Climate change mitigation and adaptation through soil conservation in Central Coast Vineyards – Lessons learned from controlled field trials

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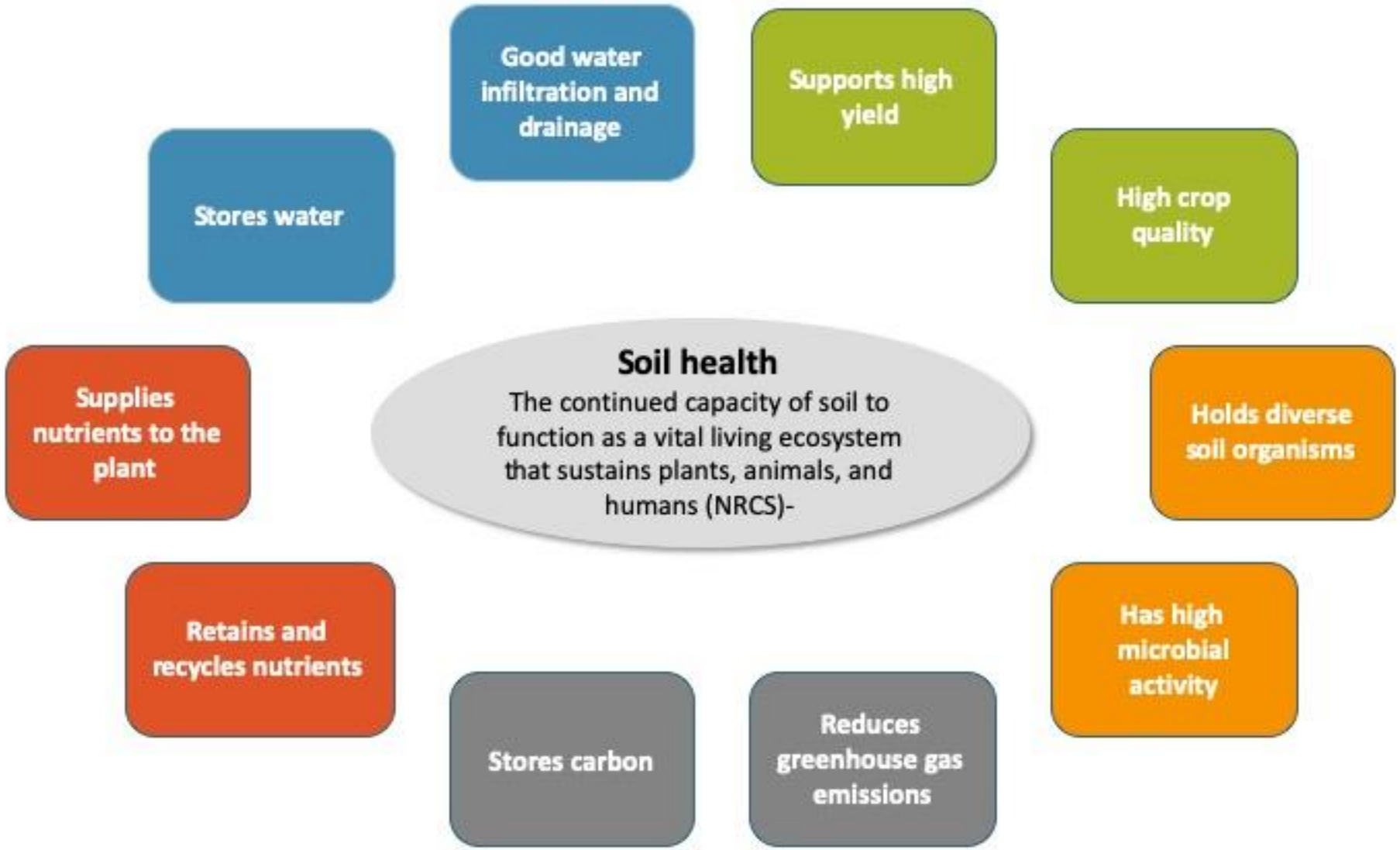
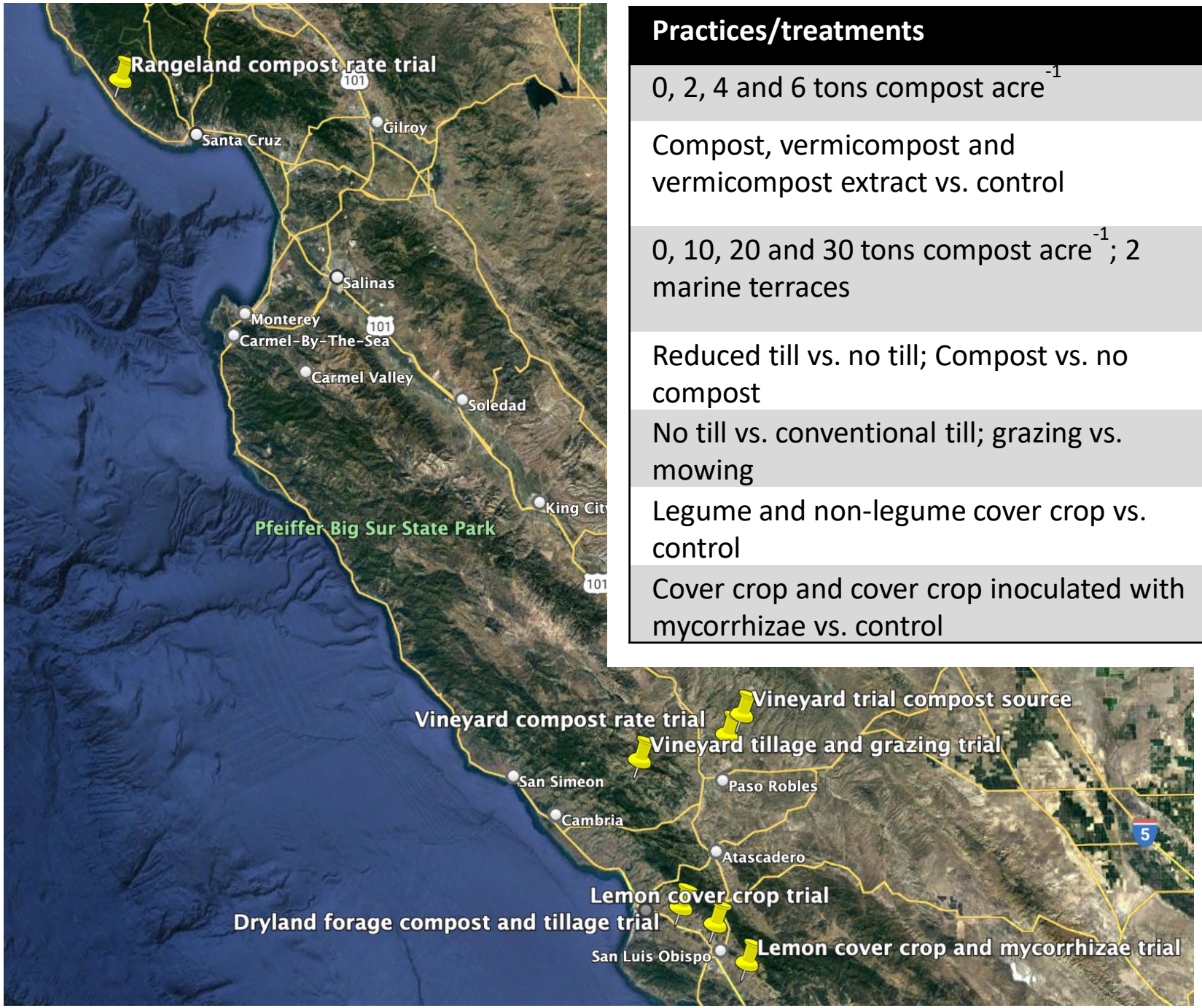
Climate Smart Agriculture at Cal Poly

- In 2016, the California legislature passed Senate Bill 859, which established the Healthy Soils Program (HSP).
- The program is funded from the State's cap and trade proceeds, also known as California Climate Investments (CCI).
- The program includes two components, the HSP Incentives Program and the HSP Demonstration Projects.
- This program funded Cal Poly to conduct **seven controlled field trials** across various agroecosystems assessing the potential of HSP practices to improve soil health and mitigate climate change in California's Central Coast region.


Good water infiltration and drainage
Supports high yield
Stores water
High crop quality
Soil health
The continued capacity of soil to function as a vital living ecosystem that sustains plants, animals, and humans (NRCS)-
Supplies nutrients to the plant
Holds diverse soil organisms
Retains and recycles nutrients
Has high microbial activity
Stores carbon
Reduces greenhouse gas emissions



Practices/treatments	Crop type	Topsoil texture
0, 2, 4 and 6 tons compost acre^{-1}	Wine grape	Sandy loam
Compost, vermicompost and vermicompost extract vs. control	Wine grape	Sandy loam
0, 10, 20 and 30 tons compost acre^{-1}; 2 marine terraces	Rangeland	gravely sandy loam, loam
Reduced till vs. no till; Compost vs. no compost	Dryland forage	Clay
No till vs. conventional till; grazing vs. mowing	Wine grape	Clay loam
Legume and non-legume cover crop vs. control	Lemon	Silty clay loam
Cover crop and cover crop inoculated with mycorrhizae vs. control	Lemon	Clay

Compost application

- Rate
- Timing
- Placement
- Source

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- Reduced till

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- Crop type
- Planting strategy
- Termination strategy

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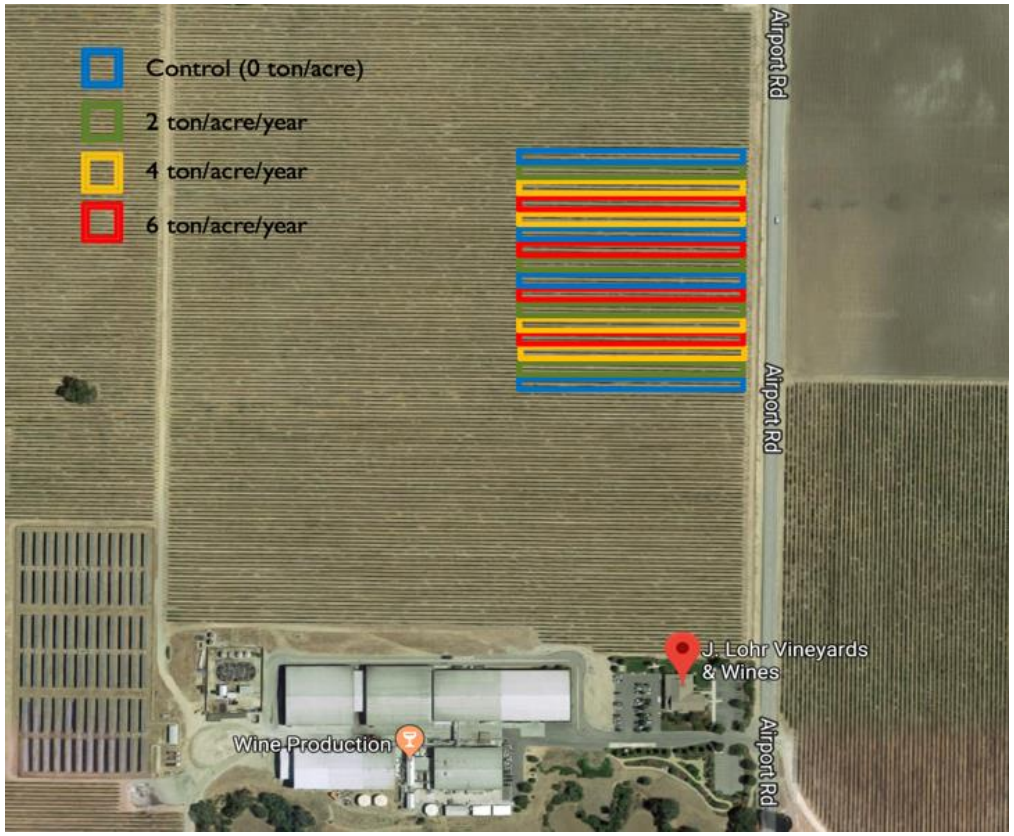
Biologicals

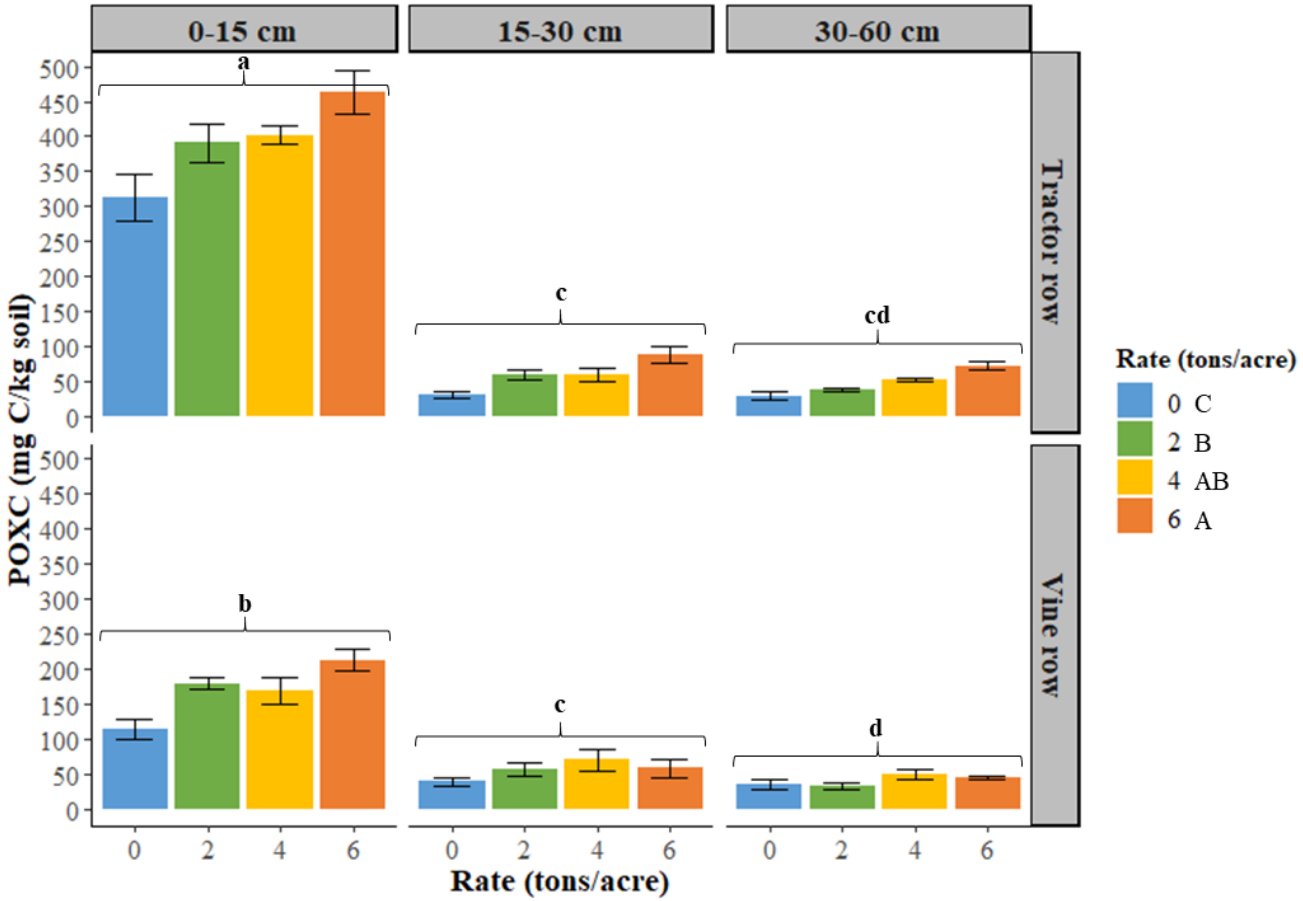
Compost application – the right rate



Vineyard

0, 2, 4 and 6 tons compost acre^{-1}

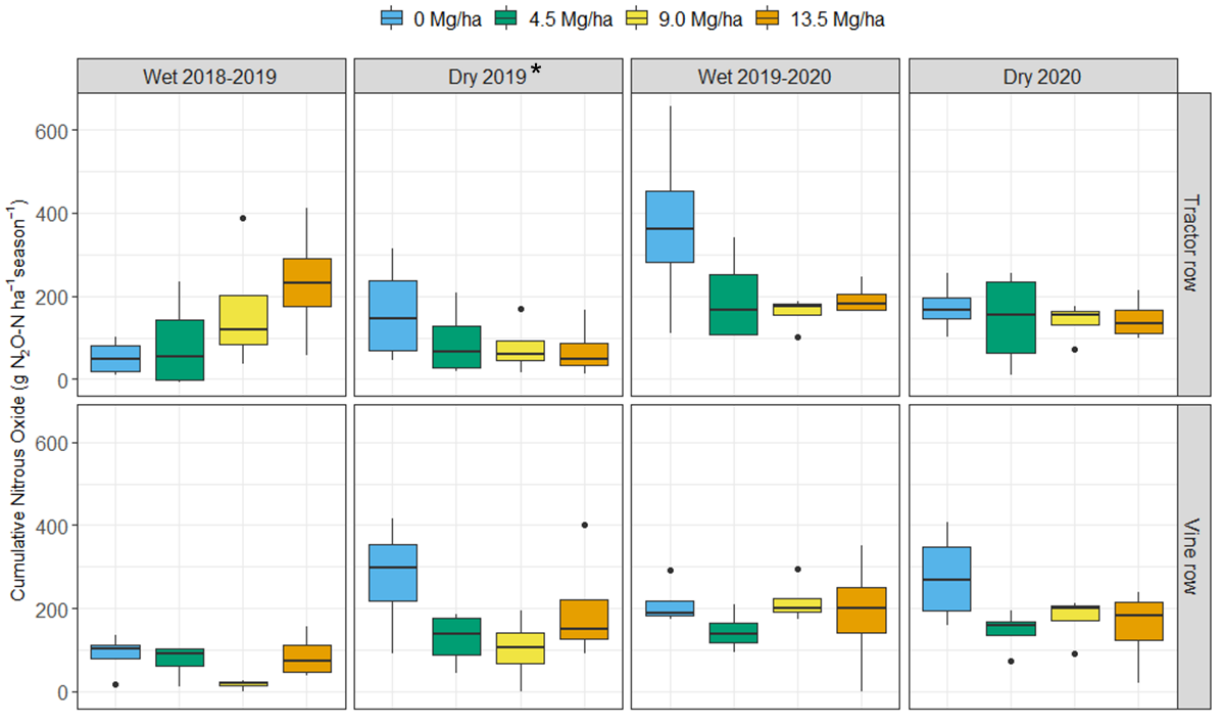
More compost = more benefits



Vineyard

0, 2, 4 and 6 tons compost acre^{-1}

No negative externalities



Vineyard

0, 2, 4 and 6 tons compost acre^{-1}

Compost application – other considerations

IMPACTS OF COMPOST ON SOIL HEALTH WERE ONLY OBSERVED ON THE OLDER TERRACE

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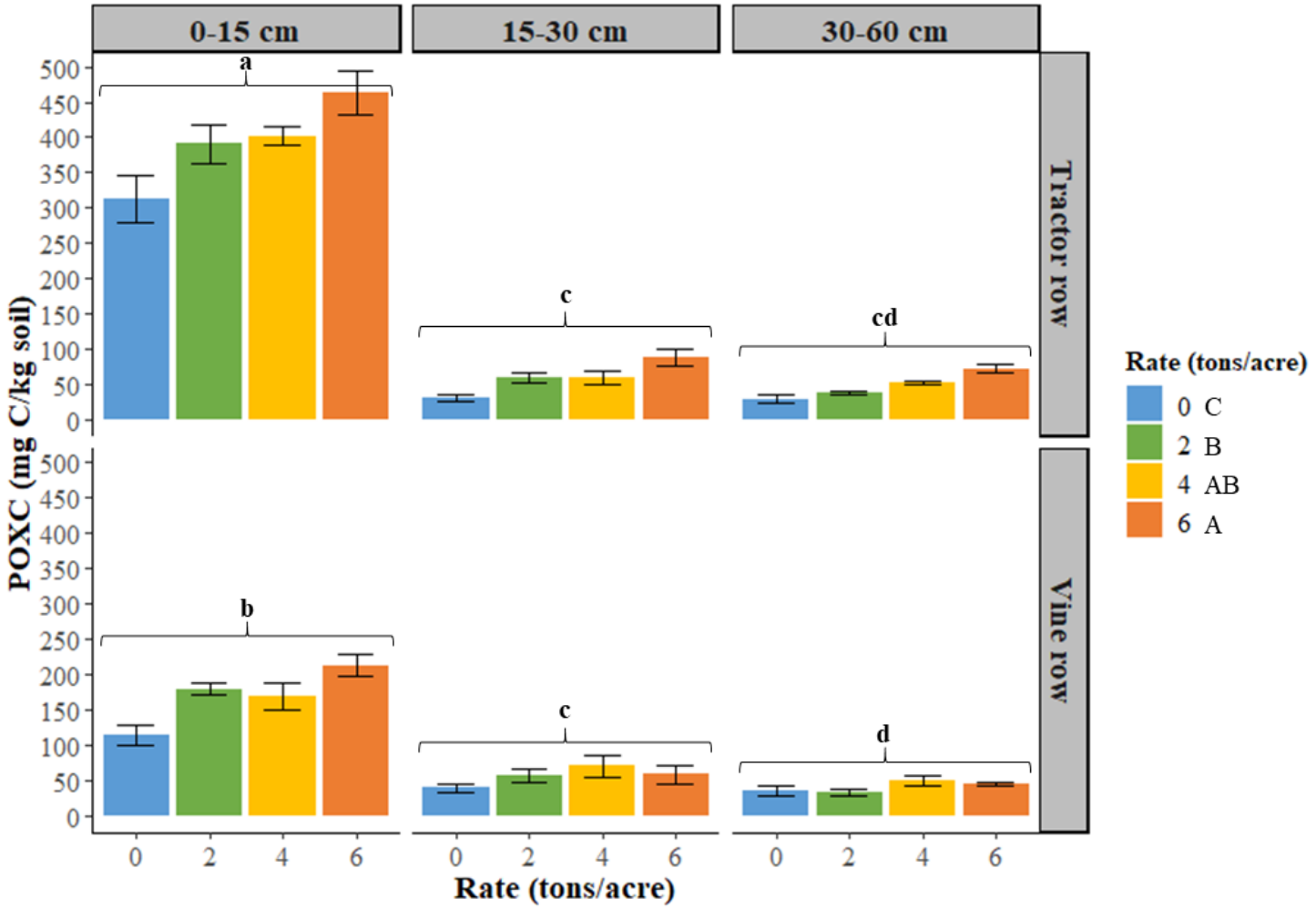
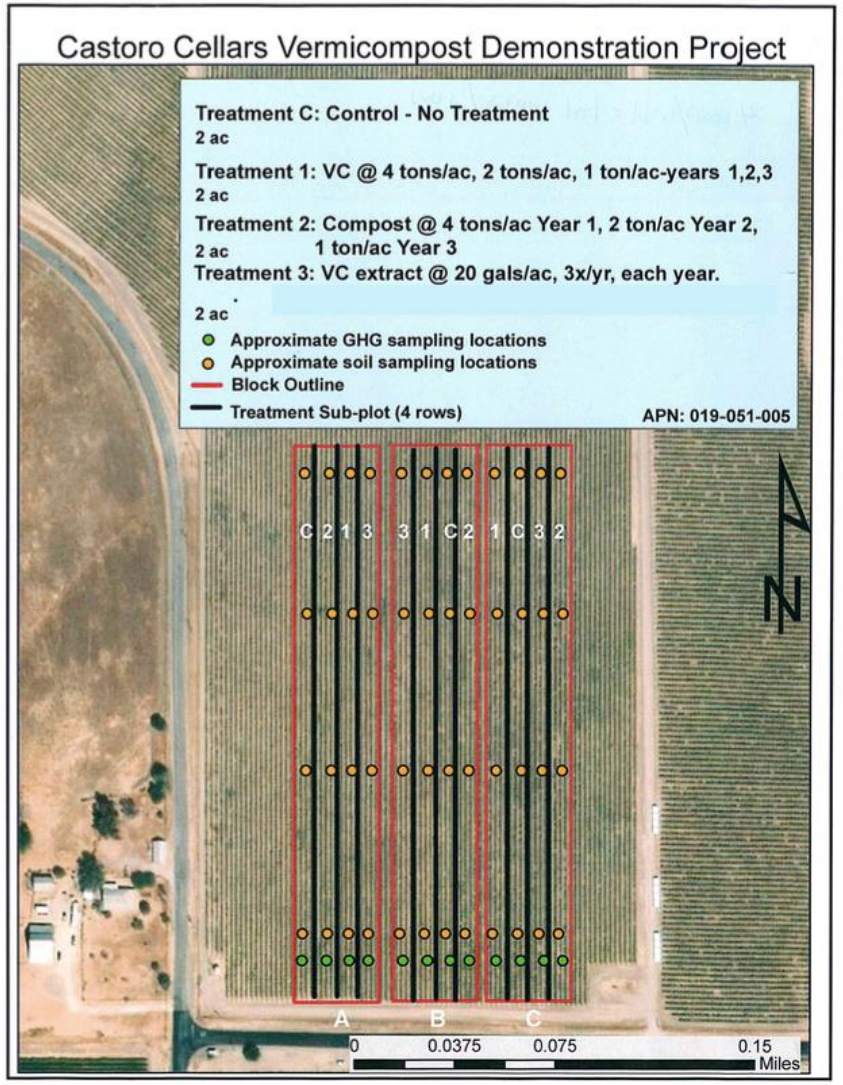
PEDOGENESIS MATTERS FOR SOIL HEALTH PRACTICES

Compost application – the right place and time



- Surface application broadcast over the entire vineyard in Fall increased POXC to 2 feet depth
- Implications for stacking soil health practices

Compost application – the right source



- Fall application
- Banded under the vine
- Cover crop

Nutrient Percentage	Vermicompost	Dairy Compost
C:N ratio	12	9.1
Organic matter (%)	67.1	30.5
Carbon (%)	29.0	14.0
Organic Nitrogen (%)	1.9	1.6
pH Value	6.95	9.18
Phosphorus (mg/kg)	3300	7100
Potassium (mg/kg)	10000	29000
Sodium (Na) (%)	0.31	0.66

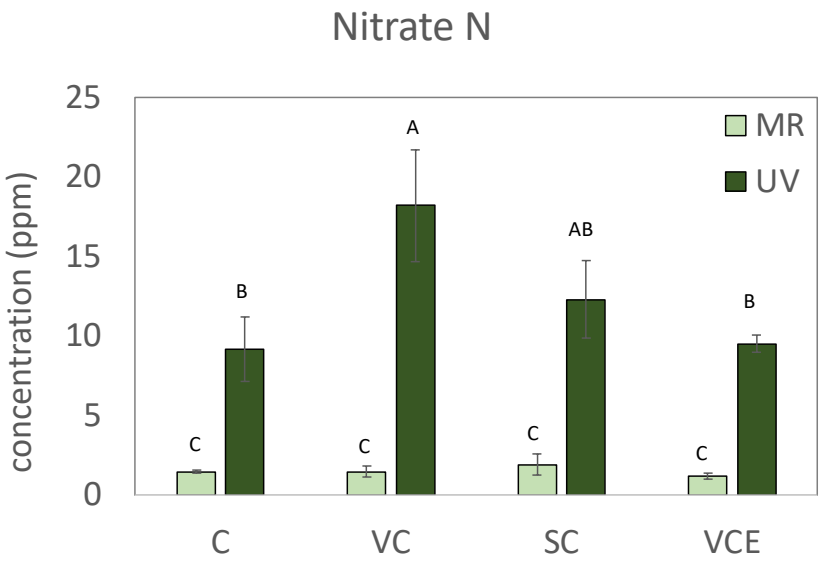
Soil responses mimic amendment chemical composition

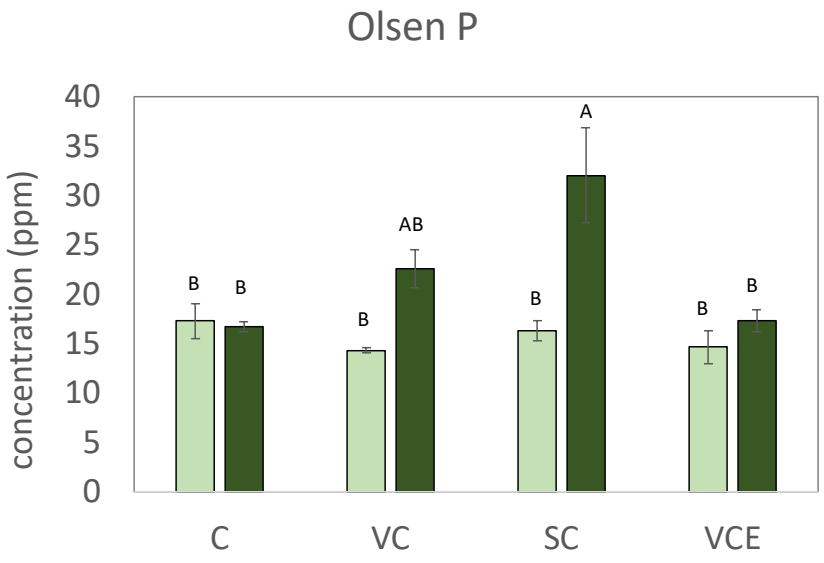
Effects on SOM and pH 2 years after practice implementation

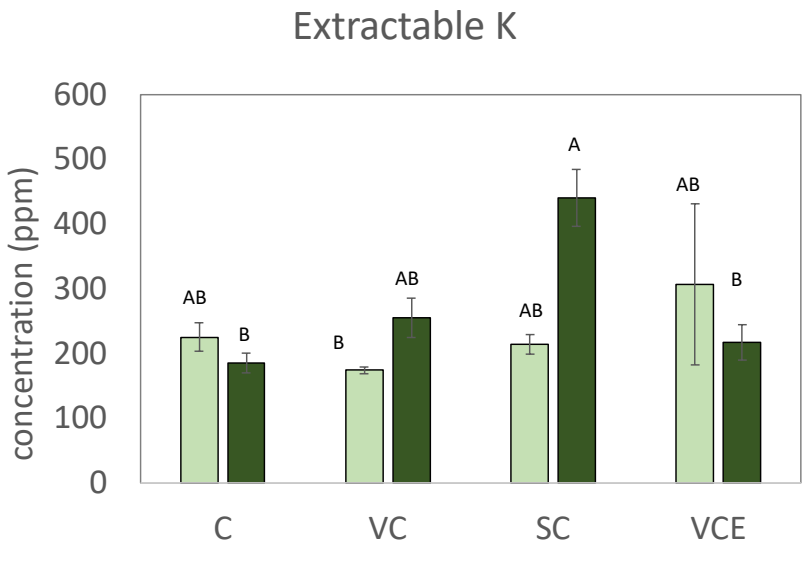
Treatment	SOM (%)		pH (-)		
	MR	UV	MR (B)	UV (A)	
Control	1.8± 0.1 (A)	1.4± 0.0 (B)	7.3± 0.1	7.8± 0.2	ab
Vermicompost	1.6± 0.1 (AB)	1.8± 0.1 (A)	7.3± 0.1	7.6± 0.1	b
Standard Compost	1.6± 0.1 (AB)	1.5± 0.1 (AB)	7.4± 0.0	8.0± 0.0	a
Vermicompost extract	1.6± 0.1 (AB)	1.3± 0.0 (B)	7.4± 0.1	7.8± 0.1	ab

Soil responses mimic amendment chemical composition

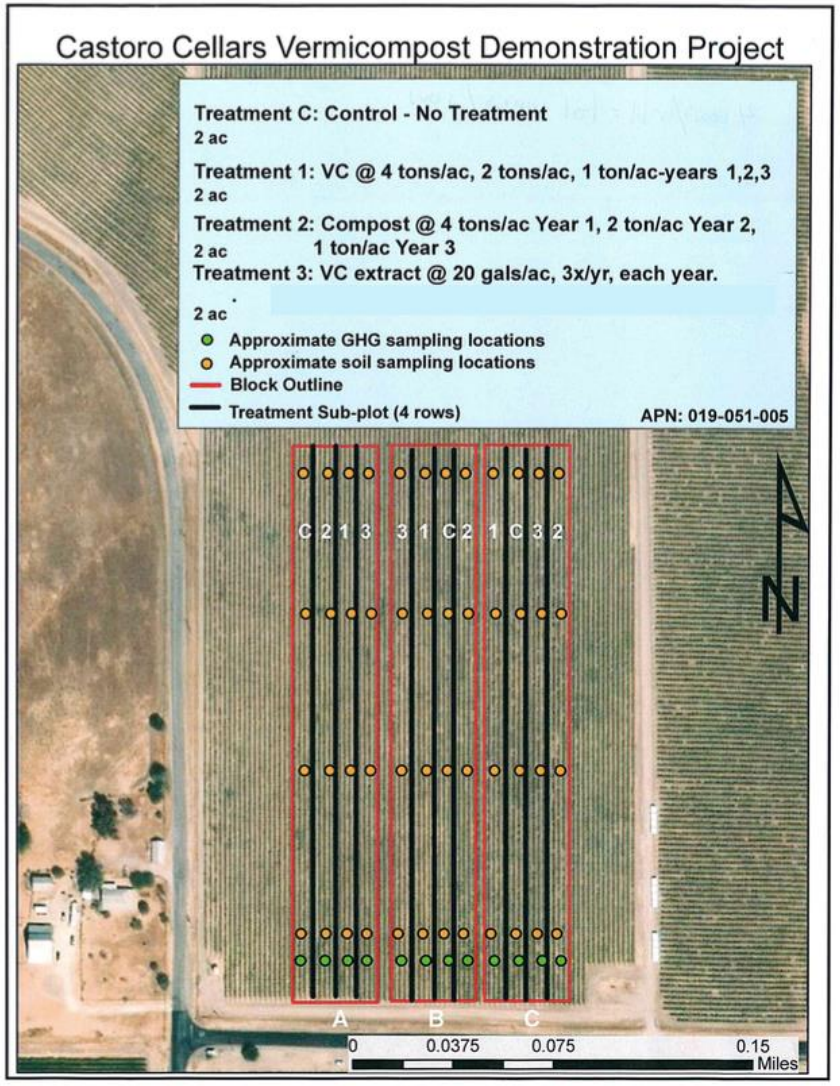
Effects on nitrate N, P and K 2 years after compost application







Compost application – other considerations



EFFECTS OF TREATMENTS ON SOIL HEALTH FADED OUT IN YEAR 3

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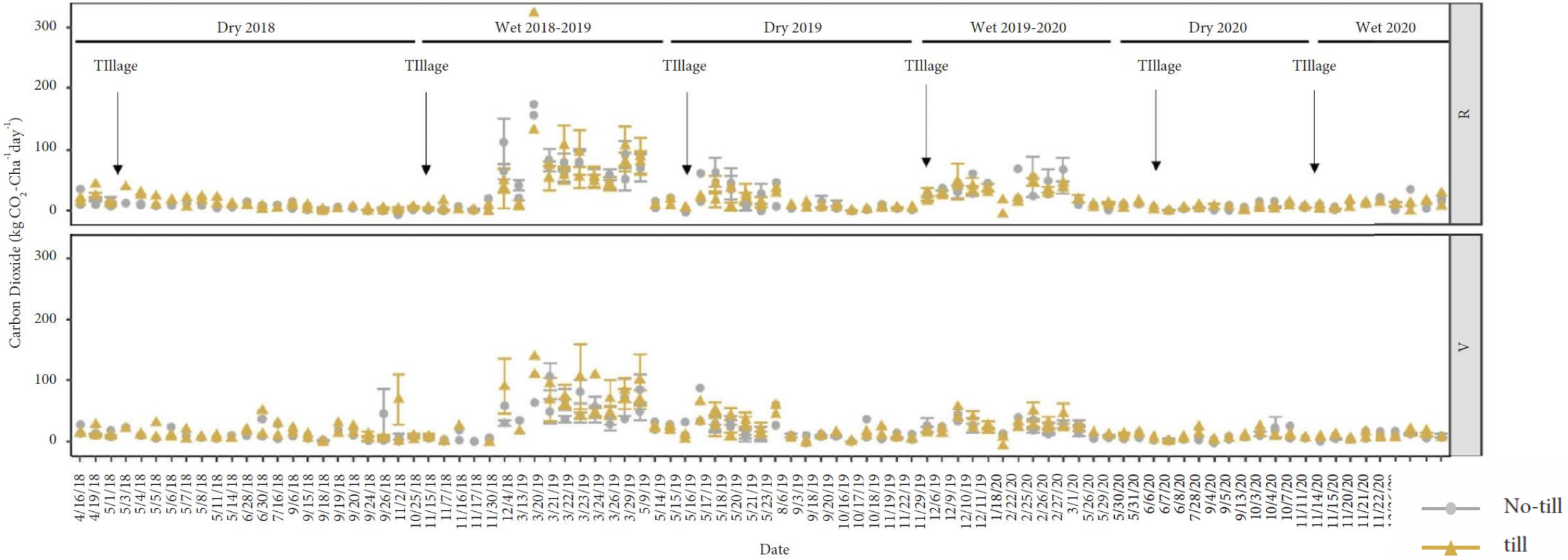
SUSTAINED PRACTICE ADOPTION OVER TIME IS KEY

Tillage - Many shades of grey

Conservation tillage (> 30% residue cover after planting)				Minimum tillage (> 40% reduction in passes)
No-tillage	Ridge tillage	Strip tillage	Mulch tillage	
 Direct seeding; Soil is left undisturbed	 Low soil disturbance; Cultivation uses sweeps, hilling disks, furrowing wings	 Only seed row is tilled	Uses conventional broadcast tillage implements such as disks, chisel plows, rod weeders, or cultivators, but with limited passes across a field	 The use of equipment that combines tillage tools onto a single frame E.g.; Optimizer (New World Tillage, Modesto, CA), Eliminator (Wilcox Agriproducts, Walnut Grove, CA)

Definitions and images adopted from Mitchell et al. 2009

Tillage: No till in a biodynamic vineyard



- No-till increased stratification in the distribution of POXC
- No-till slightly reduced the daily fluxes of CO_2 from the soil during the rainy season, showing that these plots were less prone to lose C than tilled plots.
- No-till did not increase total soil C stocks.

Lazcano *et al.*, 2022

Tillage: Reduced tillage in dryland forage production

- Periodic increased infiltration and increased moisture in reduced till compared to conventional tillage
- Year 3 effects on SOC, MinC, and soil aggregation in progress.

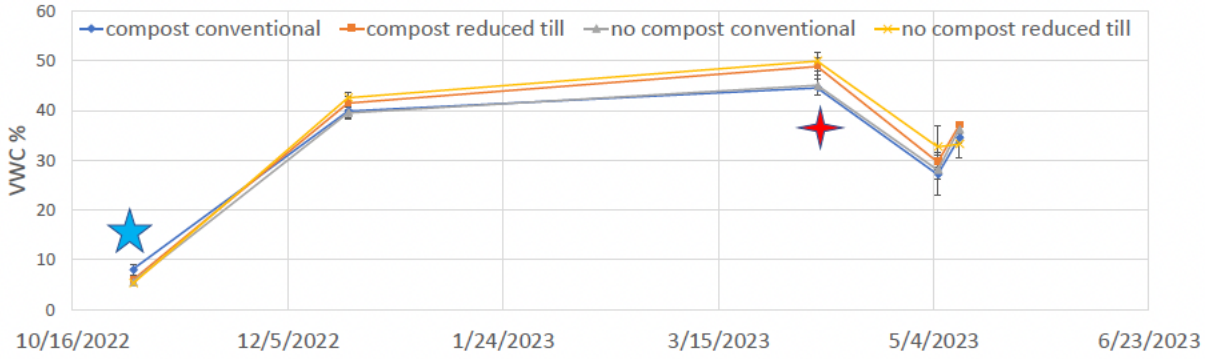


Figure 3. Soil Moisture

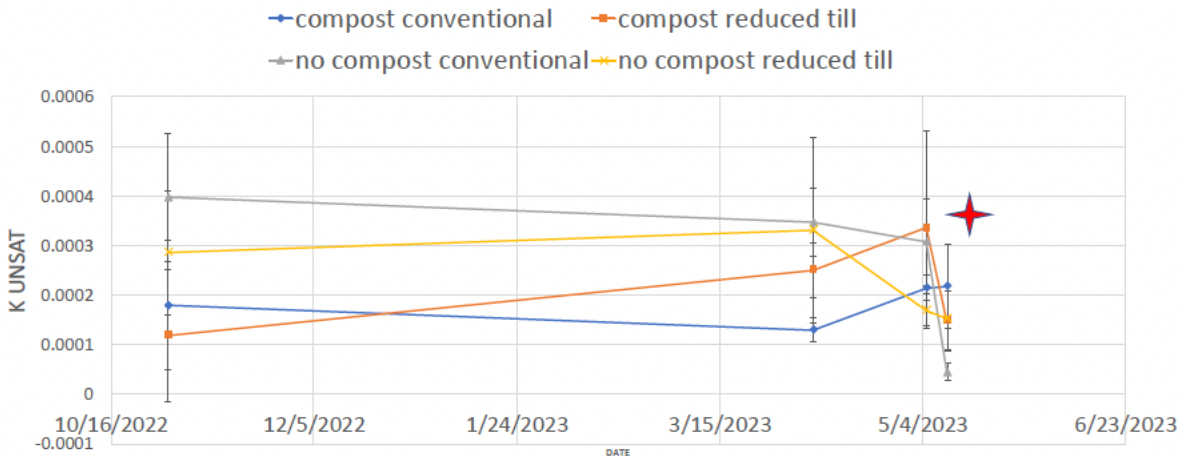
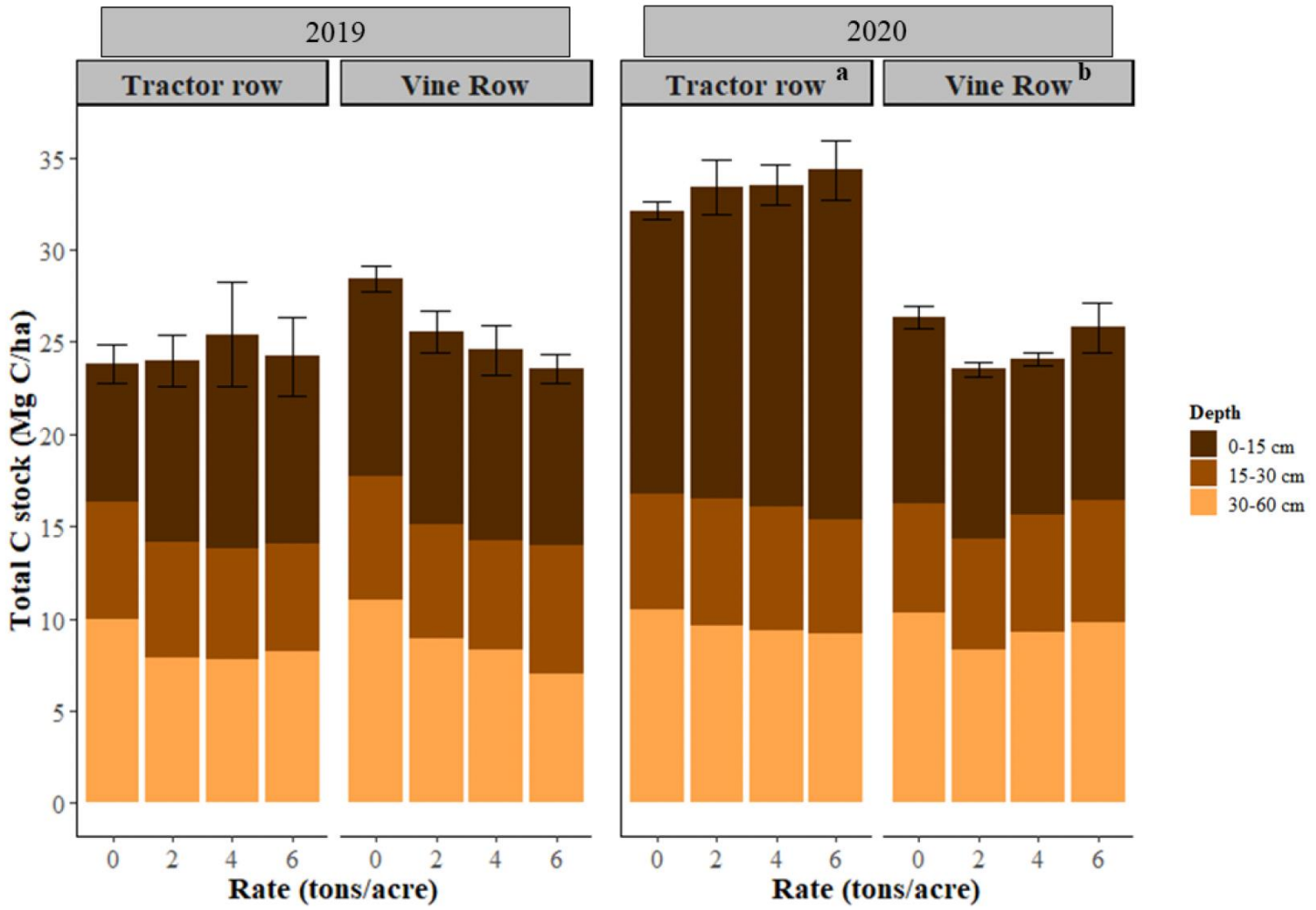


Figure 4. Infiltration

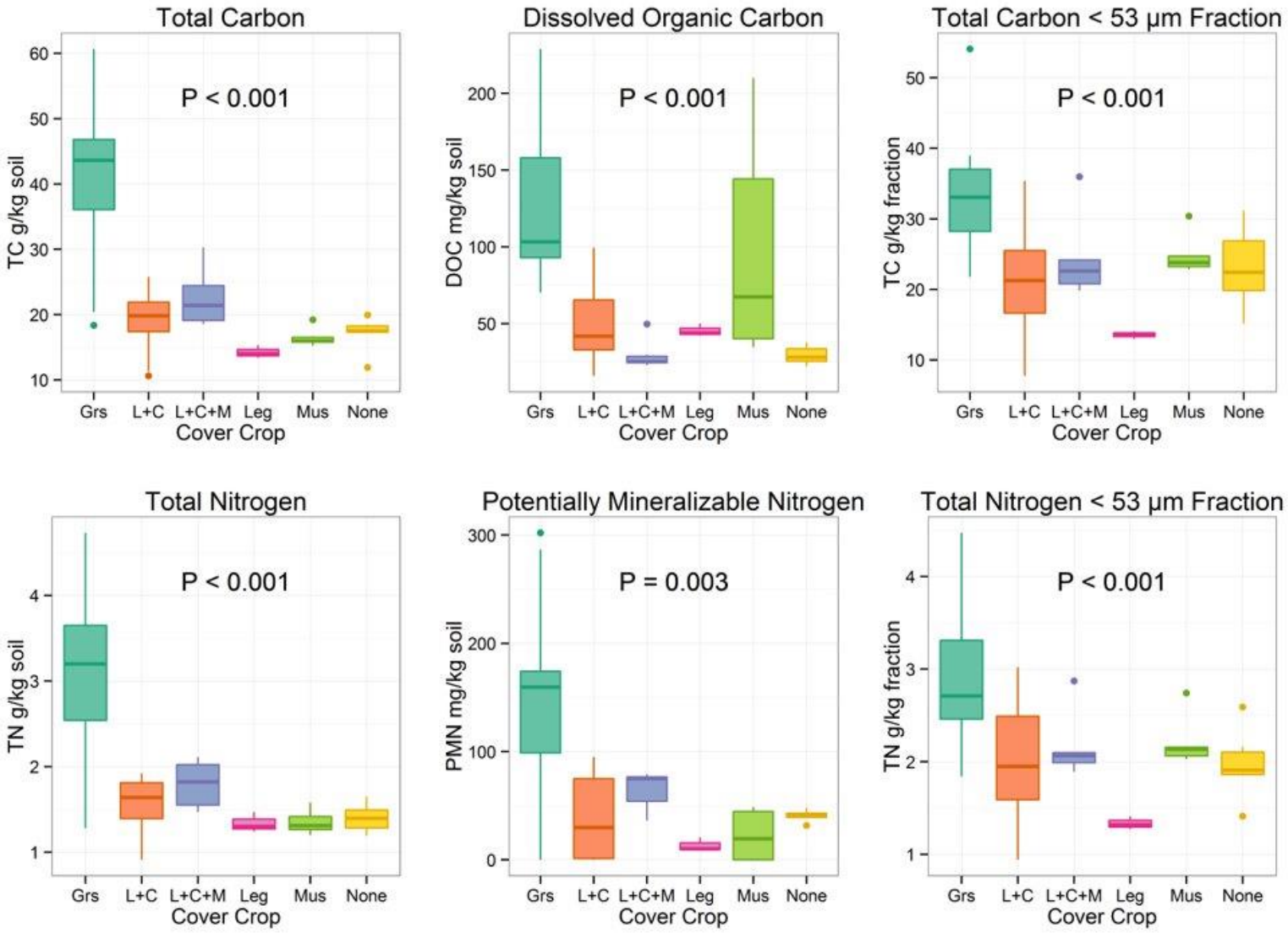
Significant Effect from Tillage

Significant Effect from Compost

Cover crops


2019
2020
Tractor row
Vine Row
Tractor row a
Vine Row b
Total C stock (Mg C/ha)
0
5
10
15
20
25
30
35
0
2
4
6
Rate (tons/acre)
Depth
0-15 cm
15-30 cm
30-60 cm

Cover crops – Species effects



Burns et al. 2015, 2016

Cover crops – Grazing as a termination strategy

- Grazing resulted in sporadic and localized peaks in daily N_2O, CH_4 and CO_2 emissions.
- Nevertheless emissions were not significantly larger than non-grazed soils when extrapolated to the cumulative emissions of the whole season.
- Sheep grazing and tillage did not have a significant effect on the yield and quality of the grapes during the two years of the study.

Lazcano *et al.*, 2022

STACKING PRACTICES

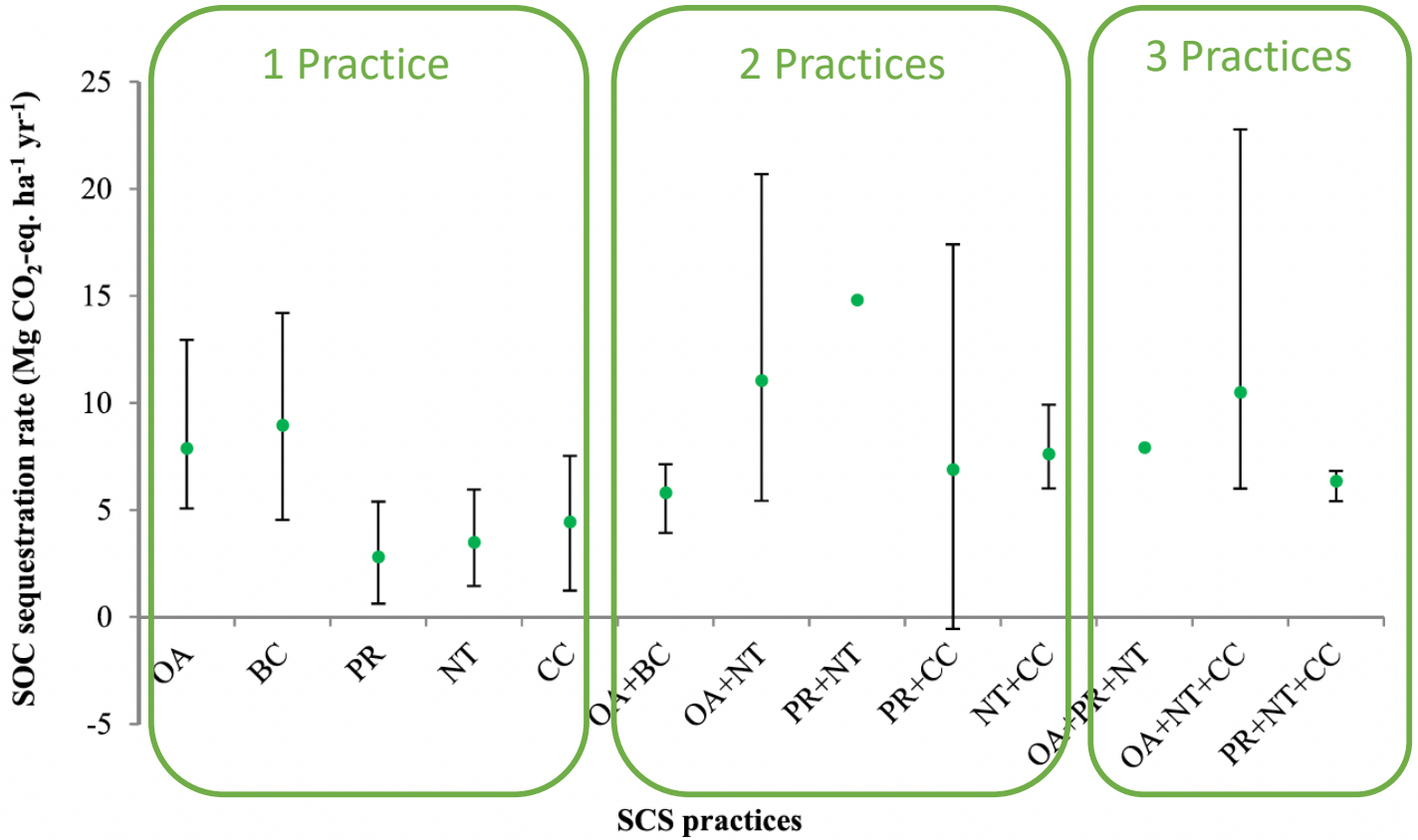
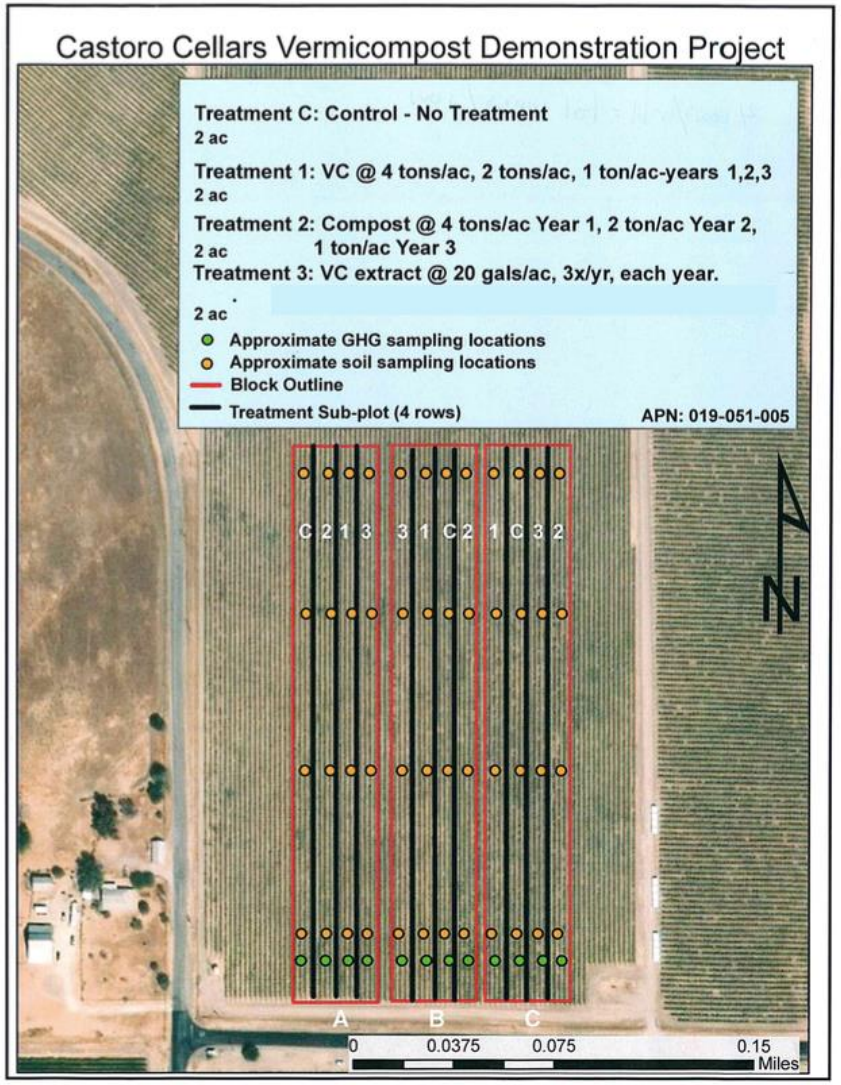


Fig. 8. Impacts of SCS practices (OA, organic amendments; BC, biochar; PR, pruning residues; NT, no-tillage; and CC, cover cropping) on the SOC sequestration rate to 30-cm depth. PR+NT and OA+PR+NT were not included in the analysis, since only one comparison was observed for these categories. Points represent weighted average values, whereas error bars correspond to the 95% confidence intervals.

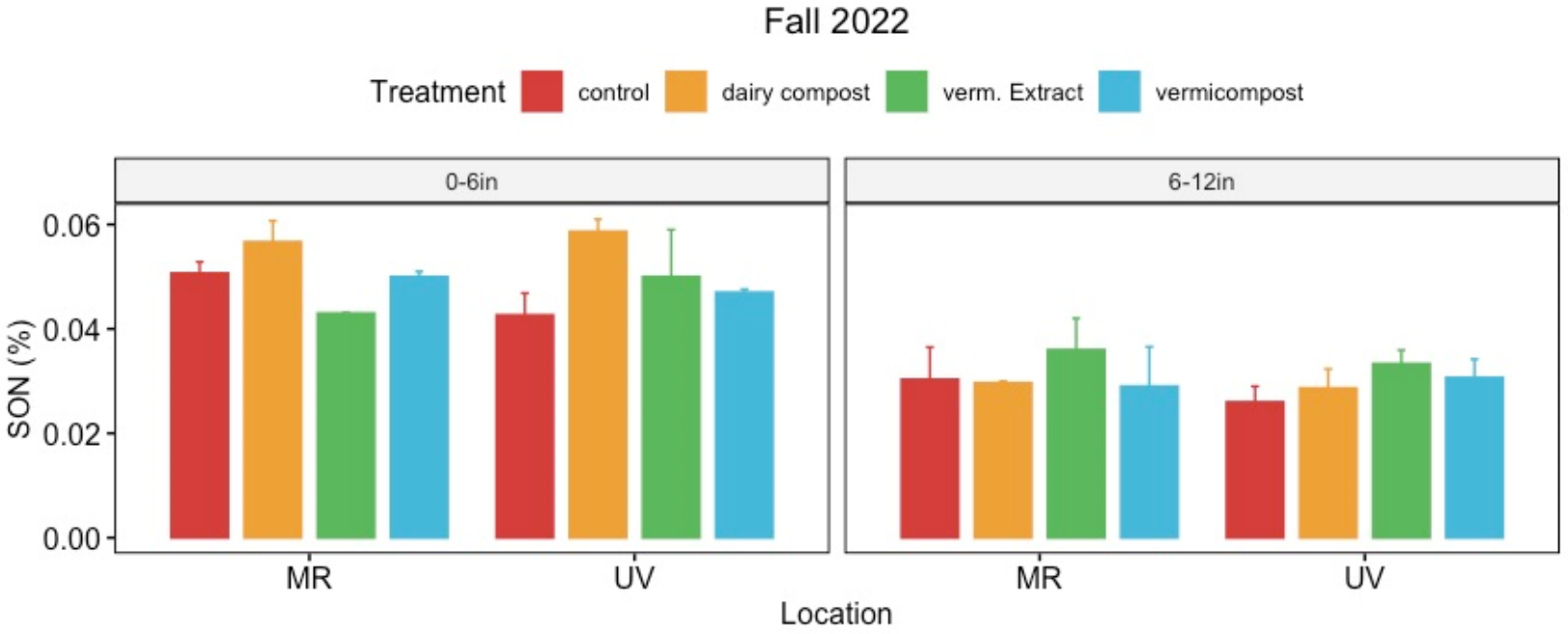
Payen *et al.*, 2021

Biologicals



Vermicompost extract affected stratification of select microbial groups and total N

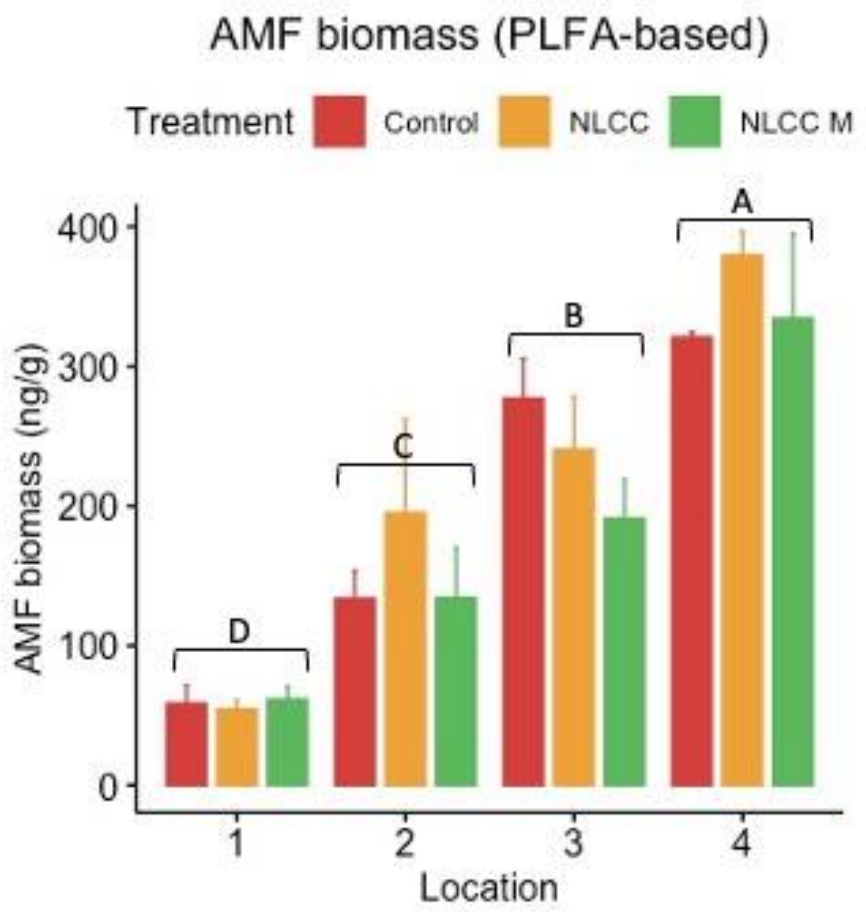
- Relative abundance of select microbial groups was similar between the topsoil and the subsoil in the vermicompost extract treatment, while there were distinct differences between the topsoil and the subsoil in the control, dairy compost, and vermicompost treatment.

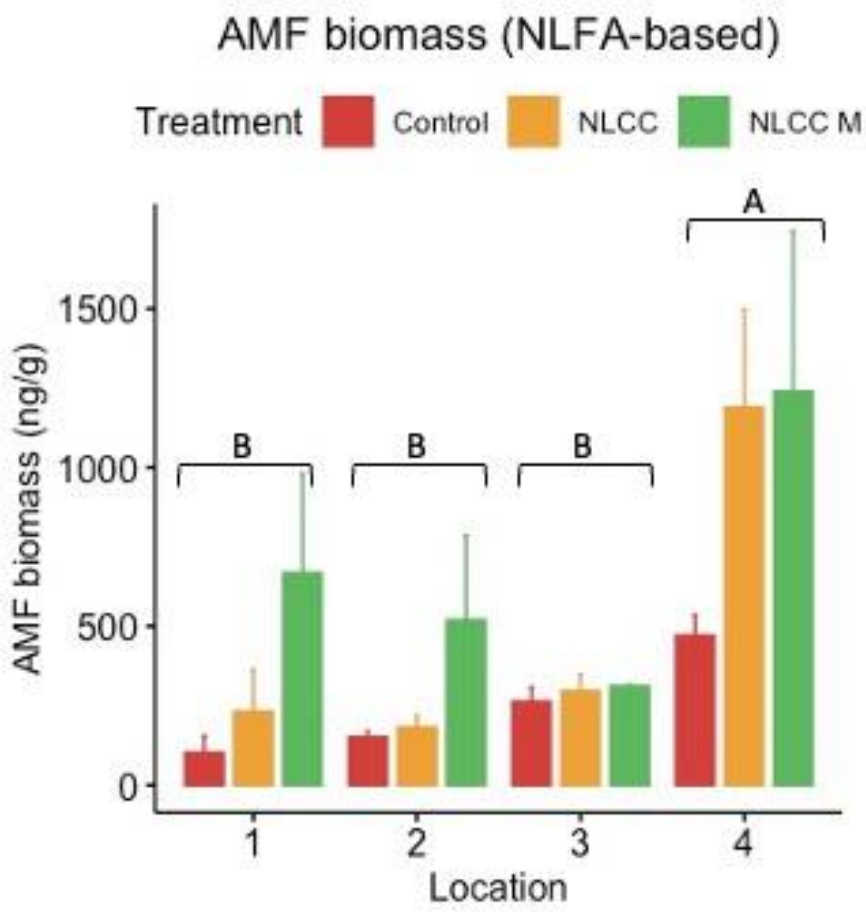


- Likewise, there was no difference in SON concentration between the topsoil and the subsoil in the vermicompost extract treatment, while topsoil SON was significantly greater than subsoil SON in the three other treatments.

- Possible, vermicompost extract distributes the active root zone over a deeper depth.

No significant effects of AMF inoculation on GHG emissions and soil health metrics measured





Key Lessons Learned

- No effects of conservation practices on grape yield in the short term
- No tradeoffs in terms of increased emissions of the potent GHG **N_2O** with the adoption of conservation practices.
- Benefits of conservation practices take time to develop

Compost

- Benefits increased with increasing application rates between 2-6 ton/acre/year
- 1 ton/acre/year may not be enough to sustain benefits
- Benefits of compost are likely soil-dependent
- Subsurface benefits were achieved with surface placement without incorporation
- Benefits on soil chemical properties mimicked compost composition

Tillage

- There are many options to modify tillage intensity
- In the short term, there was increased stratification of soil properties and occasional decreased C loss in no-till, without impacts on yield or grape quality compared to conventional till
- More research needed on long-term impacts of reduced till, no till and keyline plowing in California vineyards

Cover crops

- When choosing to plant a cover crop, one should consider the species, planting strategy and termination strategy
- Grazing did not show strong short-term benefits, but also no negative impacts
- More info is needed on the impact of stacking cover crops with other conservation practices

Biologicals

- Vermicompost extract changed the stratification of SON and select microbial groups in the soil
- Inoculation of a cereal cover crop with AMF did not change the abundance of AMF or affect soil health in a lemon orchard after 3 years of treatment