# Soil Health and the Arid Microbiome in a Warming Climate: Challenges for Reclamation

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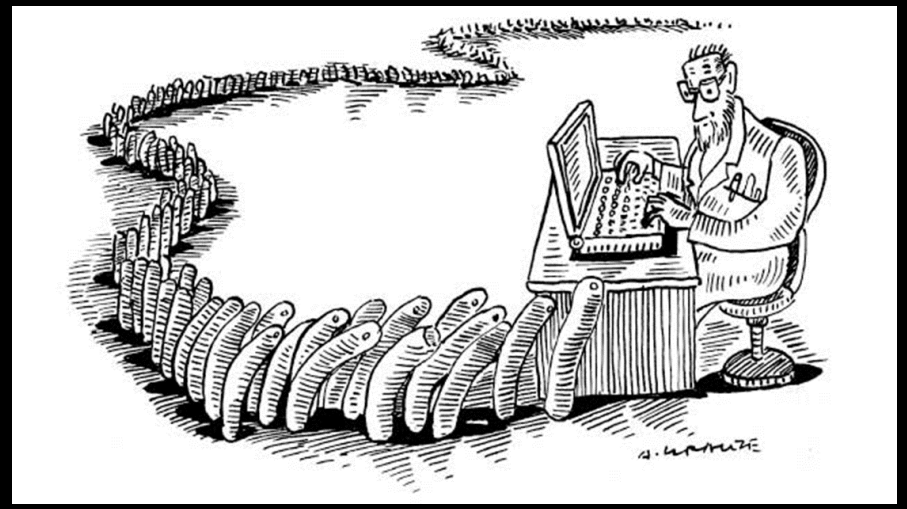
# Fun Facts



Earth’s microbiome is composed of a quadrillion quadrillion microorganisms living in Earth’s crust and waterways

The mass of the Earth’s microbiome is greater than all of the plants and animals on the planet

The importance of Earth’s microbiome to soil health is analogous to that of the human microbiome to human health

Dryland ecosystems comprise 41% of the Earth’s land area but are poorly studied

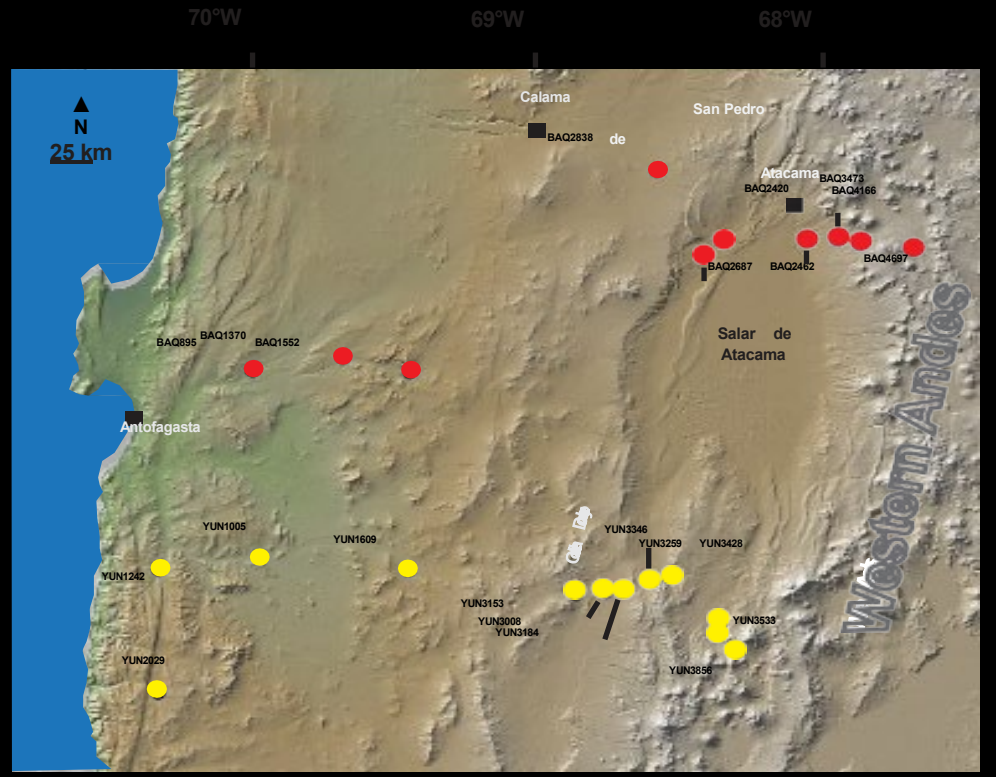
# How will a warming climate impact Earth's microbiome?

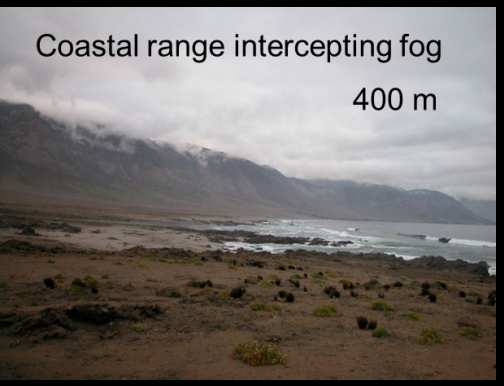
Atacama desert

Sonoran desert

Reclamation of arid mine tailings

# Microbial Diversity in the Atacama Desert

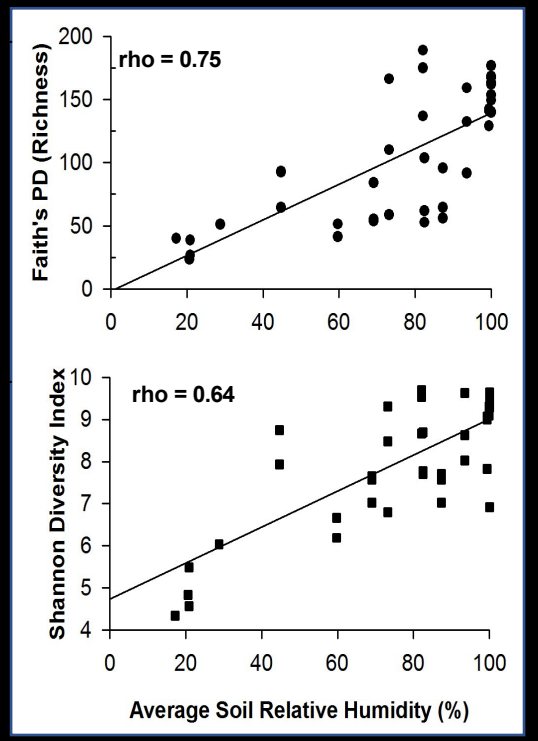





Neilson et al. 2017. MSystems. doi: 10.1128/mSystems.00195-16

# Richness, diversity and dominant microbes are a function of aridity

| | Average Soil Relative Humidity | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 17.18 | 20.7 | 20.9 | 28.79 | 44.74 | 59.69 | 69.08 | 73.21 | 82.1 | 82.5 | 87.3 | 93.6 | 99.4 | 99.99 | 100 |
| **Phylum** | **Phylum Relative Abundance (%)** | | | | | | | | | | | | | | |
| Acidobacteria | 0.04 | 0.02 | 0.06 | 0.54 | 3.64 | 1.17 | 3.21 | 6.35 | 7.97 | 4.34 | 3.76 | 5.84 | 8.18 | 9.60 | 8.82 |
| Proteobacteria | 3.13 | 5.14 | 2.26 | 15.93 | 13.41 | 7.94 | 12.83 | 12.33 | 25.34 | 20.43 | 27.94 | 20.57 | 26.14 | 23.06 | 27.83 |
| Planctomycetes | 0.20 | 0.30 | 0.09 | 0.71 | 1.48 | 0.87 | 0.94 | 2.01 | 3.19 | 1.53 | 1.50 | 2.58 | 2.52 | 3.16 | 2.52 |
| Verrucomicrobia | 0.02 | 0.00 | 0.00 | 0.35 | 0.51 | 0.07 | 0.13 | 4.43 | 1.56 | 0.22 | 1.99 | 0.74 | 4.57 | 2.63 | 6.68 |
| Euryarchaeota | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.09 | 0.05 | 0.03 | 0.01 | 0.05 | 0.16 | 0.09 | 0.07 |
| Crenarchaeota | 0.00 | 0.16 | 0.30 | 0.46 | 1.59 | 0.46 | 1.09 | 1.45 | 2.64 | 1.04 | 0.71 | 2.08 | 2.17 | 1.48 | 1.86 |
| Nitrospirae | 0.05 | 0.10 | 0.00 | 0.12 | 0.53 | 0.14 | 0.17 | 0.80 | 0.52 | 0.16 | 0.21 | 0.46 | 0.70 | 0.59 | 0.78 |
| Elusimicrobia | 0.00 | 0.00 | 0.01 | 0.00 | 0.10 | 0.00 | 0.00 | 0.04 | 0.06 | 0.08 | 0.01 | 0.04 | 0.07 | 0.14 | 0.10 |
| Actinobacteria | 86.20 | 79.41 | 80.82 | 67.24 | 54.05 | 75.94 | 54.22 | 53.56 | 39.81 | 44.14 | 47.16 | 42.26 | 37.65 | 37.67 | 31.86 |
| **Aridity Class** | H | H | H | H | M | H | M | A | A | M | A | A | A | A | A |




Aridity classes:

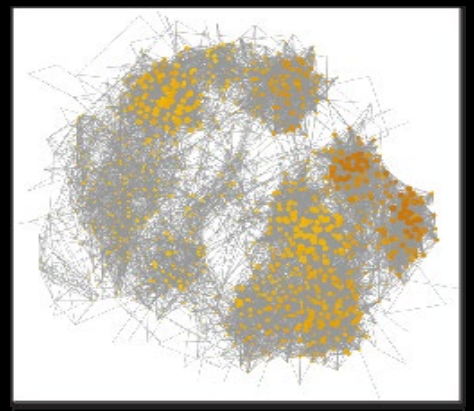
H = hyperarid

M = margin

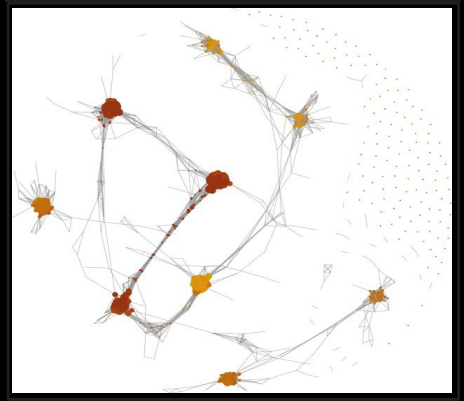
A = arid

# Increasing soil relative humidity supports denser, more tightly connected communities

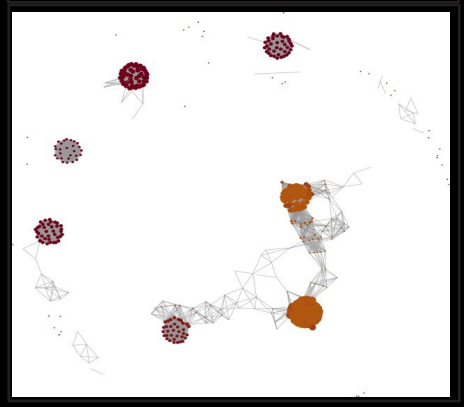
Arid sub-network

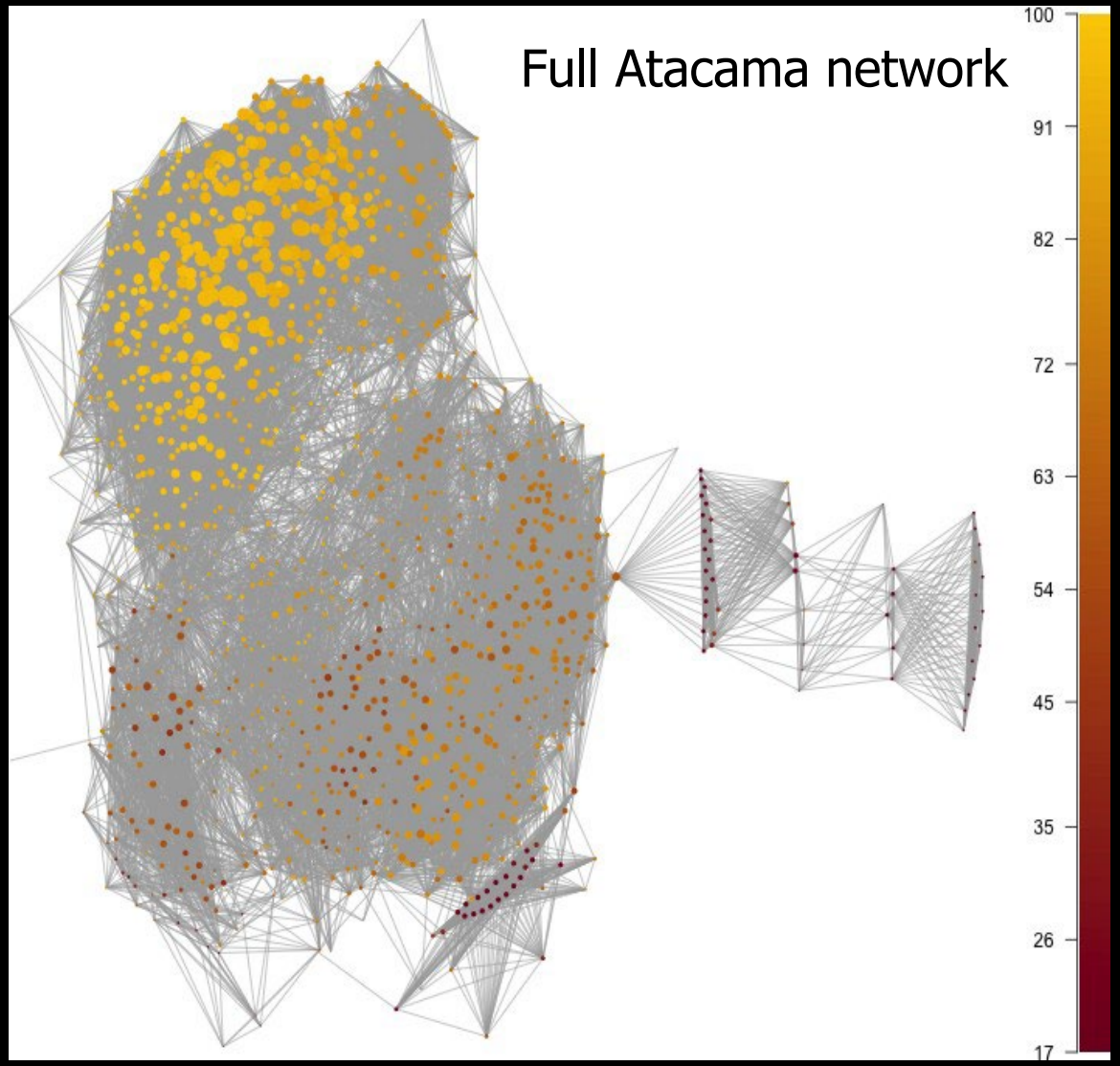


Margin sub-network

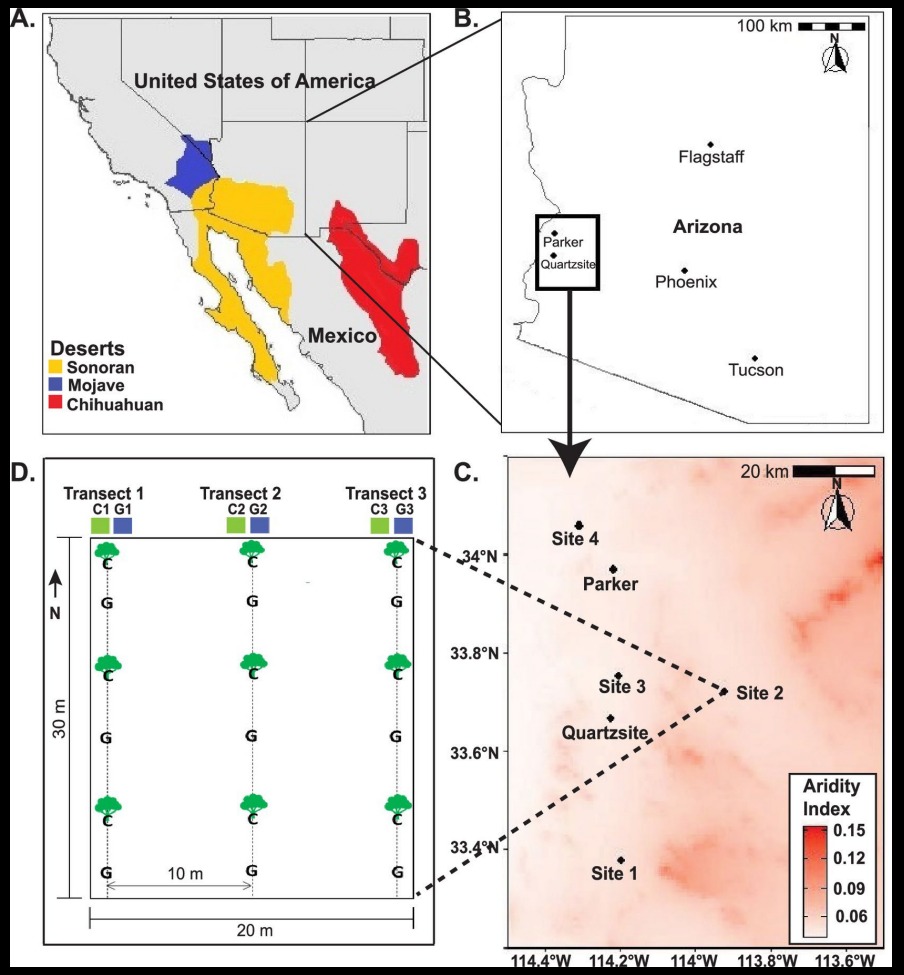


Hyperarid sub-network





# Microbial Diversity in the Sonoran Desert – Comparing Canopy and Gap Sites



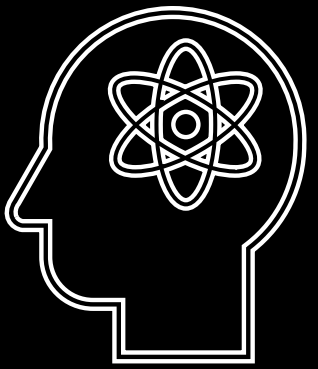


Critical microbial species may be missing in gap sites therefore new canopy sites will not be able to recruit all microbiome members from gap sites.

Kushwaha et al. 2020. Appl. Environ. Microbiol., DOI 10.1128/AEM.02780-20

## What we know:

- Dryland area and aridity will increase as Earth's climate warms
- Already, 10-20% of drylands are degraded or marginal
- Dryland gap areas may not contain keystone microbial species needed to support plant growth.

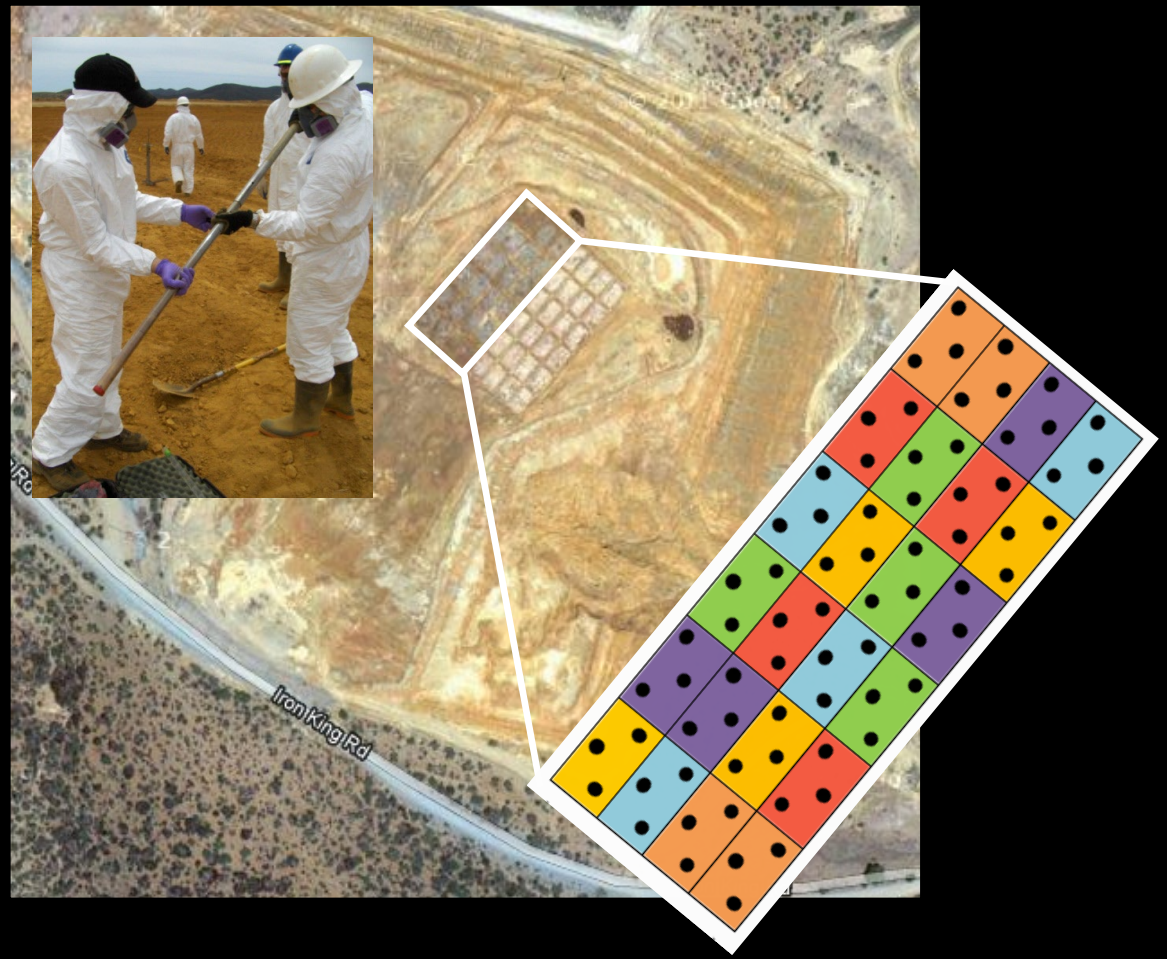


## What we need to know:

- How will climate warming impact the microbiome and the ability of soils to maintain a plant cover
- What are the best management practices that will help maintain and recover degraded lands

Nkonya, E. et al. Economics of land degradation and improvement: a global assessment for sustainable development. (Springer Open, 2016). https://link.springer.com/book/10.1007/978-3-319-19168-3

# Reclamation in the context of arid mine tailings



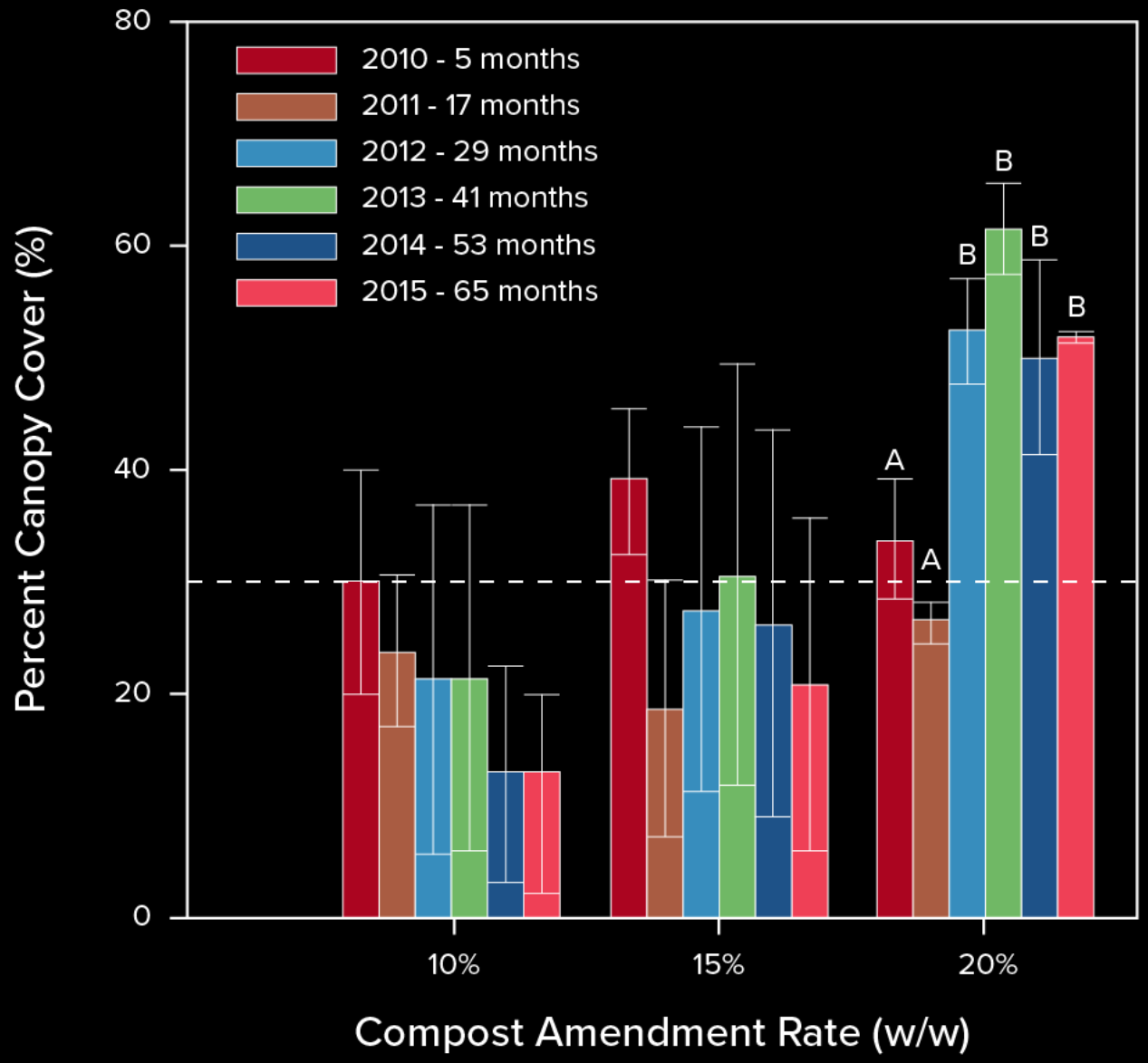

Compost-assisted direct planting
Based on greenhouse work

## Field Study 2010 - 2017

Iron King Mine and Humboldt Smelter Superfund Site

Gil-Loaiza et al., 2016. Sci. Total Environ. 656:451-461

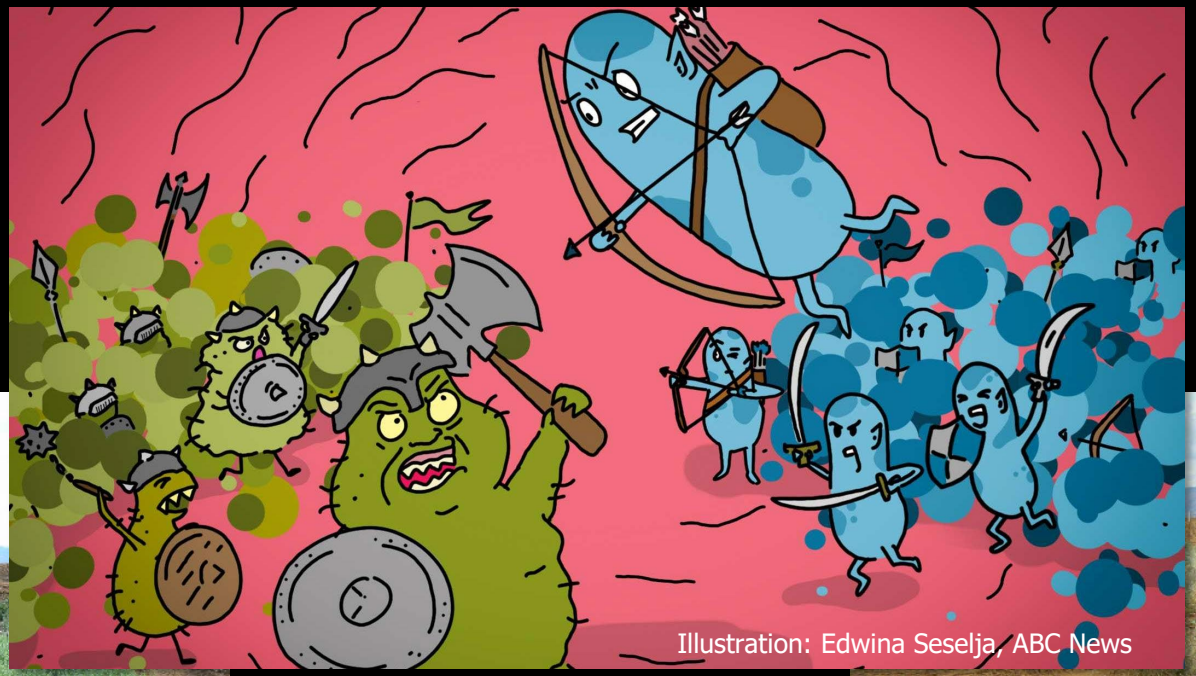
# IKMHSS field trial - Initiated May 18, 2010





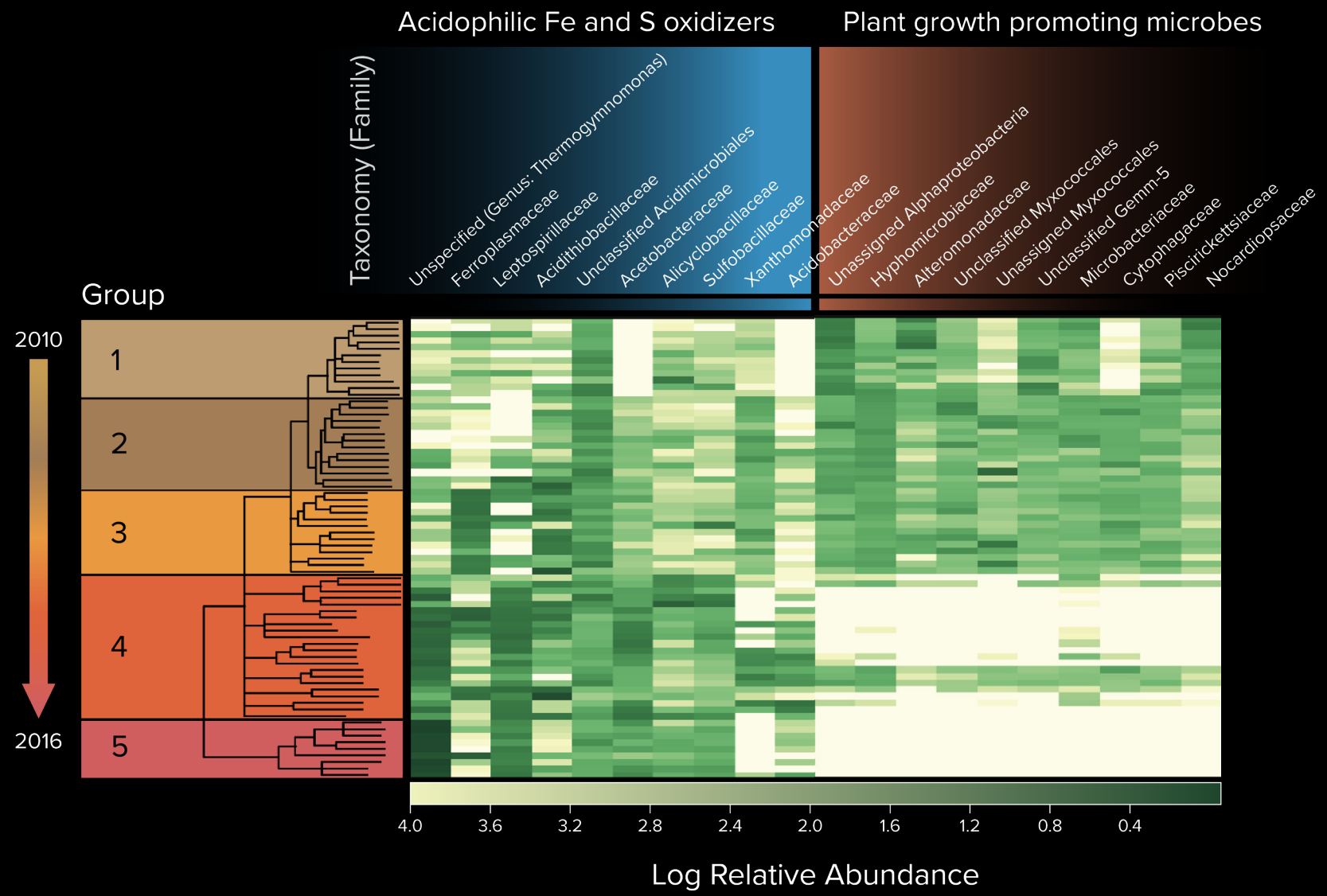

# This is a story of warring microbes

1 year




3 years

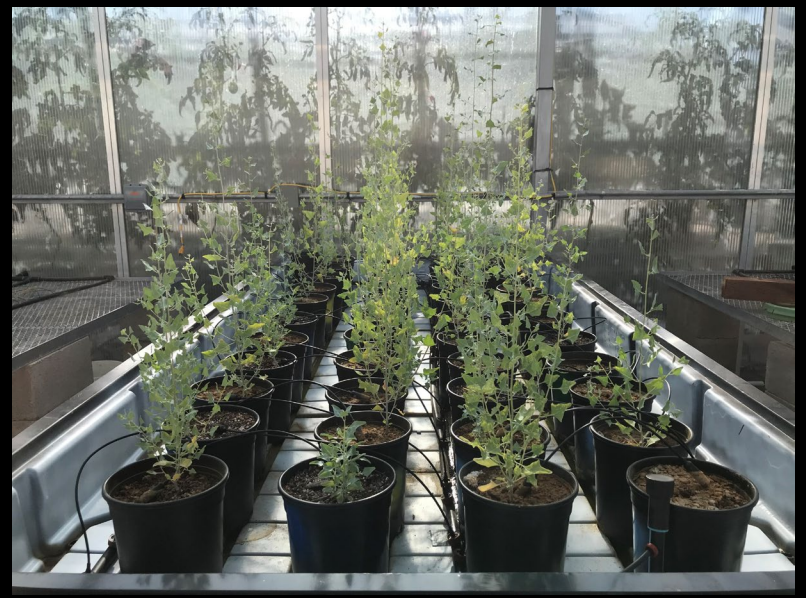
# Field microbiome progression




Hottenstein et al., 2019. Front. Microbiol. doi.org/10.3389/fmicb.2019.01211

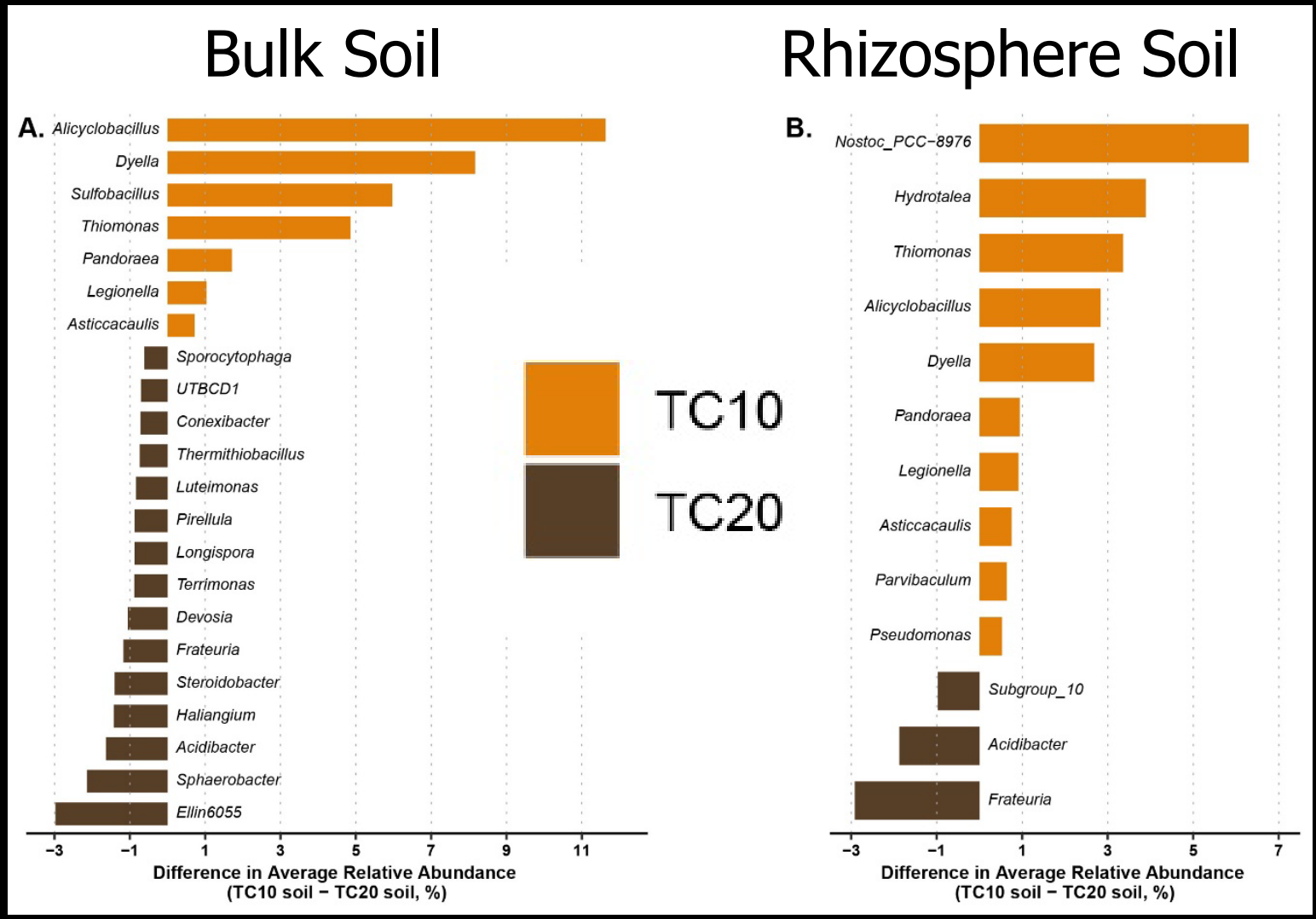
# Microbiome-plant gene expression interactions

- Greenhouse study
- Iron King mine tailings
- Compared plant and microbiome response to 10, 15, and 20% compost amendment

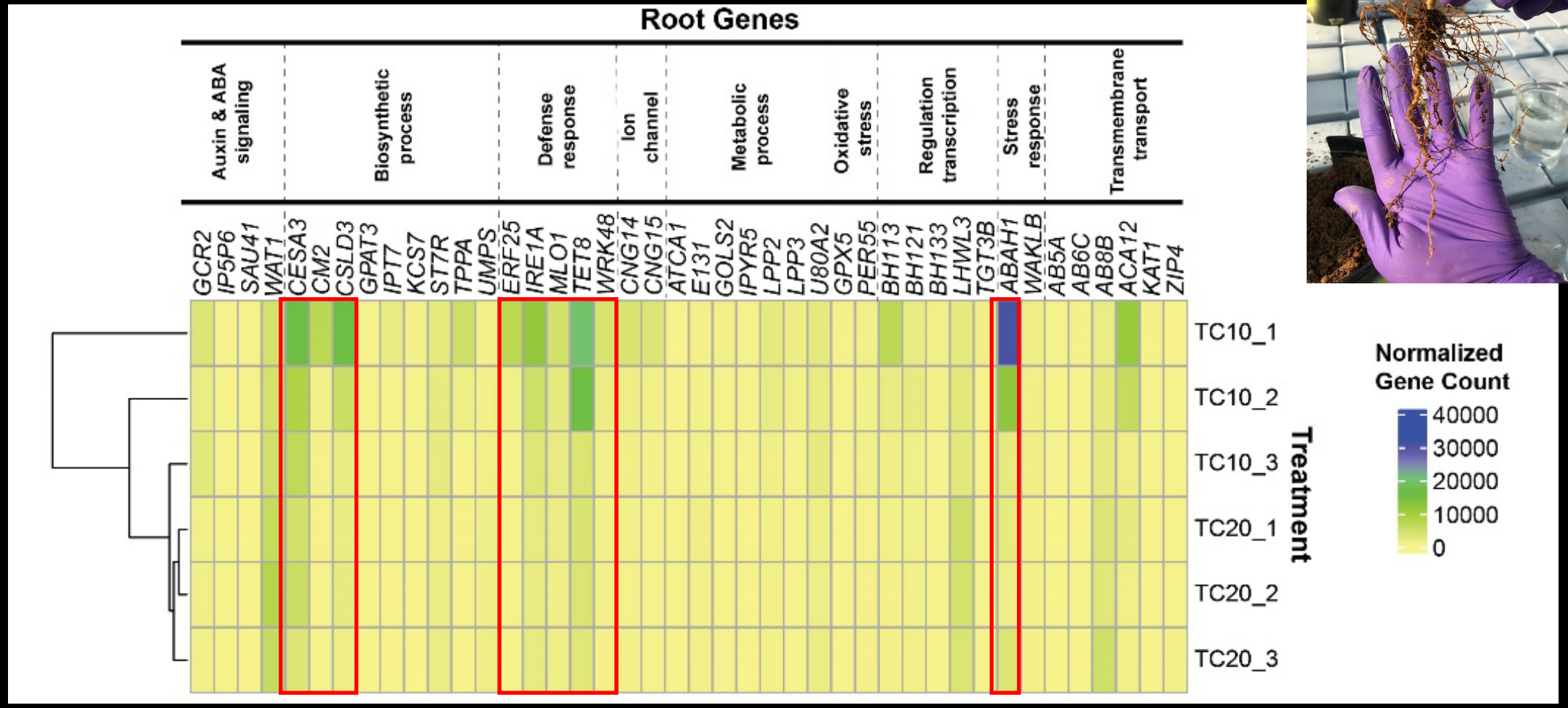


Kushwaha et al., in prep.

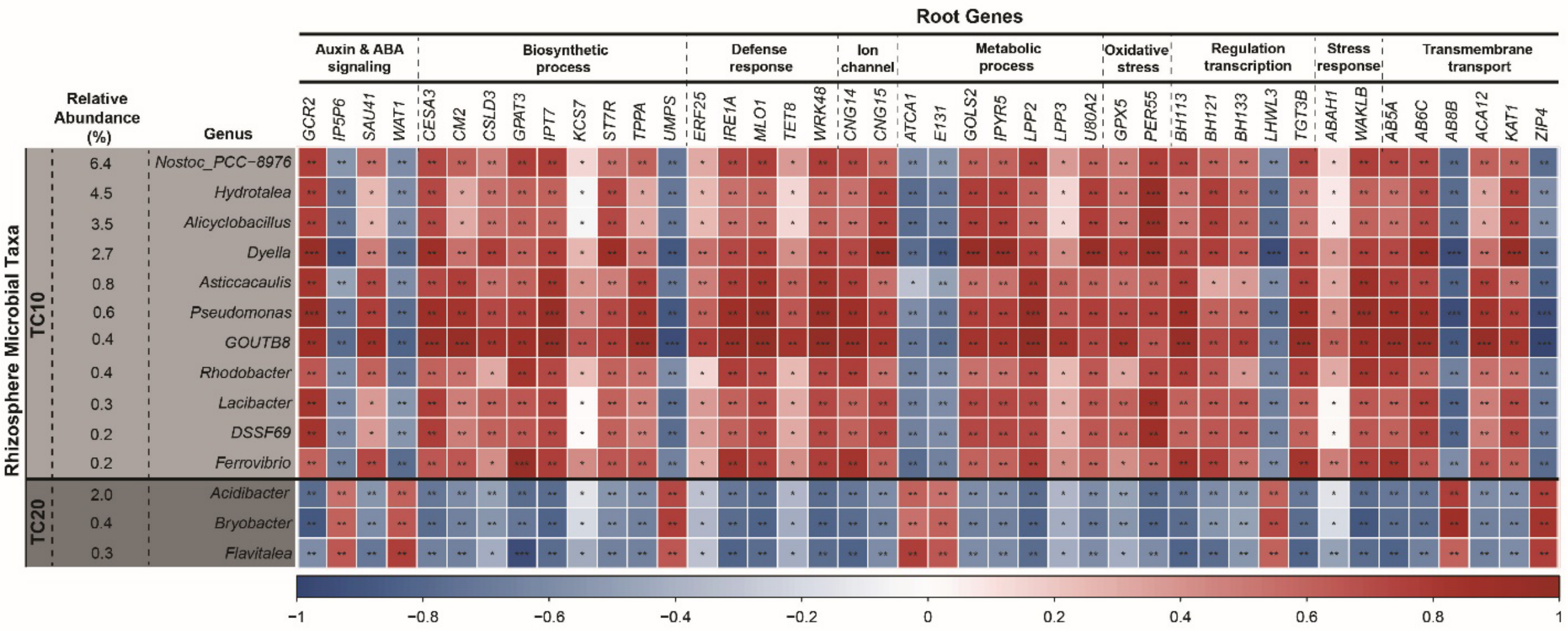
# WRT the microbiome: there are significant taxonomic differences between 10 and 20% compost-amended treatments



# WRT plants: root stress response genes have significantly higher expression in 10% compost treatment



# WRT plant-microbome interaction: key taxa are significantly associated with plant stress response at the 10 and 20% compost treatments

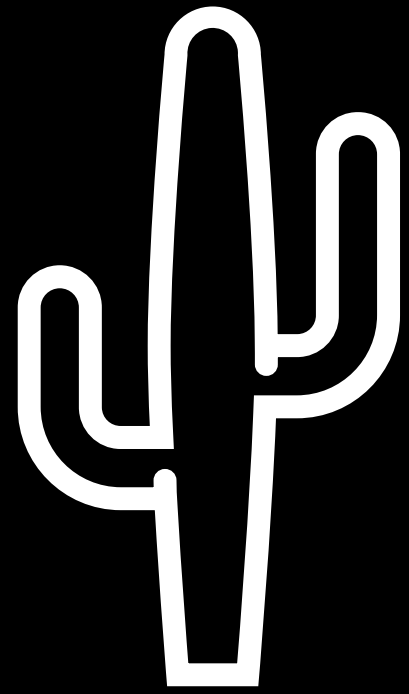


# Lessons I have learned over the past 30 years

The importance of the soil microbiome for soil and plant health is vastly underappreciated and understudied

Working with stakeholders can provide unique insights and allow access to research sites

It will be important in the coming years to quickly translate research to application to combat effects of climate warming



# UArizona Center for Environmentally Sustainable Mining

https://cesm.arizona.edu/

Translating Innovation into Practice through development of environmental educational and research initiatives related to mining activities in arid and semi-arid environments

**Key components:**

- Advised by a technical advisory committee (TAC)
- Provides student training
- Bidirectional research translation to the mining industry
- Neutral tech transfer to policy makers and regulators

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