Safety and soil: Unintended impacts of sanitizers on soil health in leafy green production systems

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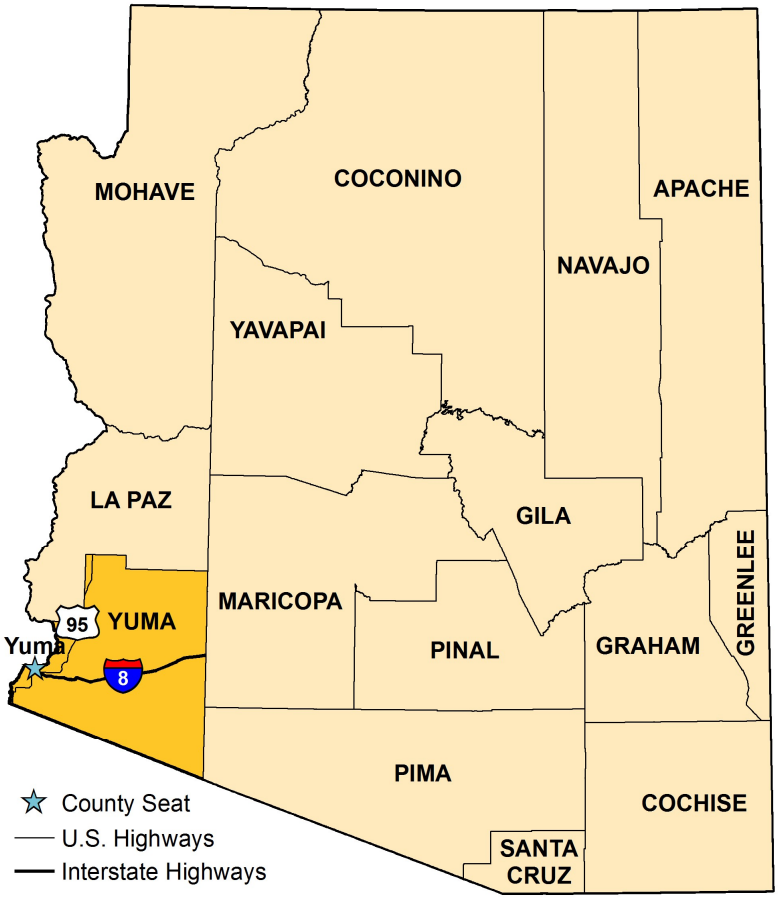
Background

- AZ shares 25% of total harvested acreage in the United States under romaine
- 2021 value of AZ romaine lettuce: 300 million USD
- Sanitizers are important for safe produce
- Soil health is dependent on microbiome
- Sanitizers may alter soil microbiome
- Lacking knowledge/research

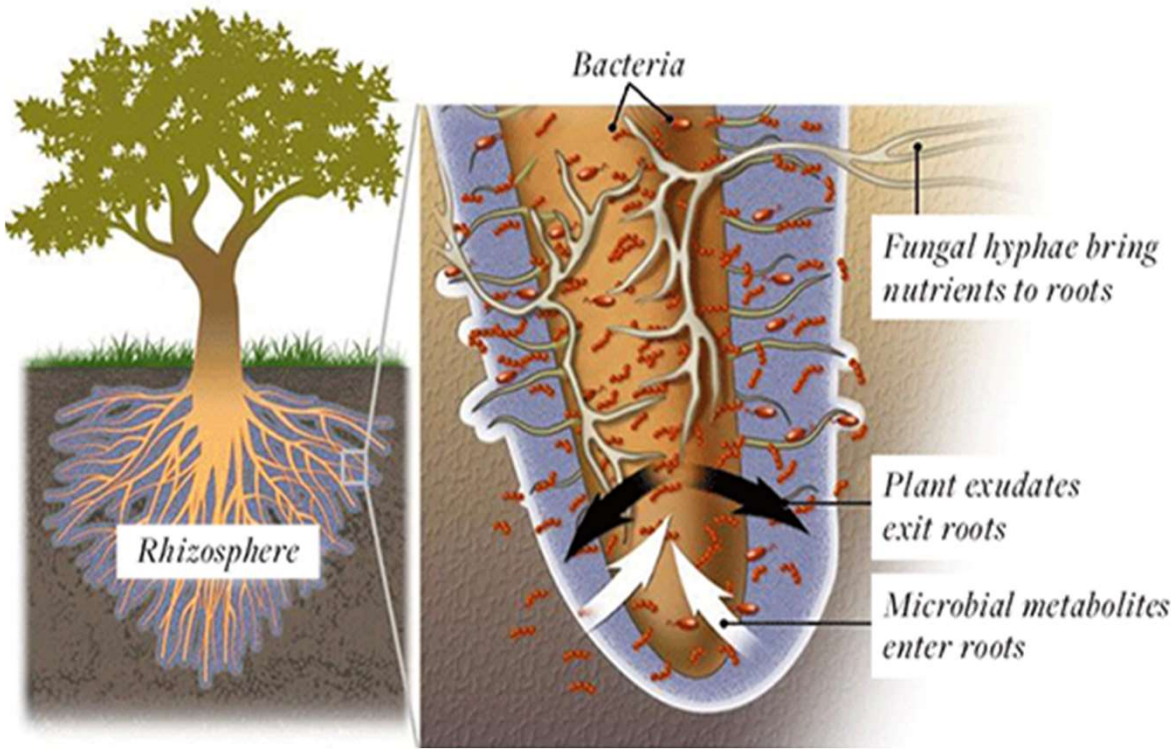


Irrigation Sanitizers

- Leafy greens tied to outbreaks of human pathogens
  - *Escherichia coli* O157:H7 (*E. coli*)
  - *Listeria monocytogenes*
- Main source of contamination: irrigation water
- Sanitizer treatments common practice
  - Mandated by Leafy Greens Marketing Agreement
- Commonly used water sanitizers:
  - Calcium hypochlorite
  - Peroxyacetic acid
- All water sanitizers have antibiotic properties

Soil Microbiome

- Important for plant growth
  - Nutrient cycling
  - Carbon cycling and storage
  - Soil structure and stability
  - Water dynamics
  - Plant immune defense
- Not just quantity, but quality
  - Presence of various species
  - Presence of important species
- Rhizobia & free-living microbiota are included



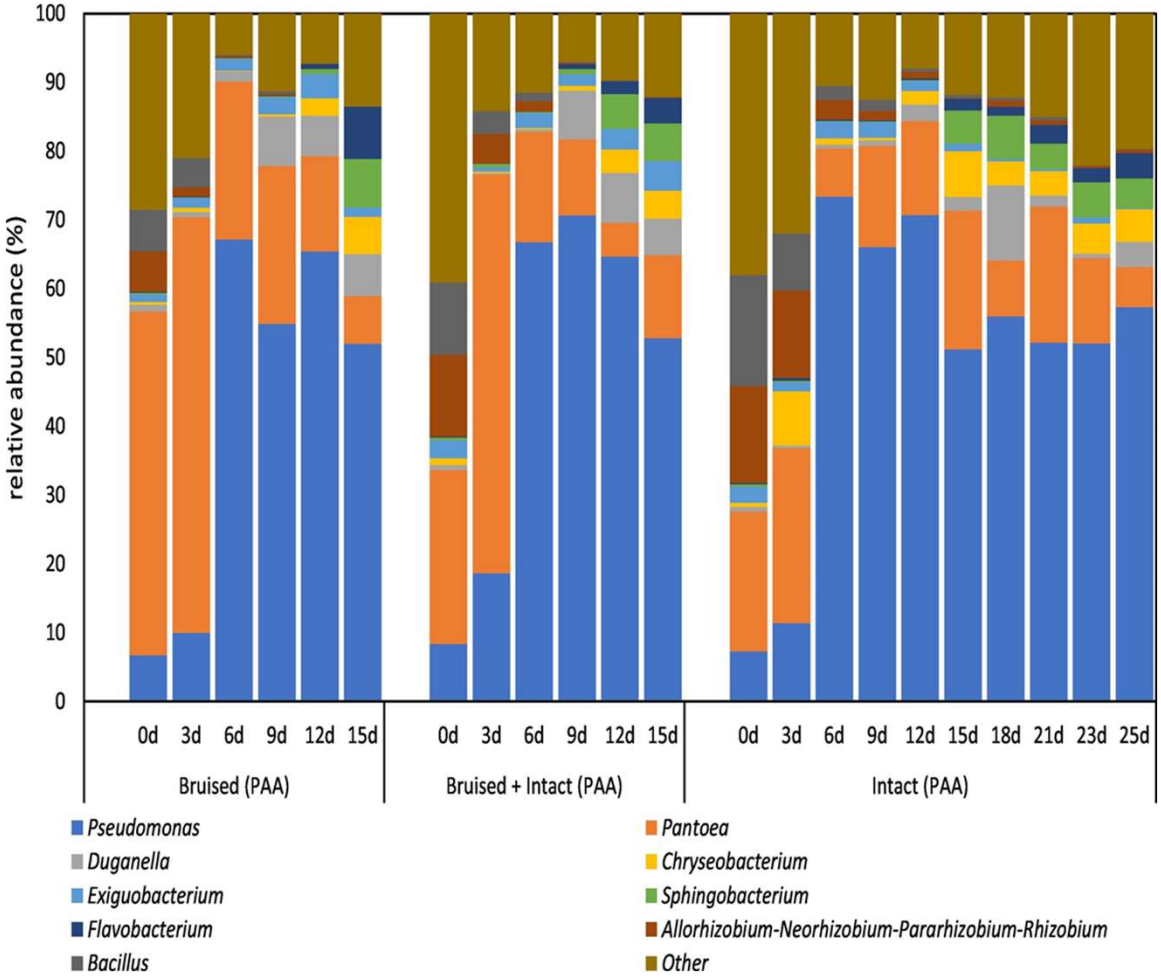
Soil Microbiome

many factors

- Impacts YOUR health

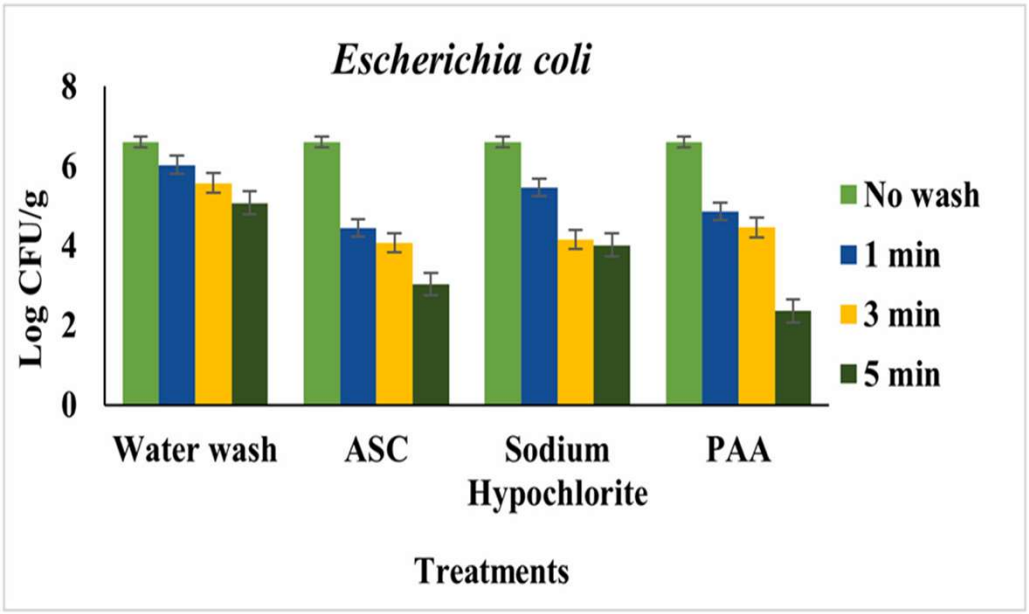
Sanitizer Impacts on Microbes

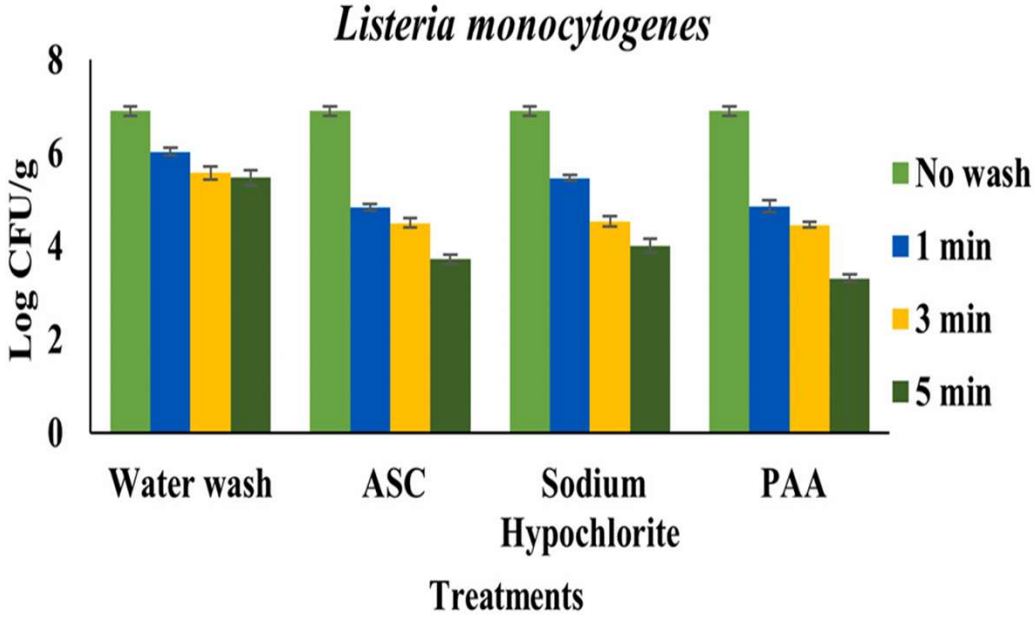
- Reduce population numbers
- Reduce population richness
  - Less productivity
  - Less fertile soil
- Stress out remaining microbes
  - Energy expended on maintaining population rather than other activities
- Nonspecific
  - Harm harmful and helpful microbes



Dakwa et al. (2021)

But!

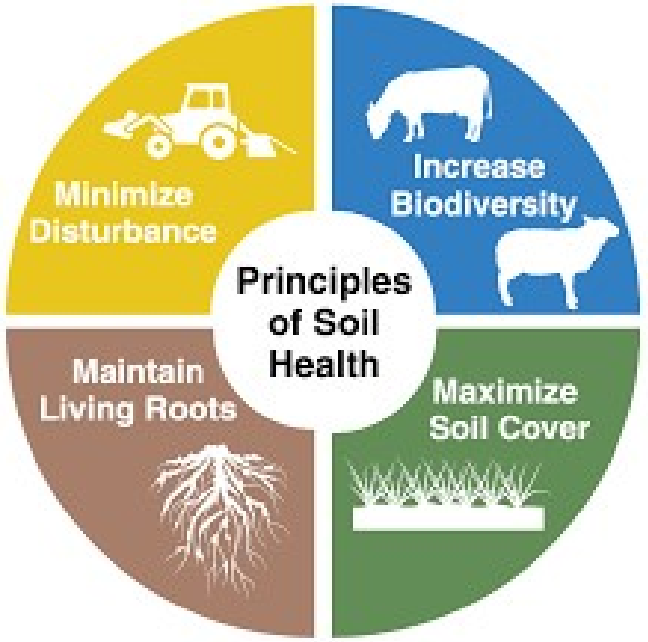




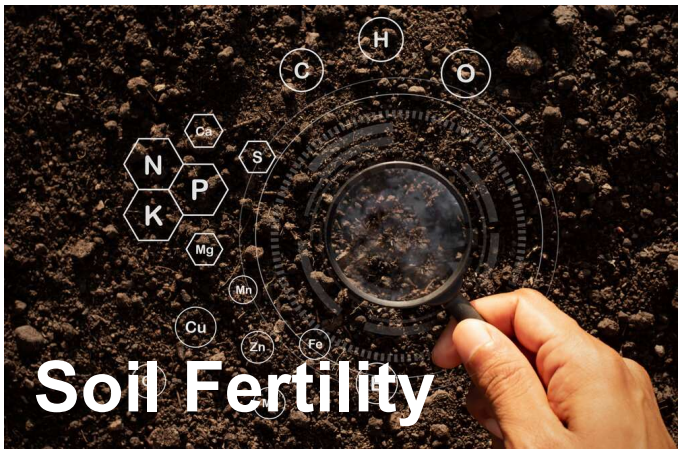
Scott et al. (2023)

Soil Fertility?
Soil Health?
Soil Quality?

- Often used interchangeably, but different
- *Soil fertility:* the ability of soil to aid plant growth
- *Soil health:* the overall status/vitality
  - Based on physical, chemical, biological properties
- *Soil quality:* the ability of soil to perform ecosystem services
  - Impact water dynamics
  - Support life
  - Store carbon and nutrients
  - And more!

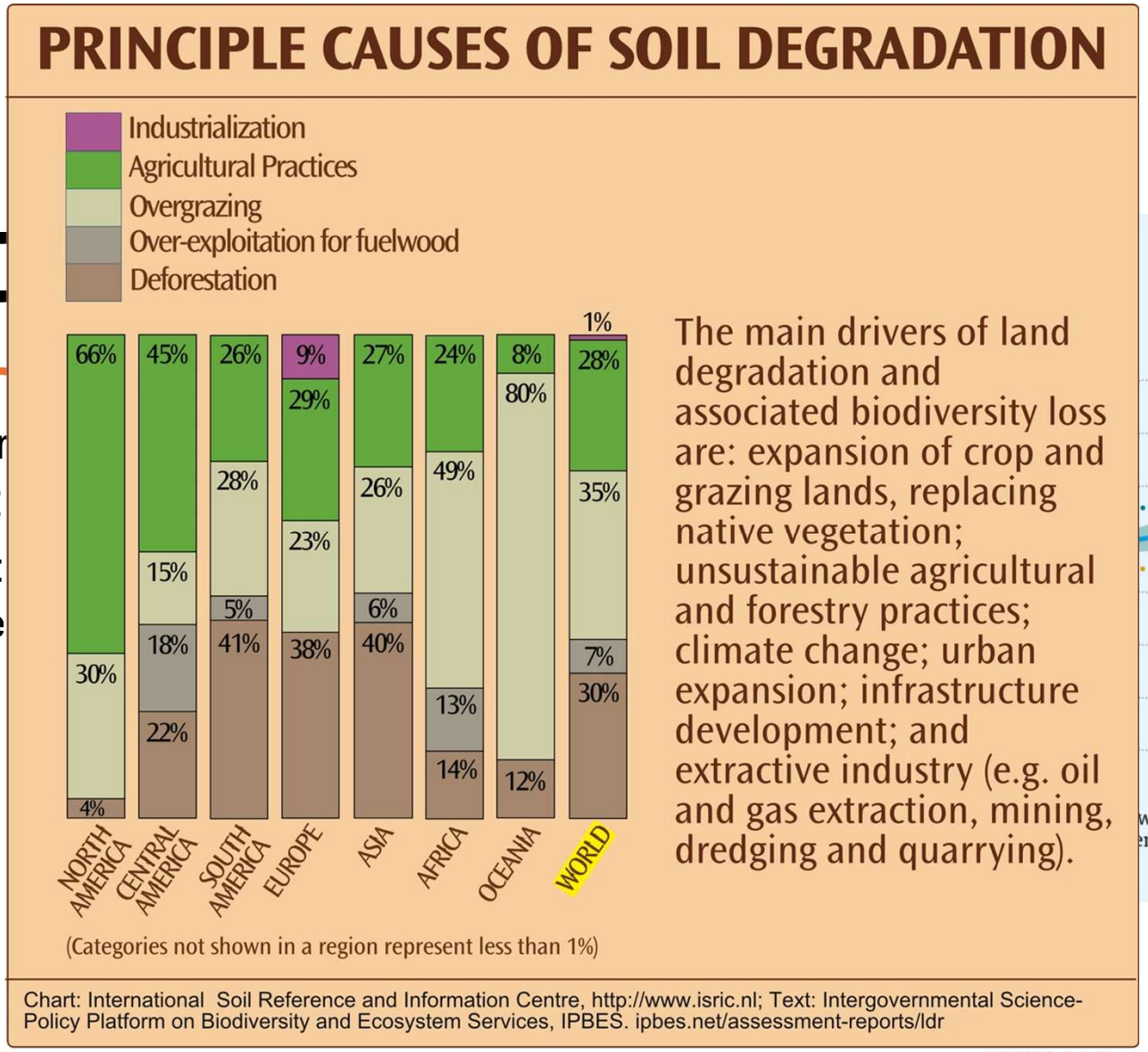


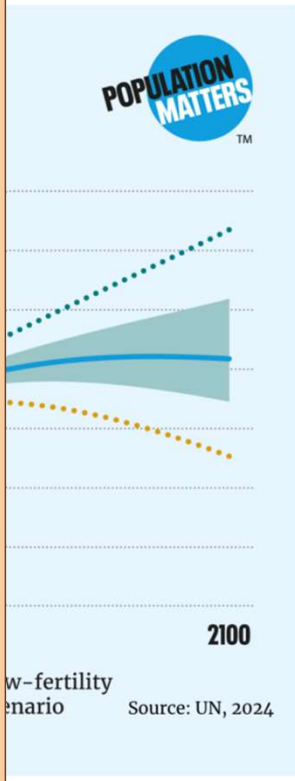
Soil Health Properties



Food D

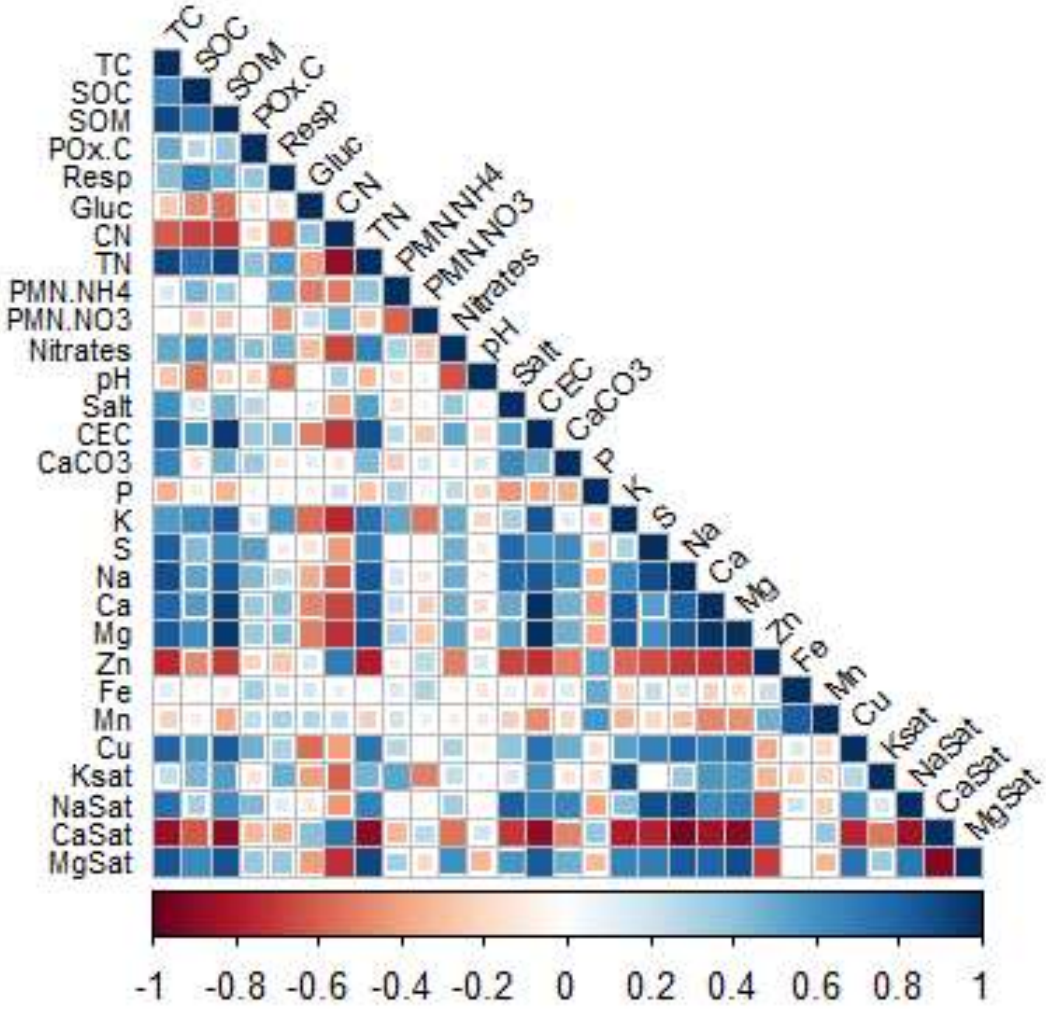
- Global pop for
  - 11 bil by 2
- Food needed:
  - 80% more



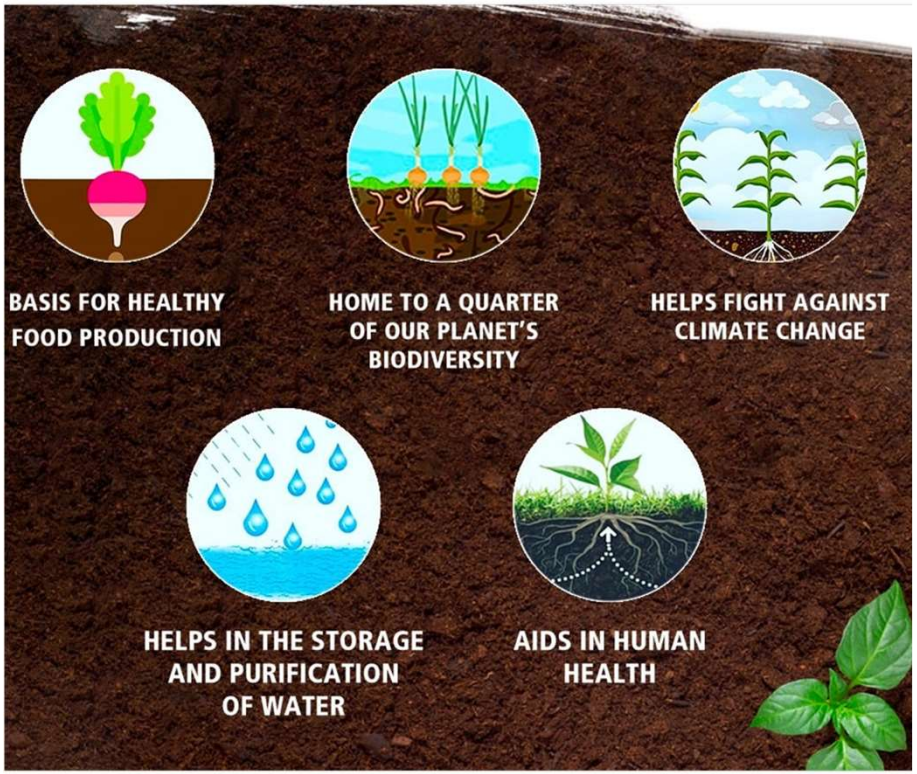


Microbes & SHIs

- Used to assess soil health
- Many SHIs are proxies
  - Microbial activity
  - Microbial potential
- Involve physical, chemical, biological properties
- Complex & Interrelated



Importance of Soil Health



Hypotheses

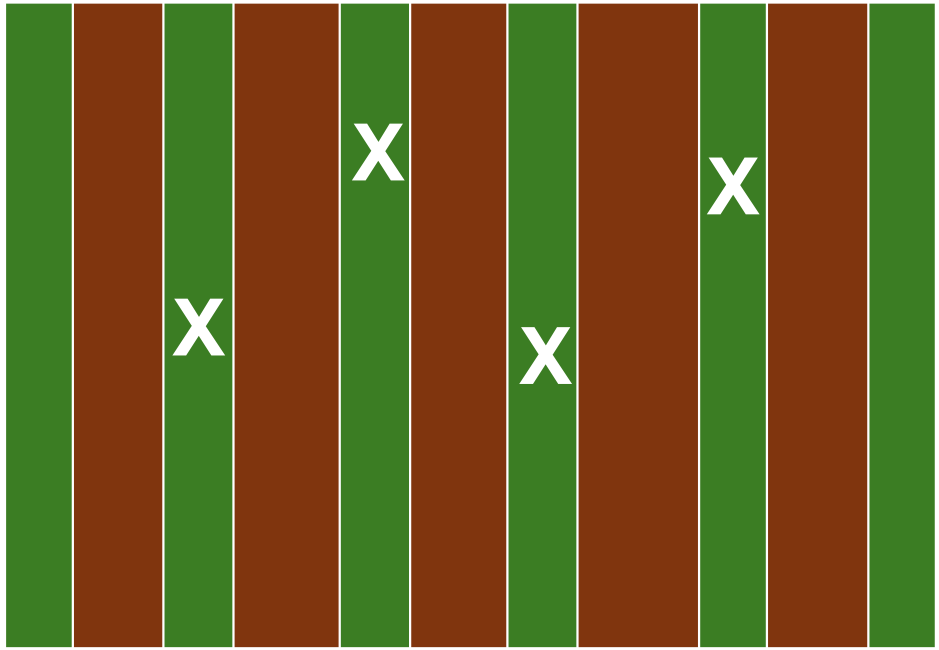
- Sanitizers may adversely affect soil health by altering soil microbiome or by harming soil microbial activities
- Specific soil health indicators may guide interpretations for potential soil health changes following sanitizer application

Project Objectives

- Evaluate soil health changes upon application of water sanitizers in commercial romaine lettuce production systems in Arizona
- Develop guidelines for stakeholders to maintain soil health in agricultural operations
- Conduct extension and education activities to share the knowledge gained from the research.

Methodology: Study Sites

- Selected fields from three commercial growers
  - All located throughout greater Yuma Valley
- Only romaine fields
  - reduce extraneous variables
- 4 locations in each field selected
  - Coordinates logged
  - Samples collected



Methodology: Sampling

- Sampled top 12” of soil
- Pre- and post-sanitizer application
  - After planting, after harvest
- Standardized sanitization protocol utilized
  - Tools washed with DDI water
  - Then 7.5% sodium hypochlorite
  - Then 70% ethanol
- PPE replaced between each rep
  - Hair nets
  - Gloves
  - Shoe covers
  - Face masks
- Samples returned to Maricopa Agricultural Center (MAC) lab
- Biological composite samples to -80° freezer for storage

Metagenomic & Metatranscriptomic Analysis (In Progress)

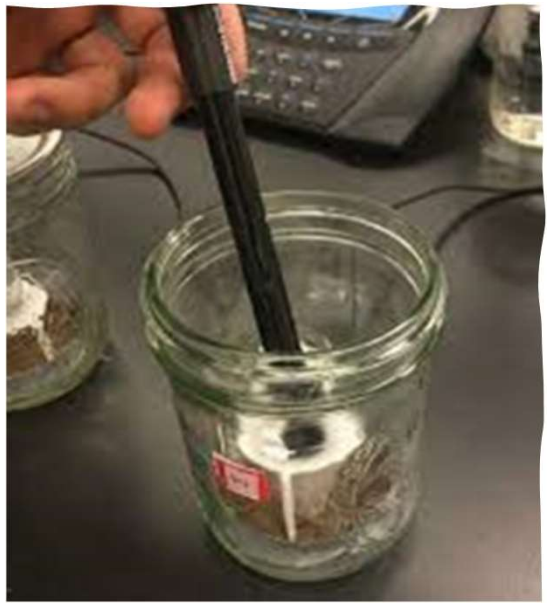
- DNA extracted
  - Qiagen PowerLyzer Powersoil Kit
- Samples sent to PANDA Core lab at UA for amplicon sequencing
  - 16S (Bacteria) & ITS (Fungi)
- Data collected in library
  - Analyzed in R
- qPCR utilized for several genes

Soil Health Indicators: Soil Carbon

- **Total Carbon (TC)**
- **Soil Organic Carbon (SOC)**
- **Soil Organic Matter (SOM)**
- **Permanganate-Oxidizable Carbon (POx-C)**
- **Soil Respiration**
- **Extracellular enzymes (ß-glucosidase)**
- **Carbon-Nitrogen Ratio**
- **Microbial Biomass Carbon (MBC)**

POx-C

Soil Respiration



Soil Health Indicators: Soil Nitrogen

- **Total Nitrogen (TN)**
- **Nitrate-Nitrogen**
- **Potentially Mineralizable Nitrogen (PMN)**
- **Soil Protein**
- **Microbial Biomass Nitrogen (MBN)**

Soil Protein

PMN

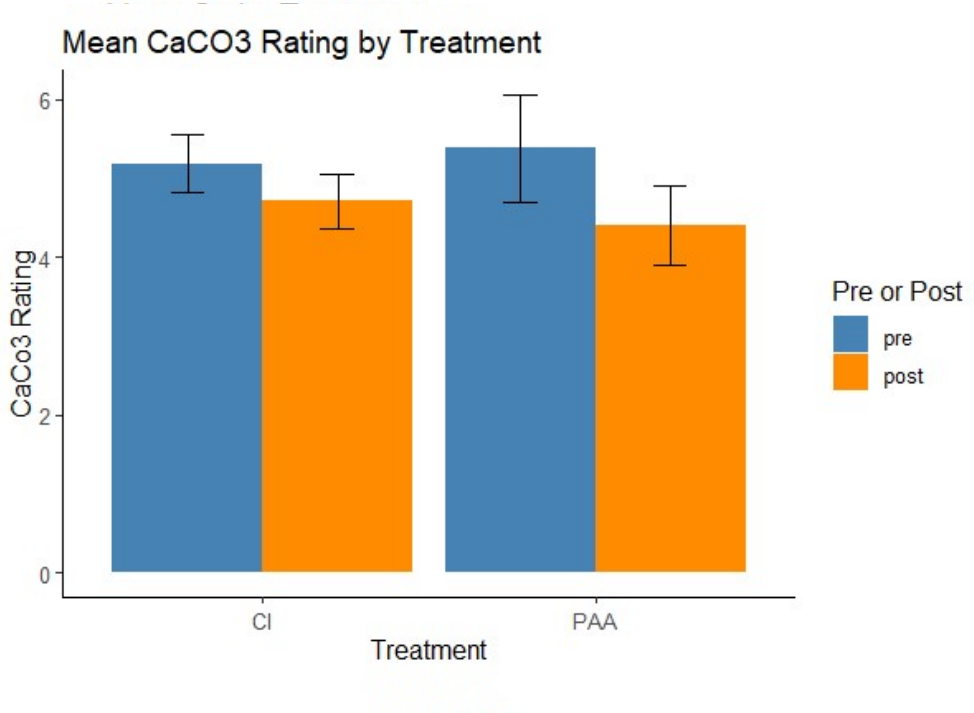
Soil Health Indicators: Physical & Chemical Properties

- Soil pH
- Soil EC
- Macro & Micro Nutrients
- Base Saturation
- Wet Aggregate Stability
- Soil Texture

Wet Aggregate Stability

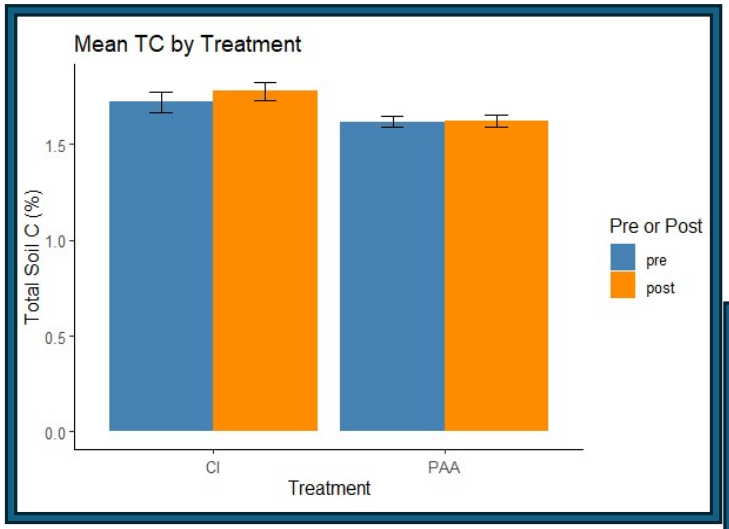
Honorable Mentions

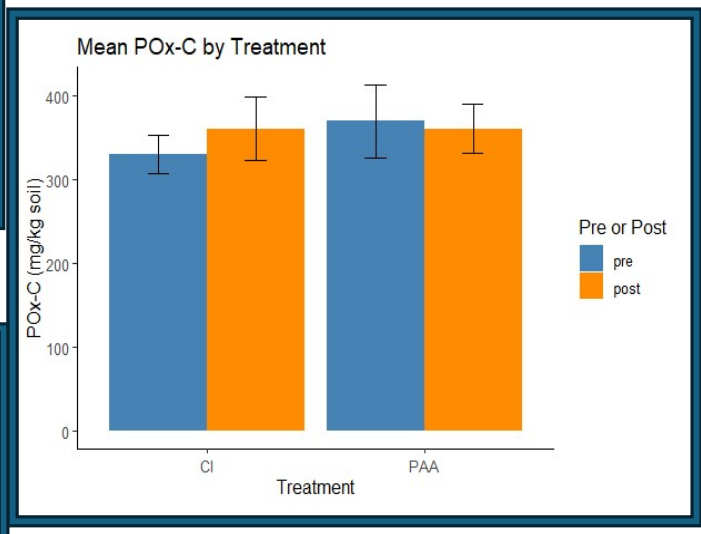
- pH
- Salts
- Sodium Saturation
- Potassium
- Calcium
- Sulfate-S
- Calcium Carbonate

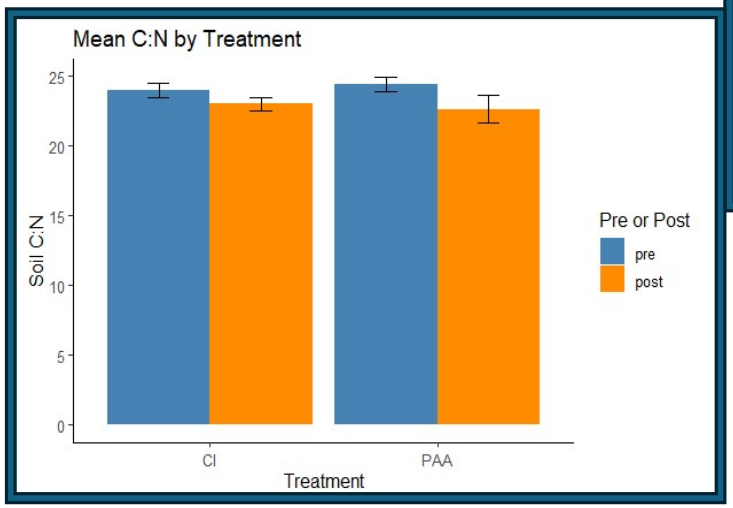


Soil Carbon

- No significant differences:
  - **Total Carbon**
  - **Permanganate-Oxidizable Carbon**
  - **Carbon:Nitrogen Ratio**

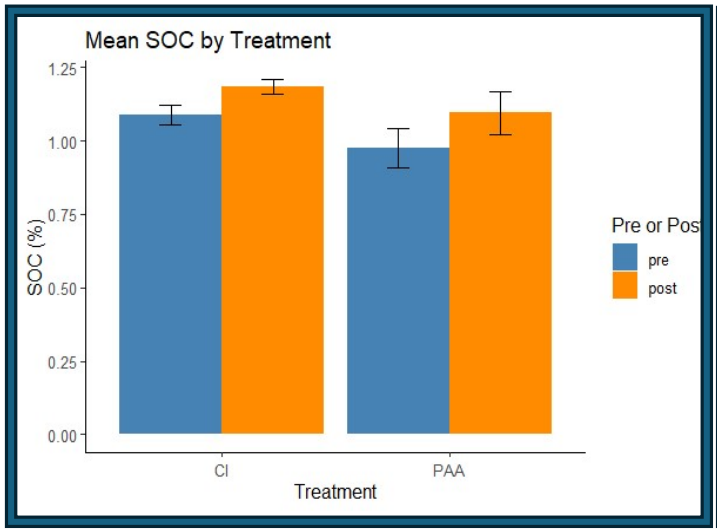


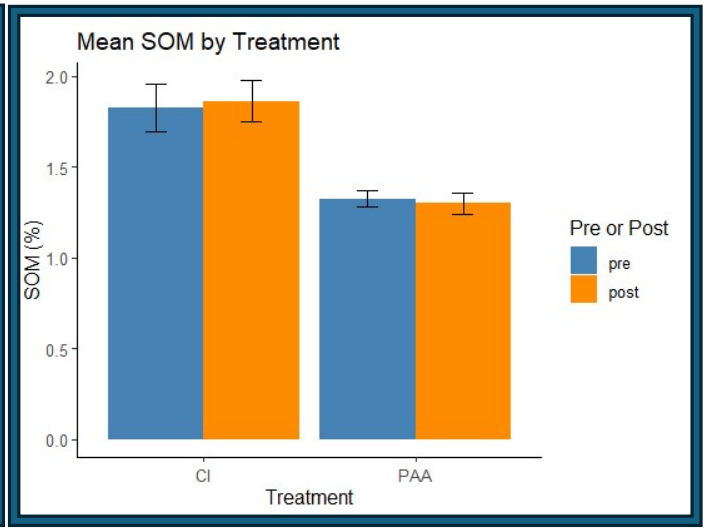


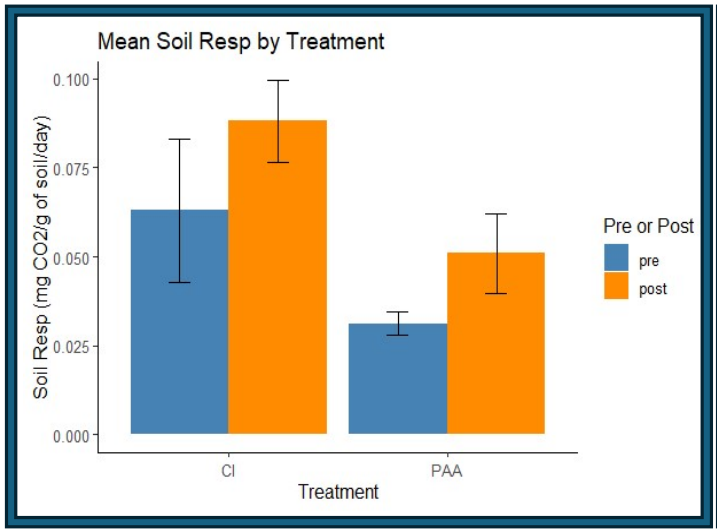


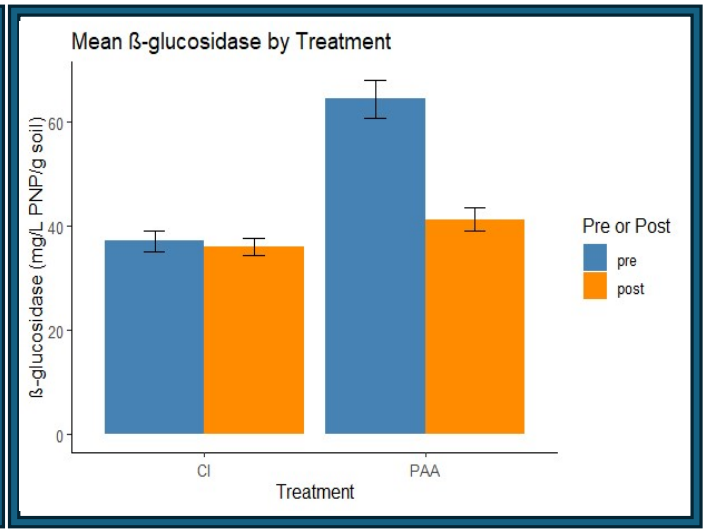
Soil Carbon (Cont.)

- **Soil Organic Carbon**
  - Sanitizer chemistries
  - Pre vs. post application
- **Soil Organic Matter**
  - Sanitizer chemistries
- **Soil Respiration**
  - Pre vs. post application
- **ß-glucosidase**
  - Sanitizer chemistries
  - Pre vs. post application



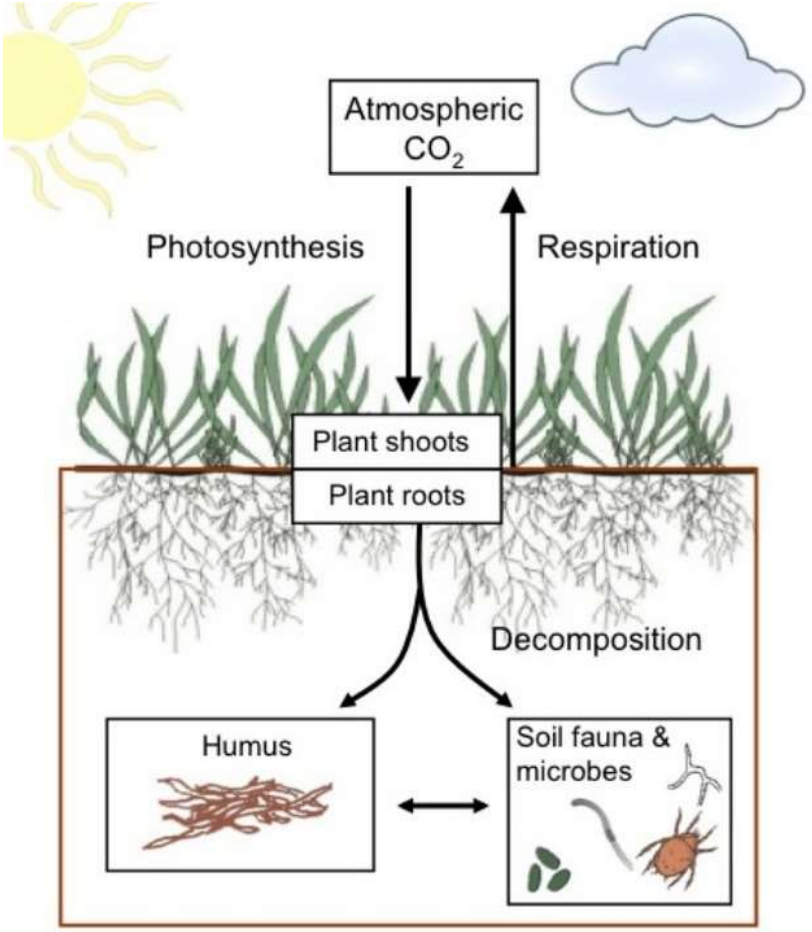






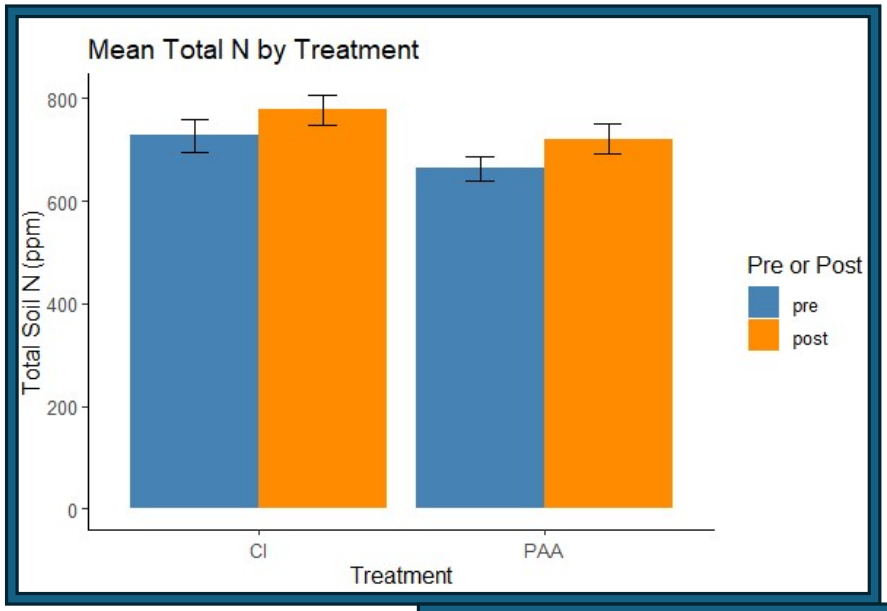
Conclusions: Soil Carbon

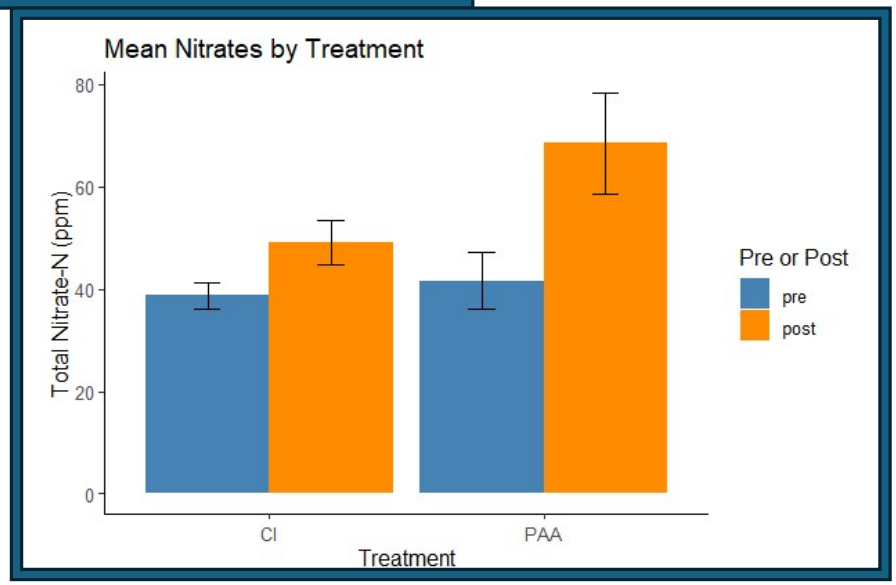
- *No* significant changes to **POx-C**
- **SOC** increased after sanitizer application
- **Soil Respiration** increased significantly after sanitizer application
  - Microbes expending more energy to maintain populations?
  - Change in structure of microbial community?
    - Disruption to nutrient cycling?
- Decrease in **ß-glucosidase** – especially after PAA application
  - Decreased activity of microbes like bacteria and fungi?
    - Decreased cellulose degradation rates moving forward?



Soil Nitrogen

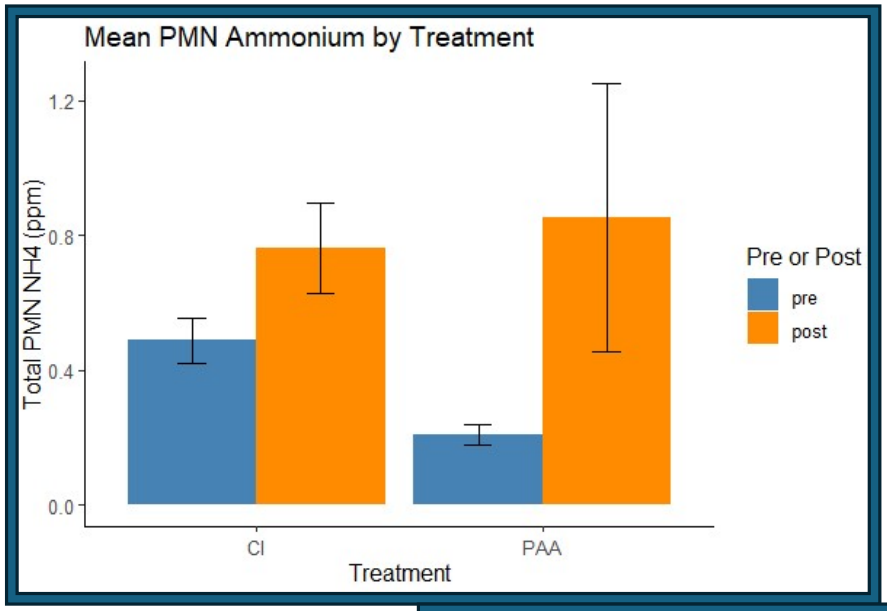
- No significant differences:
  - **Total Nitrogen**
  - **Nitrate-Nitrogen**

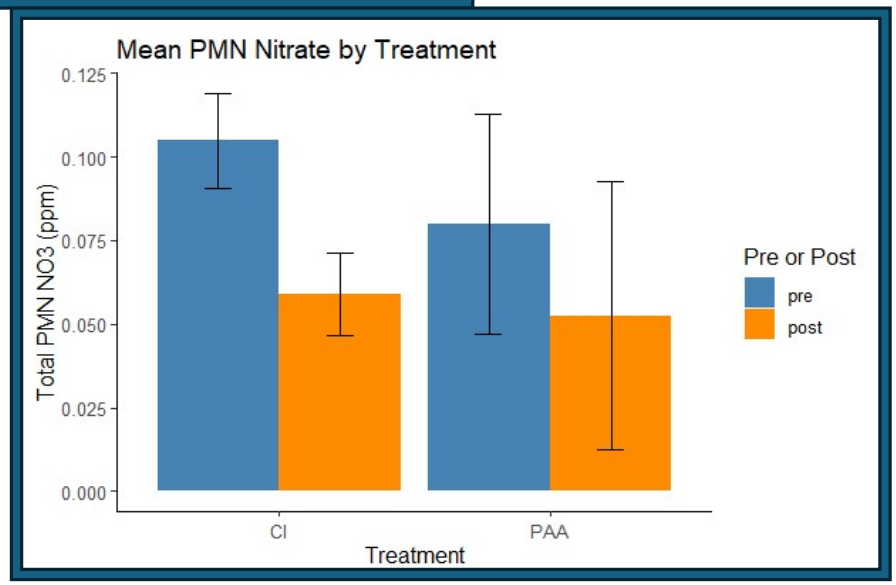




Soil Nitrogen (Cont.)

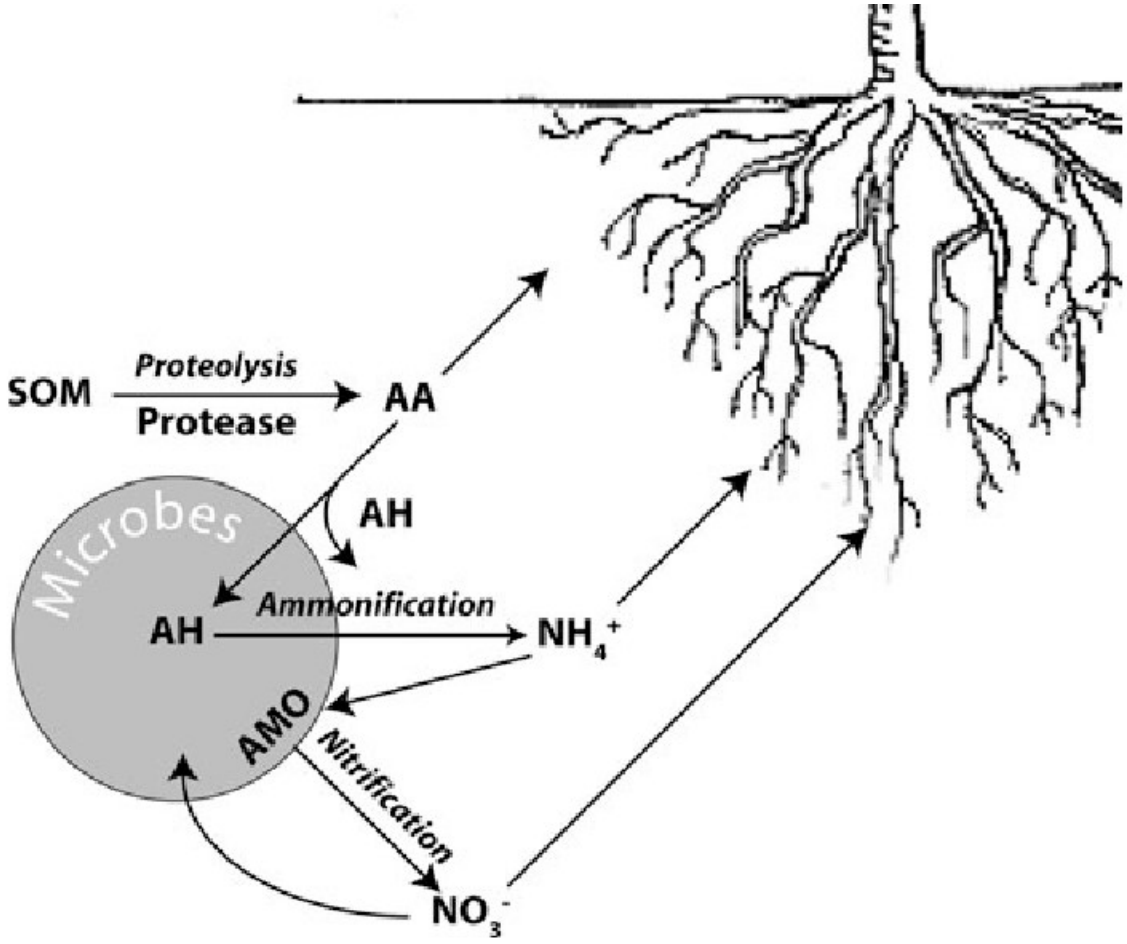
- **Potentially Mineralizable Nitrogen-Ammonium**
  - Pre vs. post application
- **Potentially Mineralizable Nitrogen-Nitrate**
  - Pre vs. post application





Conclusions: Nitrogen

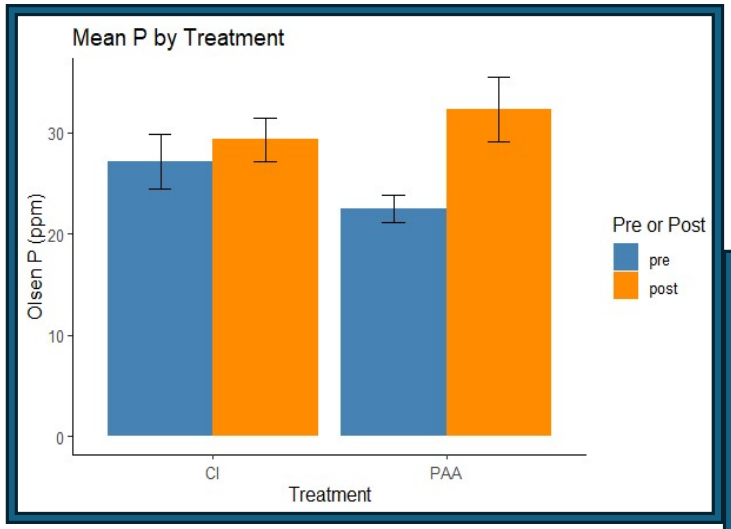
- No significant differences in total **nitrogen** or **nitrates**
- **Potentially mineralizable nitrogen** stores depleted
  - Microbes continued ammonification
  - Fewer microbes to oxidize ammonium?

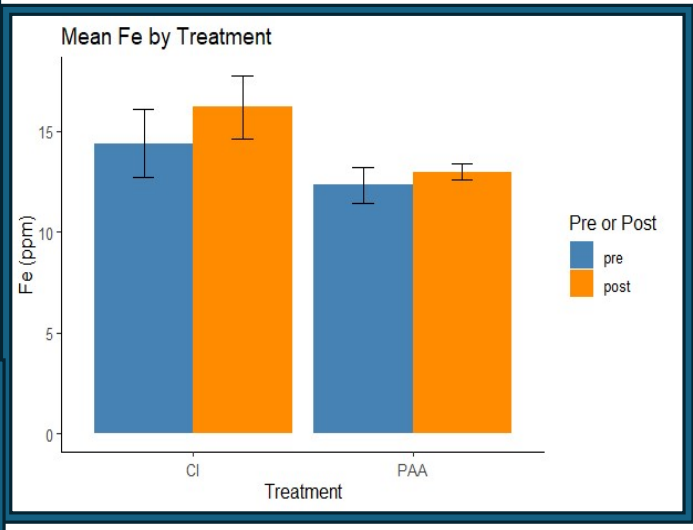


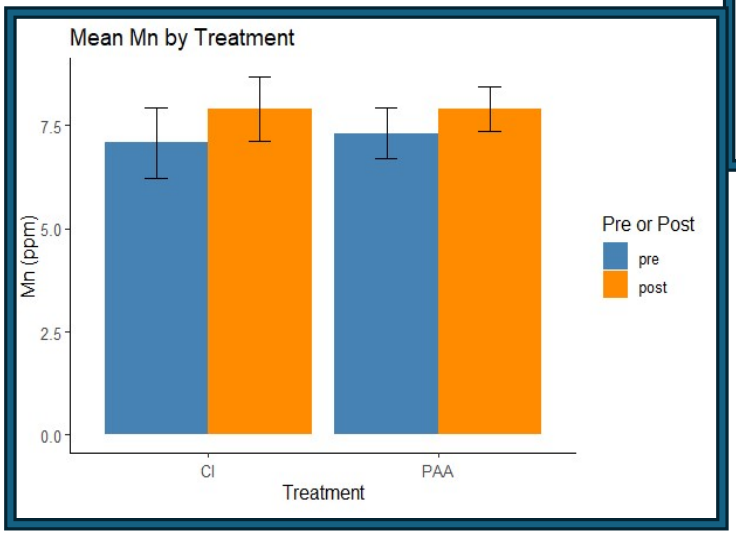
Hofmockel et al. (2010)

Soil Physical & Chemical Properties

- No significant differences:
  - **Phosphorus**
  - **Iron**
  - **Manganese**

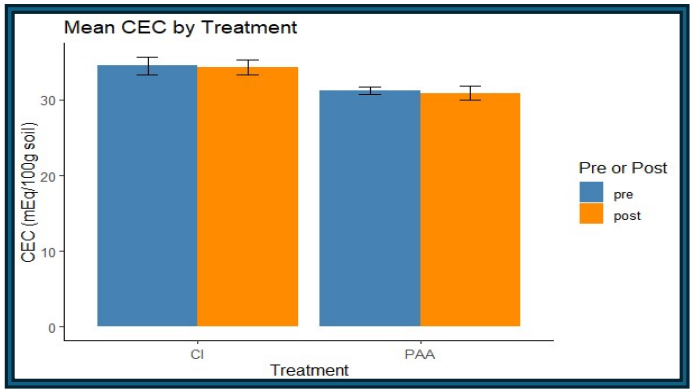


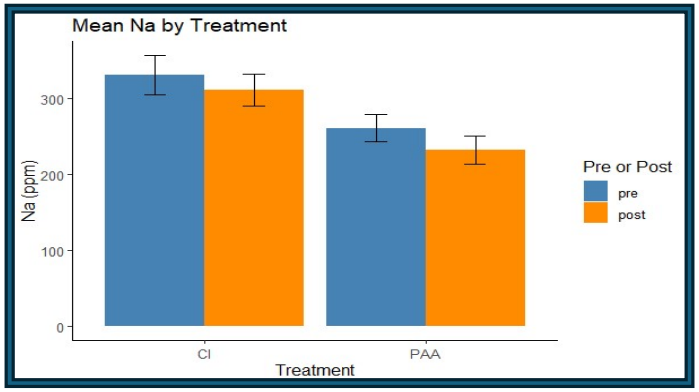


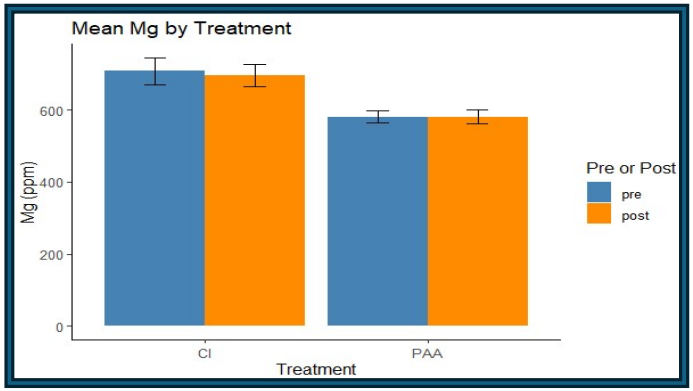


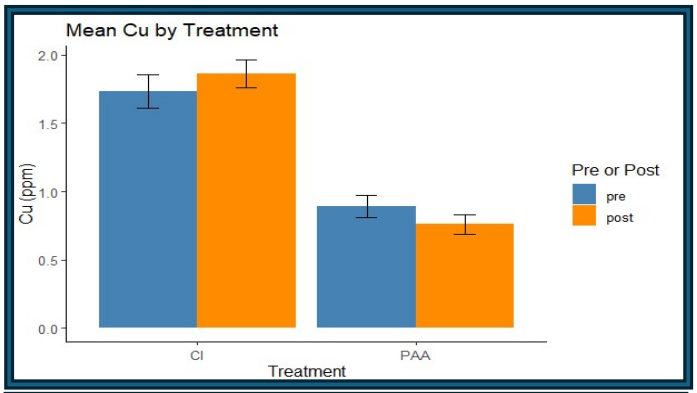
Soil Physical & Chemical Properties (Cont.)

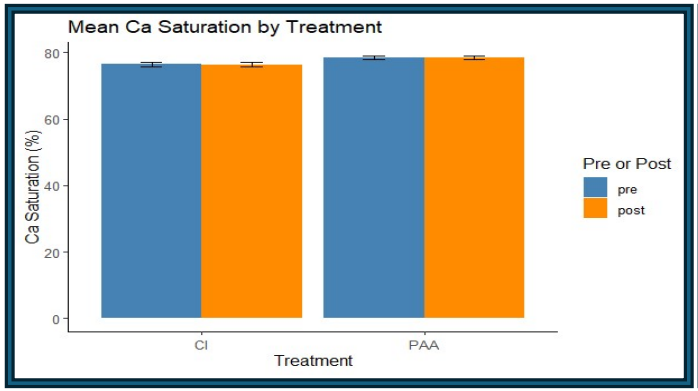
- **CEC**
  - Sanitizer chemistries
- **Sodium**
  - Sanitizer chemistries
- **Magnesium**
  - Sanitizer chemistries
- **Copper**
  - Sanitizer chemistries
- **Calcium Saturation**
  - Sanitizer chemistries
- **Magnesium Saturation**
  - Sanitizer chemistries

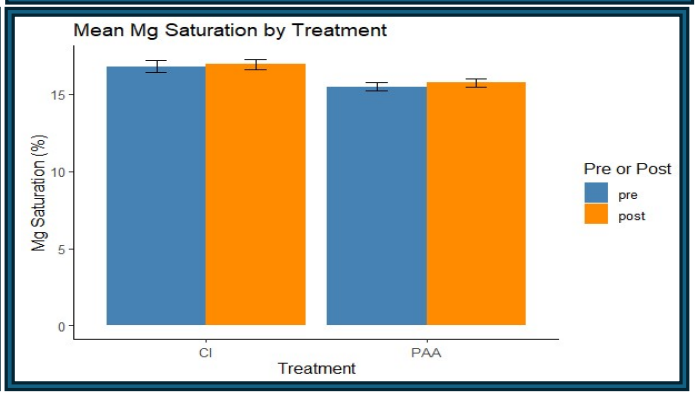






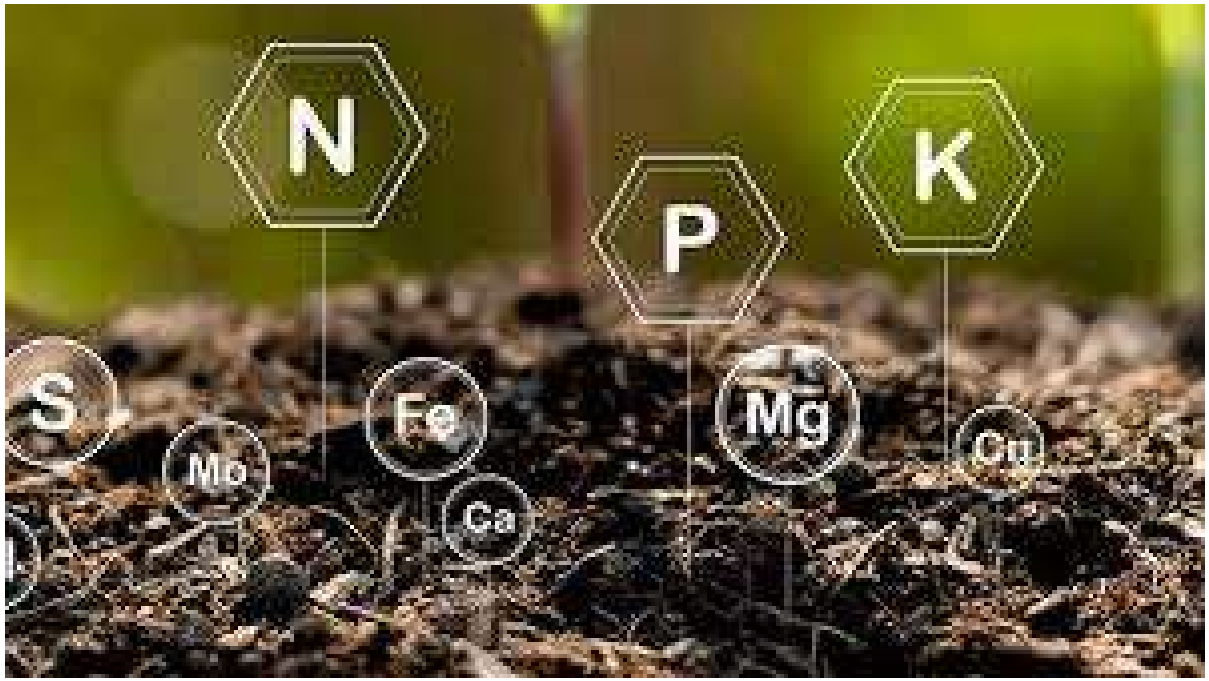






Conclusions: Soil Physical & Chemical Properties

- No significant changes after sanitizer application
- Pre- to post-application trends (non-significant)
  - **P**, **Fe**, **Mn**, **Mg** (increased)
  - **CEC**, **Na** (decreased)
- No apparent harm to micronutrient availability



Implications

- Indicators of microbial activity have been altered after sanitizer application
- **Carbon cycling and storage** may be disrupted by application
  - Increased **soil respiration**
  - Decreased **ß-glucosidase**
- **Nitrogen cycling** may be disrupted by application
  - Changes in **PMN**
    - ammonification and ammonium oxidation disrupted

Next Steps

- Complete soil health analysis
  - **Soil protein**
- Complete metagenomic analysis
  - Analyze **sequencing data**
- Disseminate findings

Looking to the Future

- Are these changes permanent?
  - Structural repair of microbiome?
- Can these changes be slowed or stopped?
  - Management practices like composting, cover crops?
- Are these changes replicable?
  - Lab setting to minimize confounding variables?
  - Randomized replicated trials necessary

Acknowledgements

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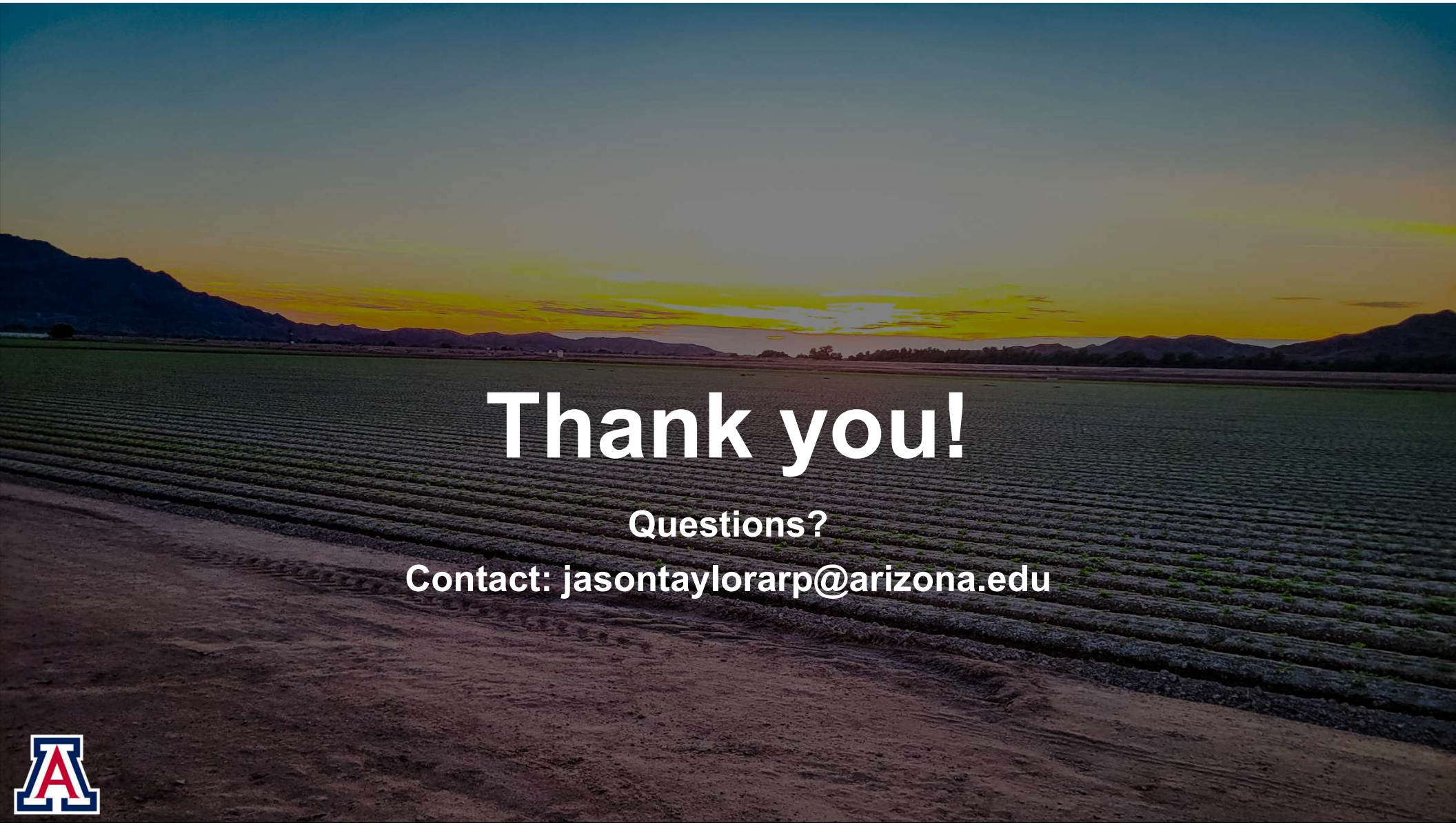
Thank you!
Questions?
Contact: jasontaylorarp@arizona.edu