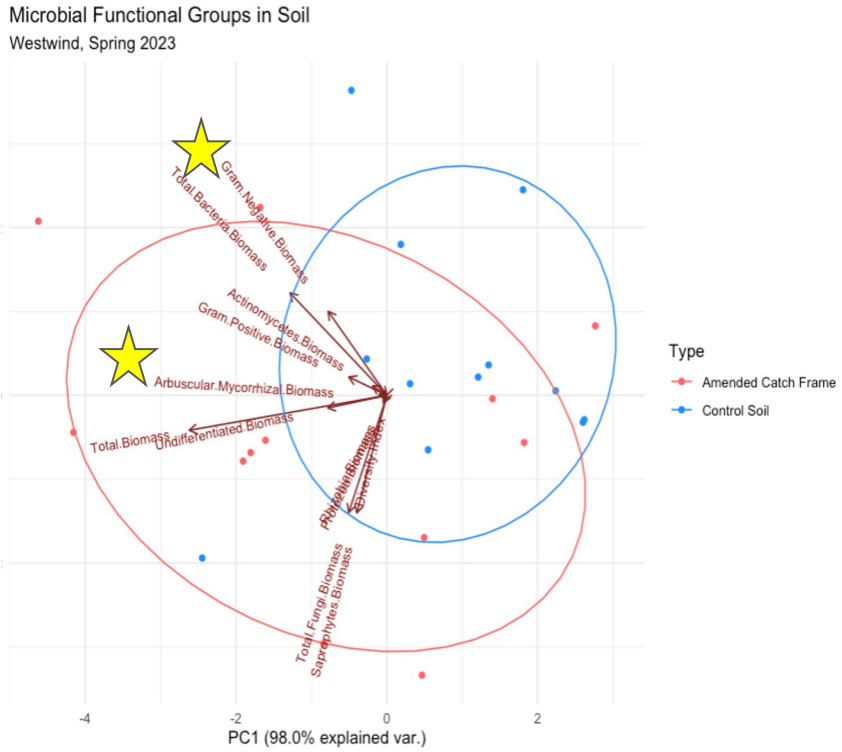




Trends show larger C and N concentrations in the two largest soil aggregate fractions, suggesting longer term storage of C can be stored in smallest fractions which is important for C sequestration

Amended soil and microbial biomass





- Higher protozoa, rhizobia, saprophytes, and overall bacteria and fungi in amended catch frame soil
- Higher fungi:bacteria may indicate increased formation of SOM and shifts to more complex C compounds

- Increased gram (+), (-) bacteria and arbuscular mycorrhizal fungi in amended catch frame cluster

Key takeaways

Potassium

- ~400 lb/ac K released from 8 tons/ac fresh hulls & shells
- ~85% release of K from hulls & shells each season
- Almond hulls & shells have the potential to meet most of your K demand and reduce the costs of fertilizer inputs (KTS, SOP, K2SO4)

Water

- Improved soil moisture and moderated soil temperature from mulch layer on soil surface
- Can moderate tree water stress during dry down periods

Soil

- Amendment and off-ground harvesters maintained the organic layer and increased soil microbial biomass
- Reduced soil disturbance and potential for improved aggregate stability with these practices

Acknowledgements

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