Potential for Mitigating Wind Erosion in the Sonoran Desert Using Organic Amendments and Microbes to Build Soil Aggregates

Joseph Blankinship

University of Arizona

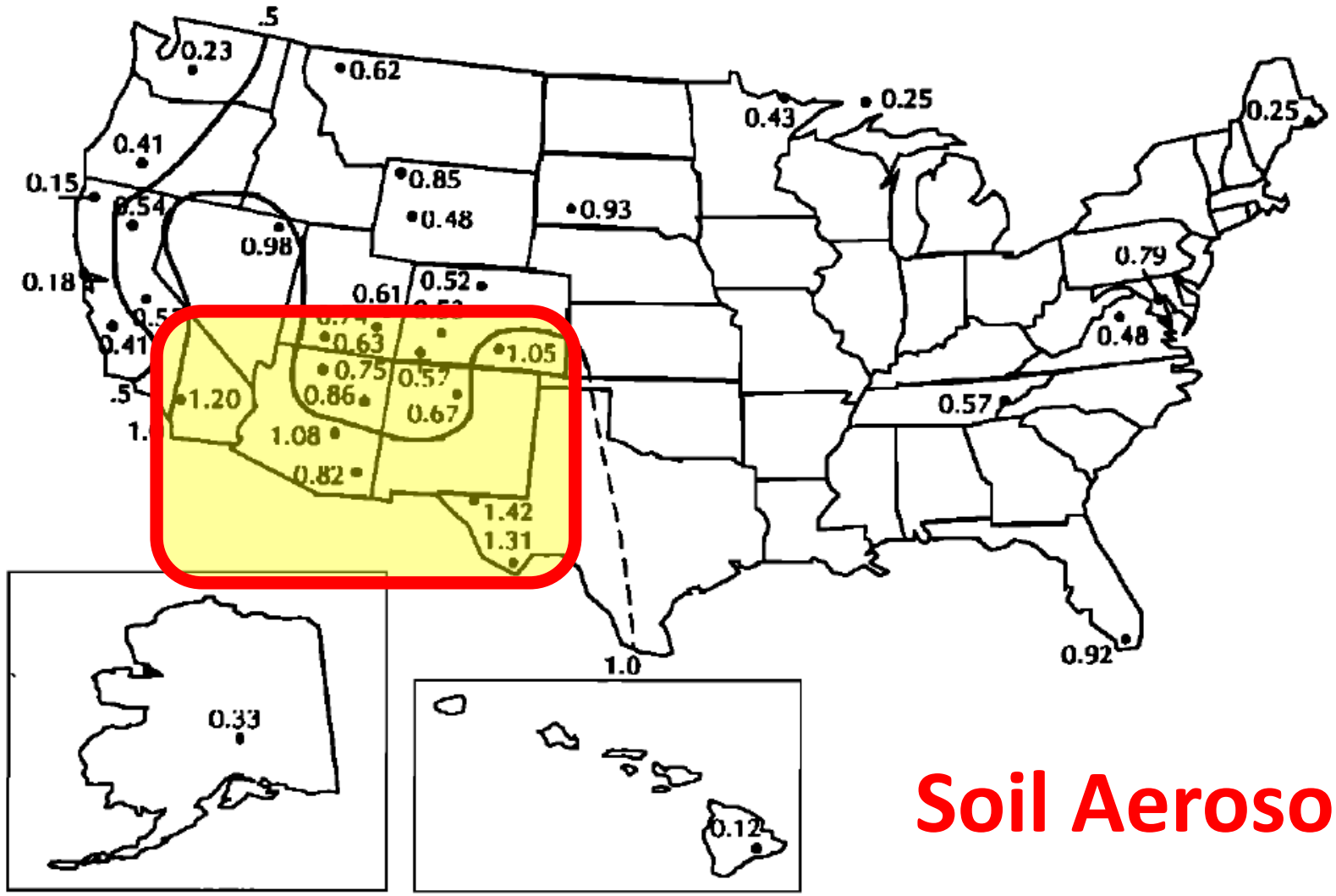
jblankinship@email.arizona.edu

COLLEGE OF AGRICULTURE & LIFE SCIENCES

Soil, Water and Environmental Science

Why should we all care about barren lands?

1. They are expanding in arid and semi-arid regions
2. Little or no forage production (no agricultural uses)
3. Low-quality habitat for wildlife
4. Poor aesthetics
5. **Likely hot spots of dust production**



Soil Aerosols

Figure 13. Three-year averages of fine soil aerosol concentrations (in $\mu g\ m^{-3}$) for each of the sites in the IMPROVE network in the United States for the 3-year period, March 1988 through February 1991.

Malm et al. (1994) *Journal of Geophysical Research*

We can't *not* talk about water erosion

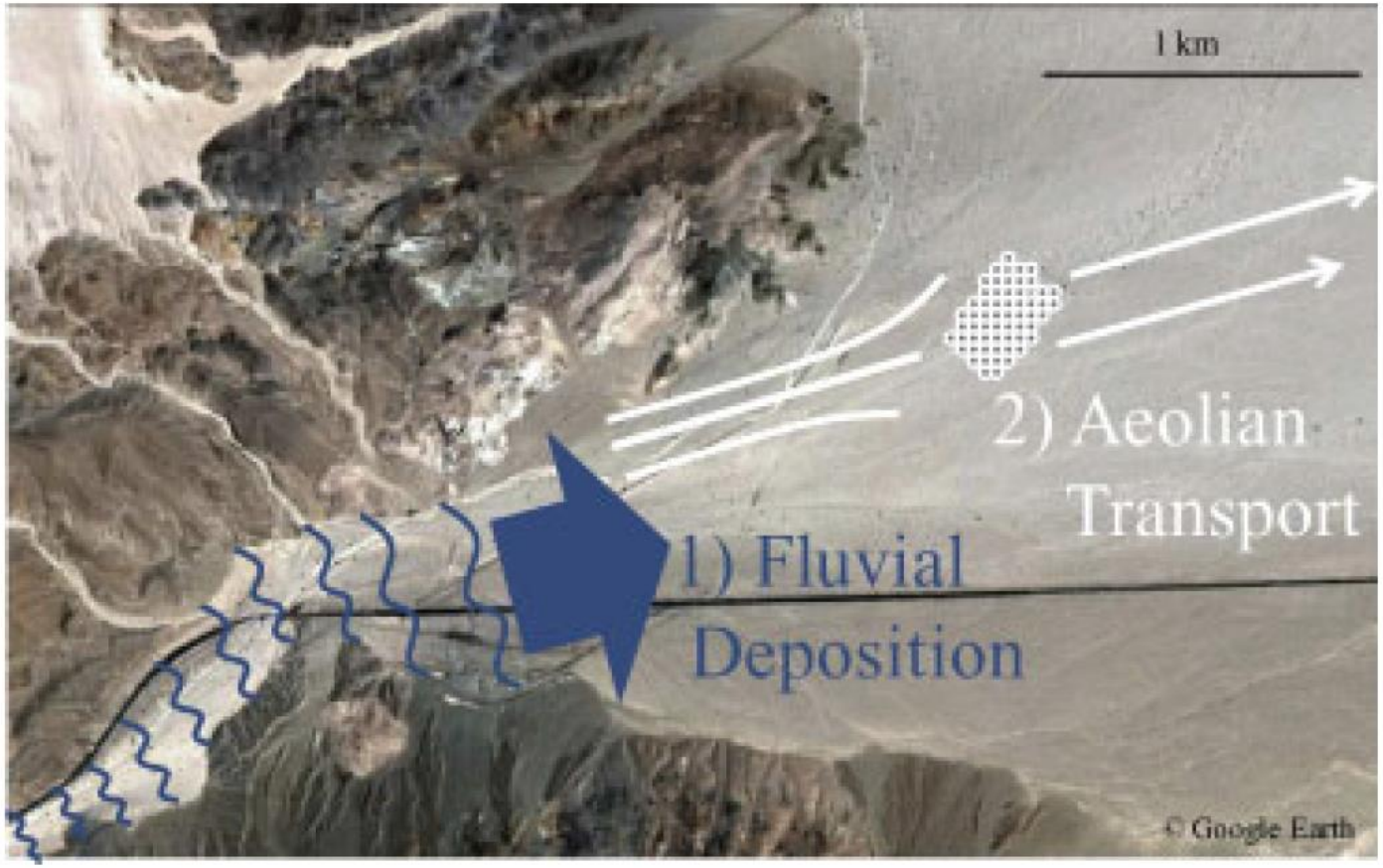


Figure 3. Fluvial–aeolian interaction at Mojave River delta in southeastern CA (USA). Fluvial deposition from adjacent mountains provides material for aeolian transport during high winds.

Belnap et al. (2011) *Ecohydrology*

Figure 4. Southeast view of the north end of Soda (dry) Lake (northeast of the Mojave River delta) during a clear day on 15 November 2010 (a) and dusty day on 30 January 2011(b). The camera used to collect these photos is part of a study to monitor dust emissions in the Mojave Desert and Colorado Plateau, USA (http://gec.cr.usgs.gov/info/sw/clim-met). Photo credit: Frank Urban (USGS) and Rob Fulton (CSU-Fullerton).

Arizona Department of Public Safety

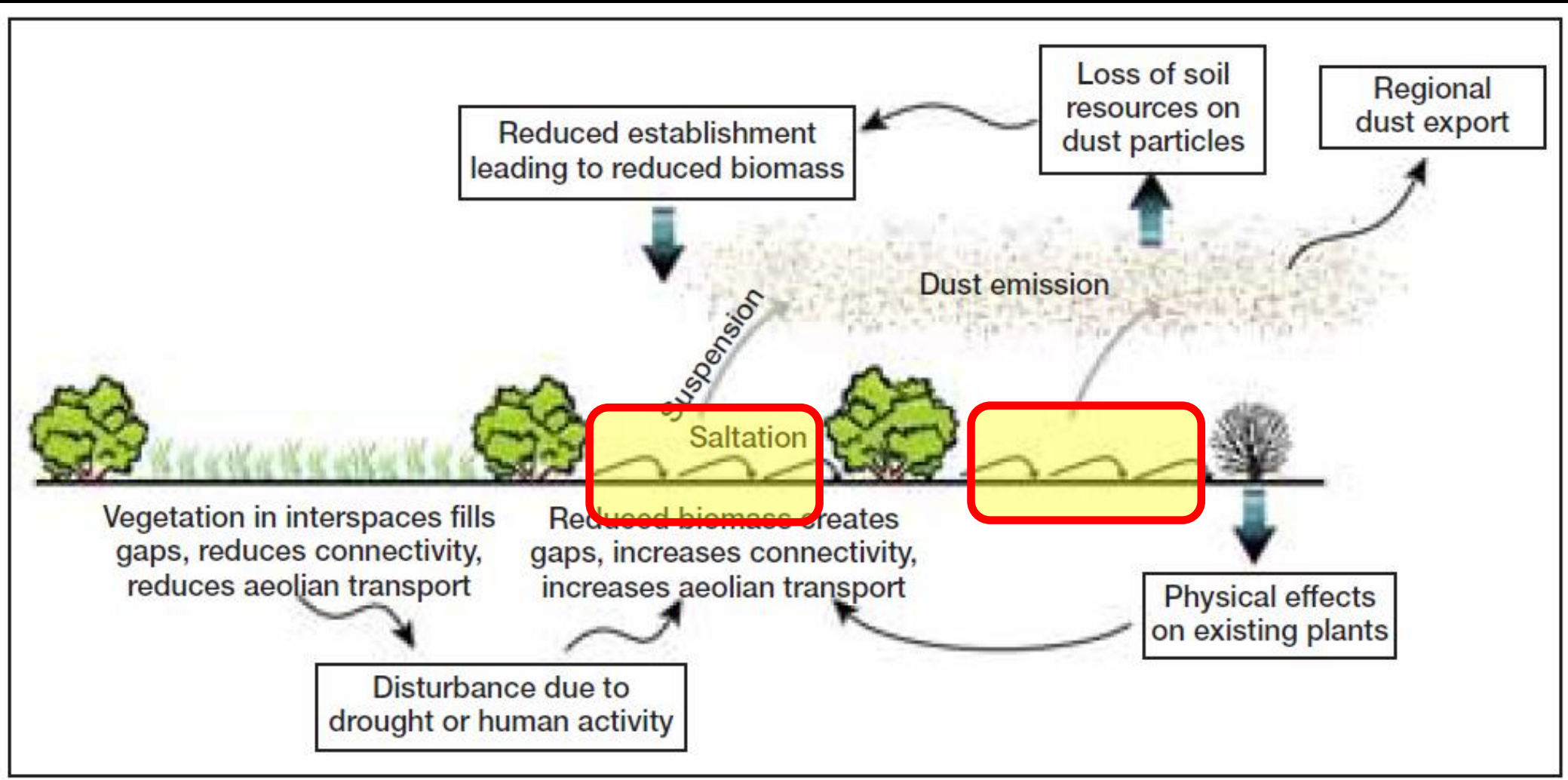


Figure 5. *Primary feedbacks between ecosystem function, wind erosion, and ecosystem structure.*

Field et al. (2012) The ecology of dust. *Frontiers in Ecology Environment*


New solutions are needed!

Currently available BMPs for barren lands

- ❑ Mechanical treatment (e.g., berms)

Underlying soil structural instability is not fixed

Currently available BMPs for barren lands

- Synthetic polymers (e.g., Soil Sement, Gorilla Snot)

Not guaranteed beyond 3 years;
Do not promote plant growth

Soil Sement applied next to Interstate-10 between Tucson and Phoenix, AZ

Currently available BMPs for barren lands

- Critical area planting



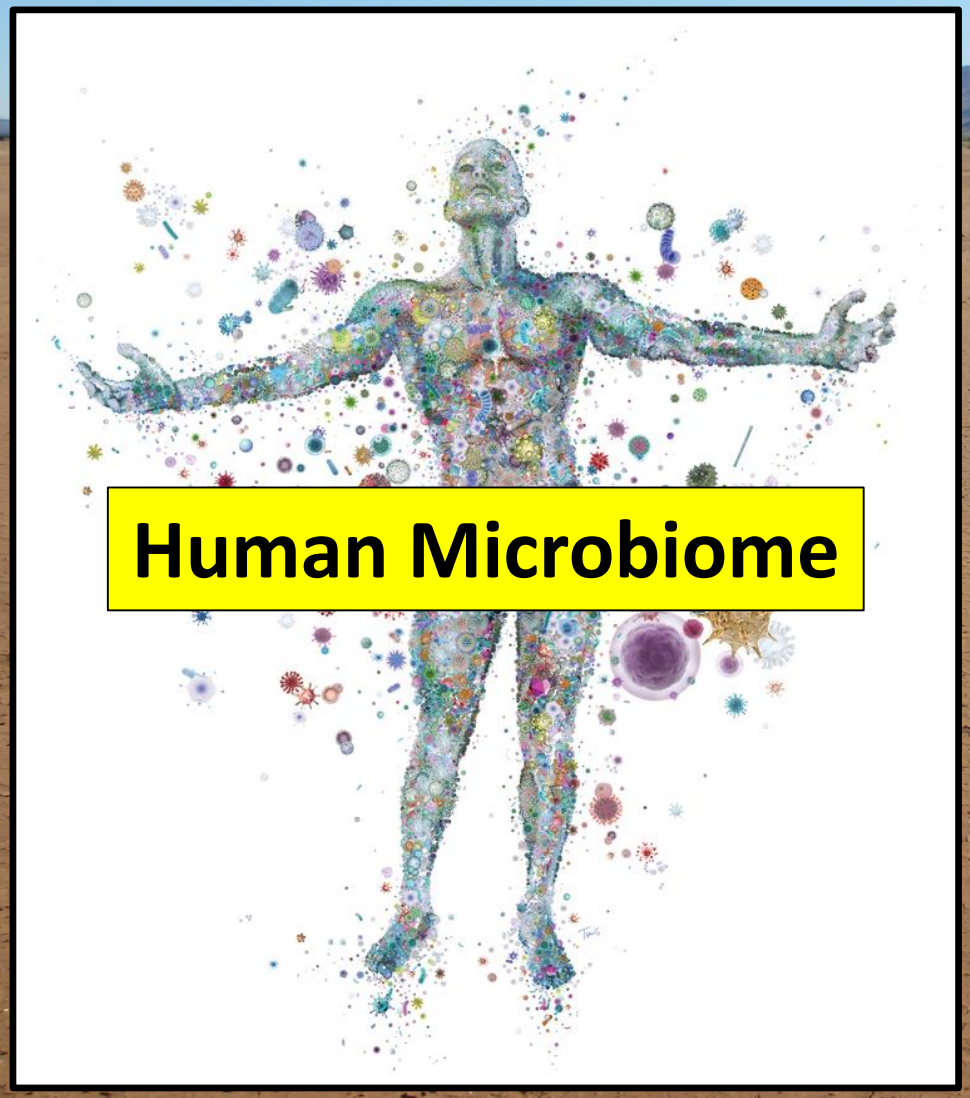
Limited success with “plant-centric” practices in arid regions, likely because soil health is not improved

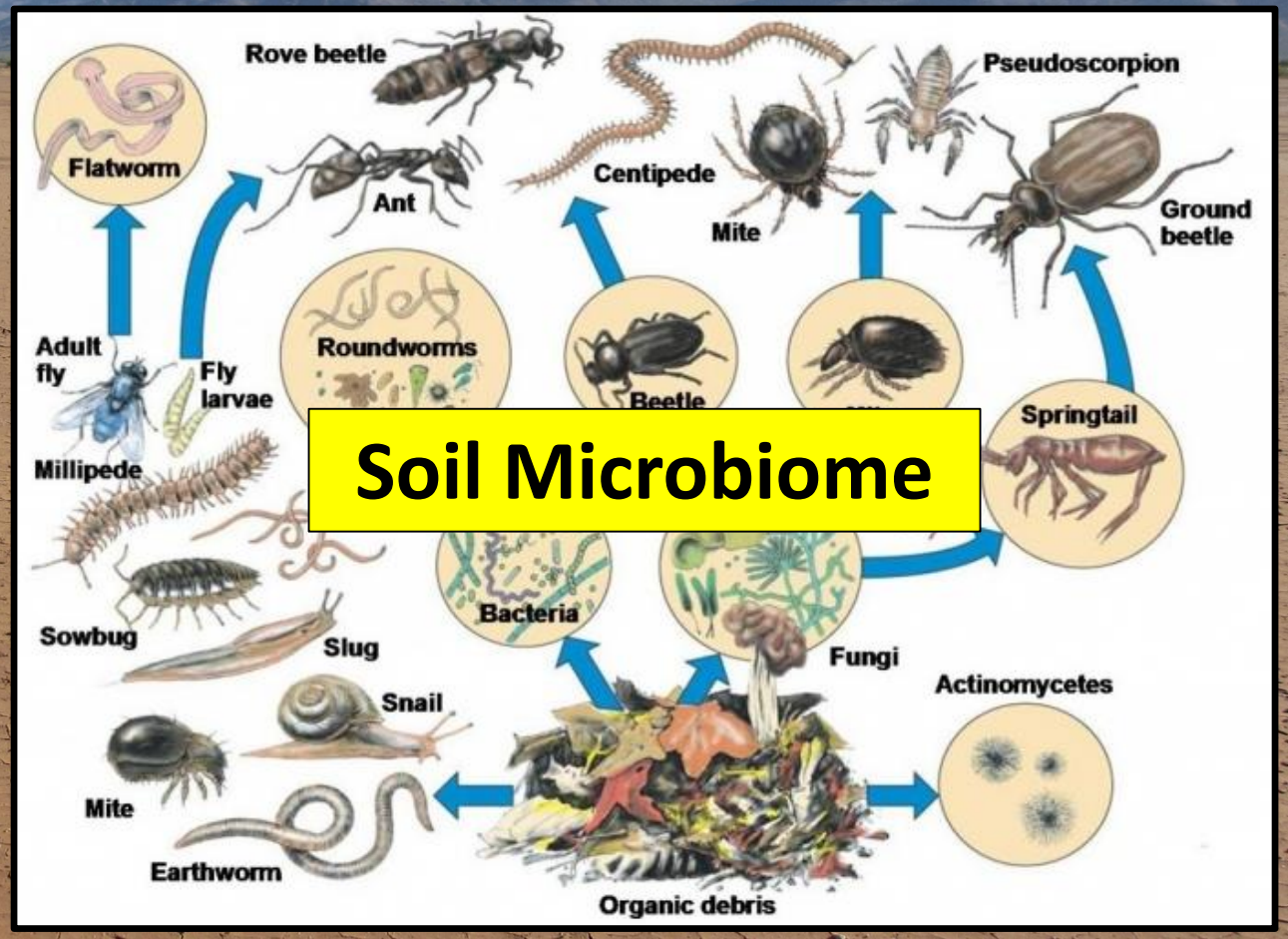
Motivating Research Questions for the Remainder of My Talk

- Can we improve the long-term success of stabilizing and revegetating barren arid soils by explicitly considering **organic matter** and the **soil microbiome**?

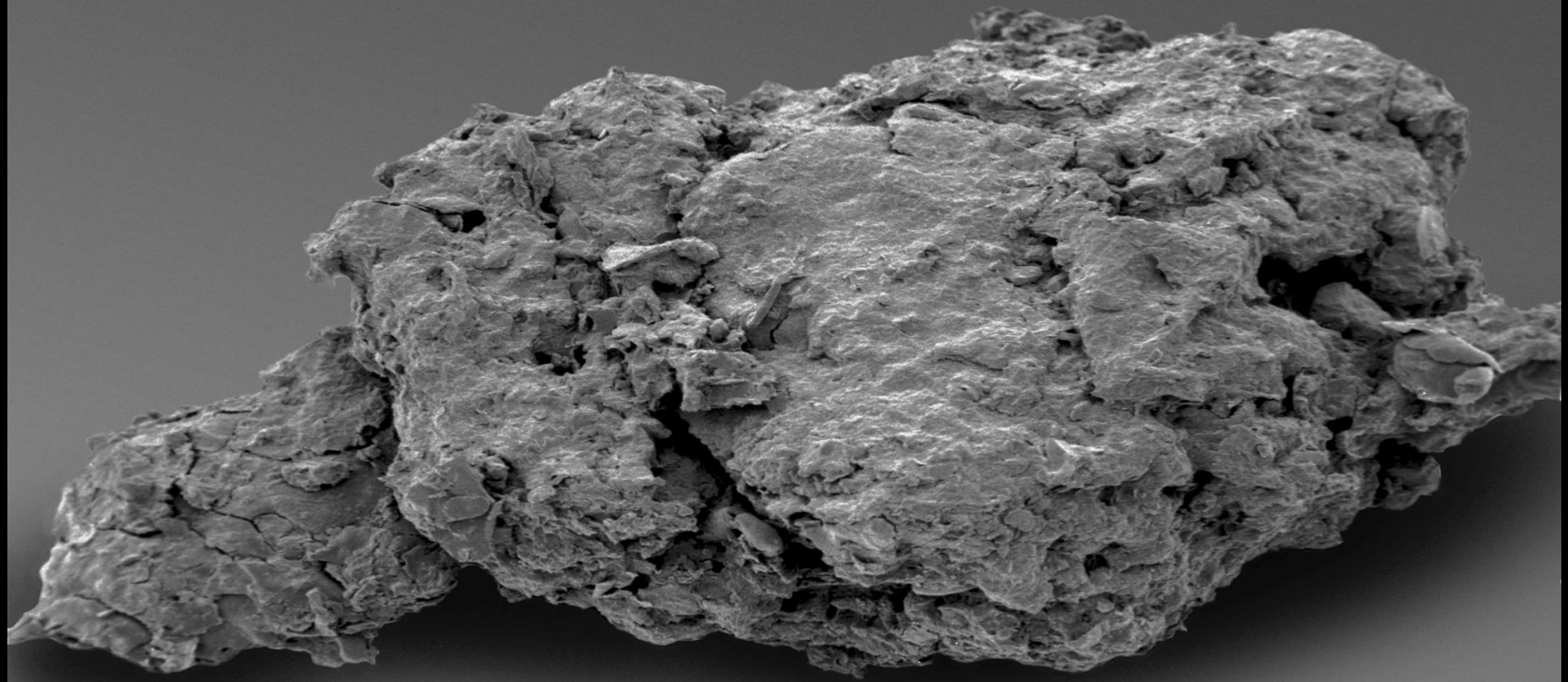
- Are organic matter and soil biology missing ingredients for "jump starting" barren systems in the Desert Southwest?

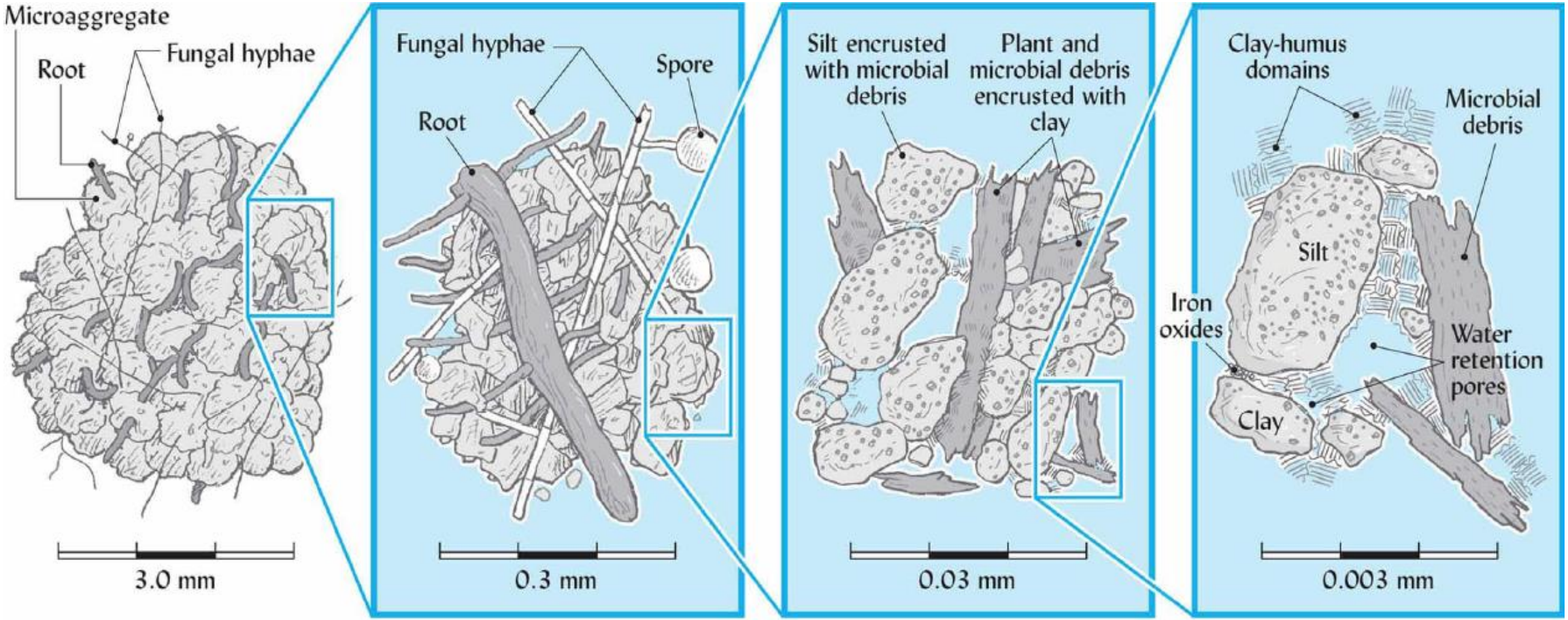
Ground zero for needing soil “probiotics?”





Water-Stable Soil Aggregate





Macroaggregate
- Roots
- Hyphae

Microaggregate
- Root hairs
- Hyphae
- Polysaccharides

Submicroaggregate
- Mineral grains encrusted with plant and microbial debris
- Plant debris coated with clay

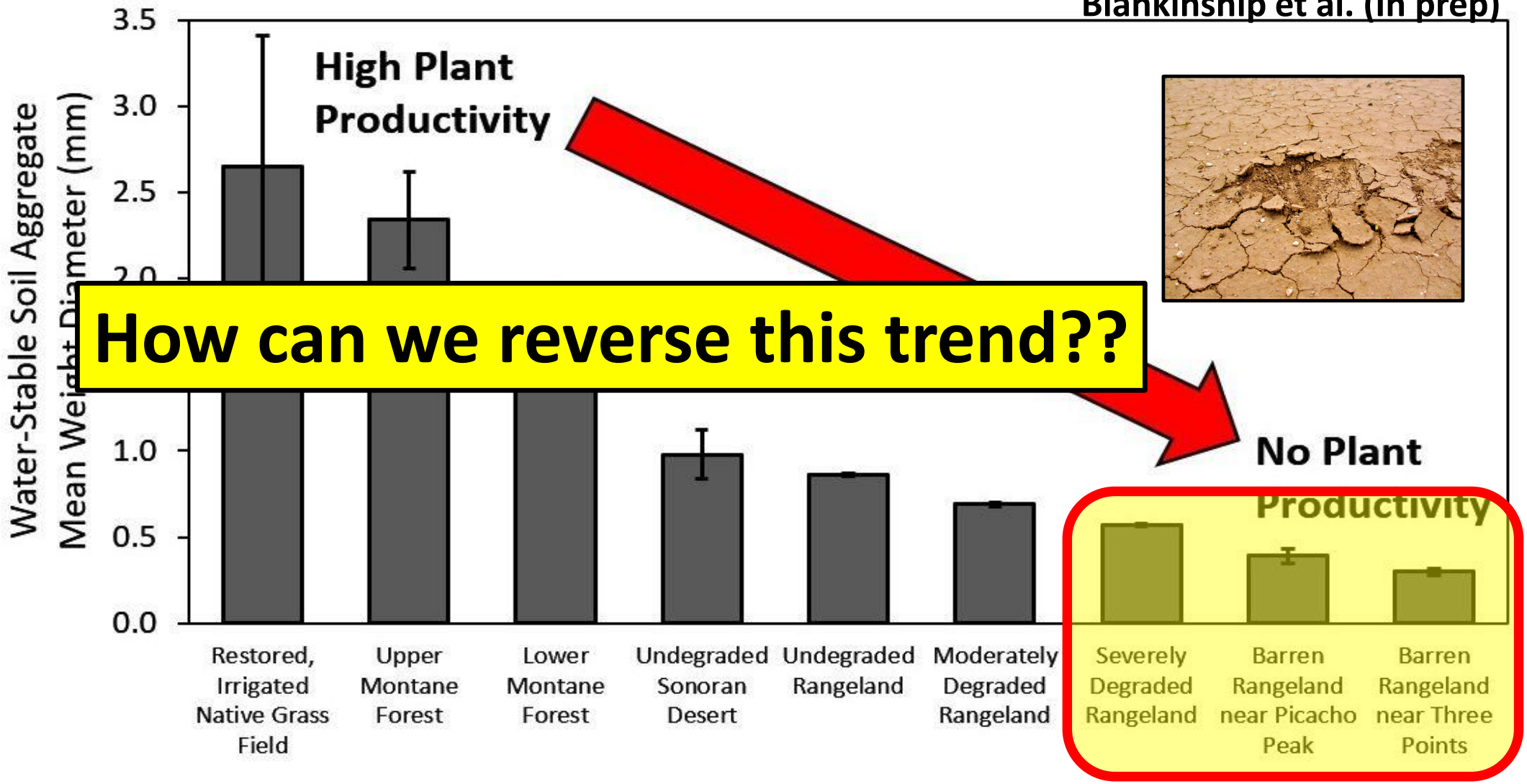
Primary particles
of silt, clay and humus
- Clay and clay-humus domains

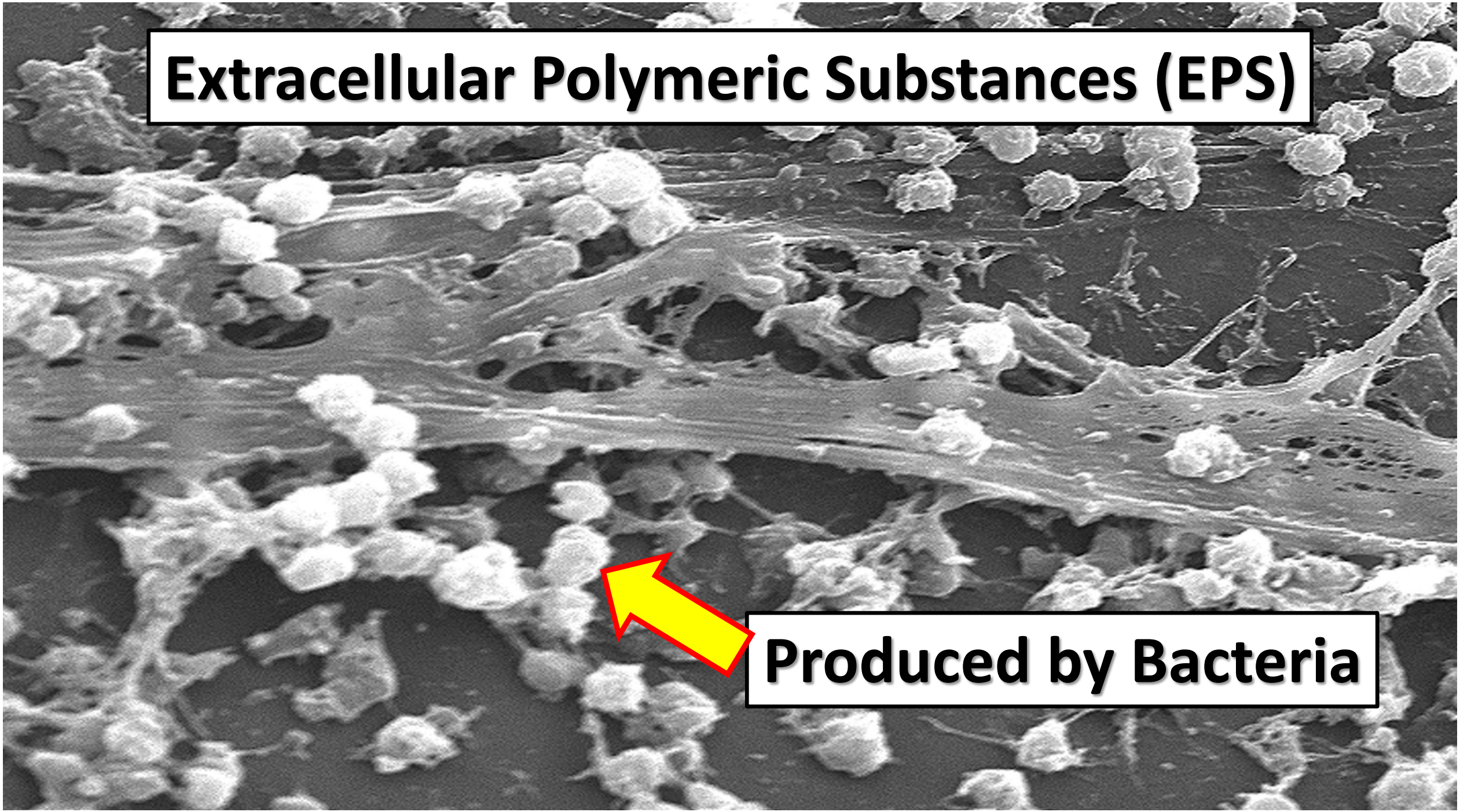
Brady & Weil 2010

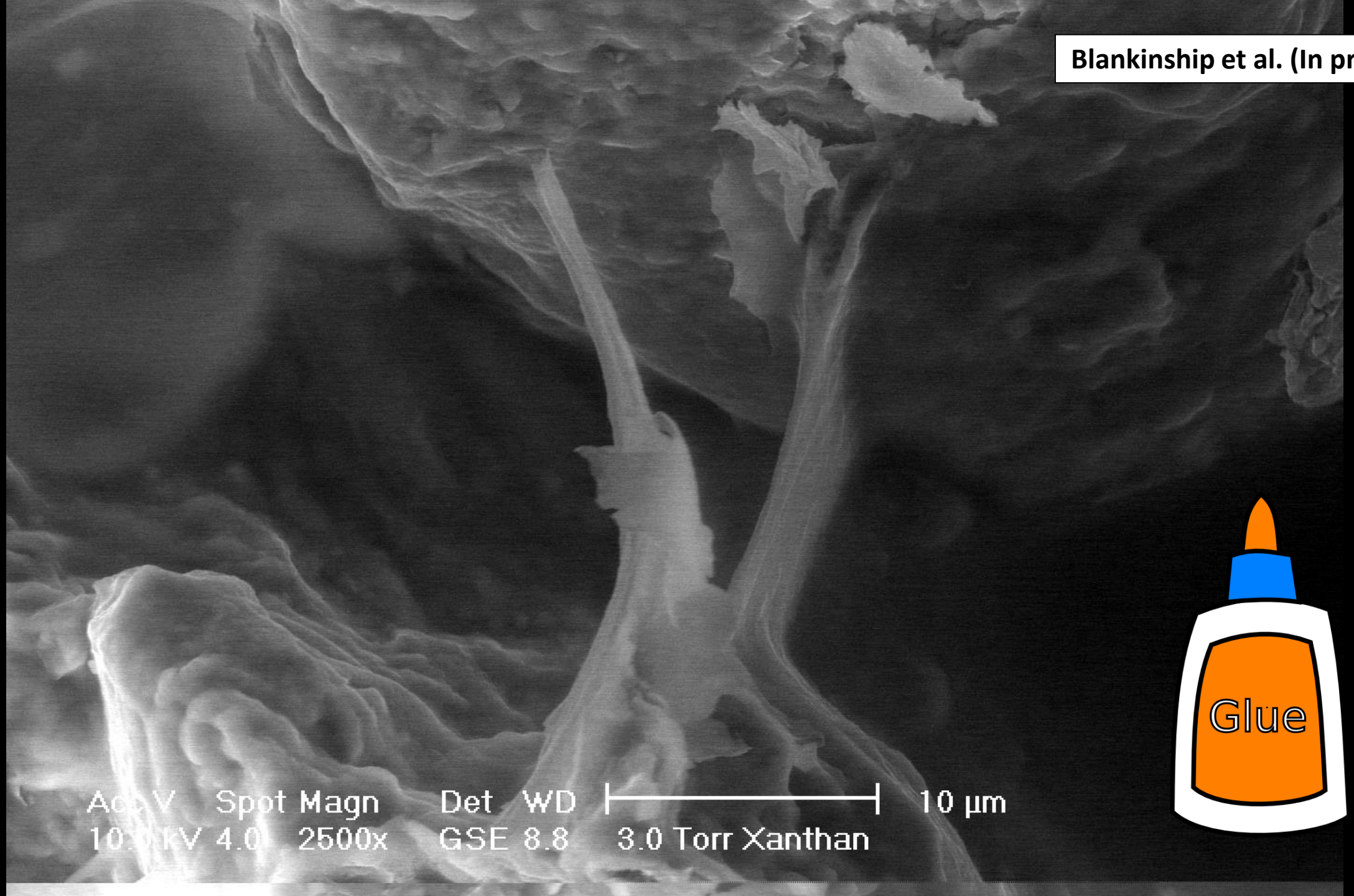
Macroaggregate separation by wet sieving

Barren lands are aggregate-poor

Blankinship et al. (In prep)

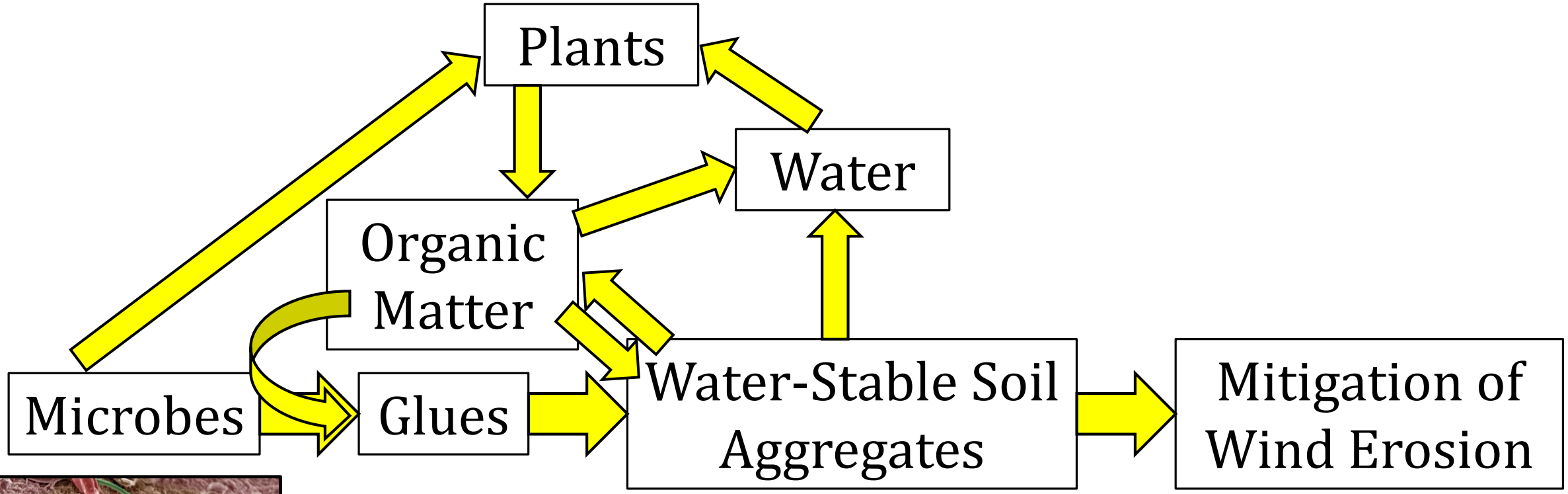


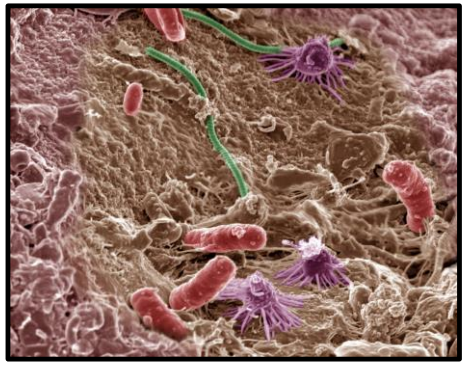

Extracellular Polymeric Substances (EPS)
Produced by Bacteria


Blankinship et al. (In prep)
Acc.V Spot Magn Det WD 10 µm
10.0 kV 4.0 2500x GSE 8.8 3.0 Torr Xanthan
Glue

Enmeshment by Fungi

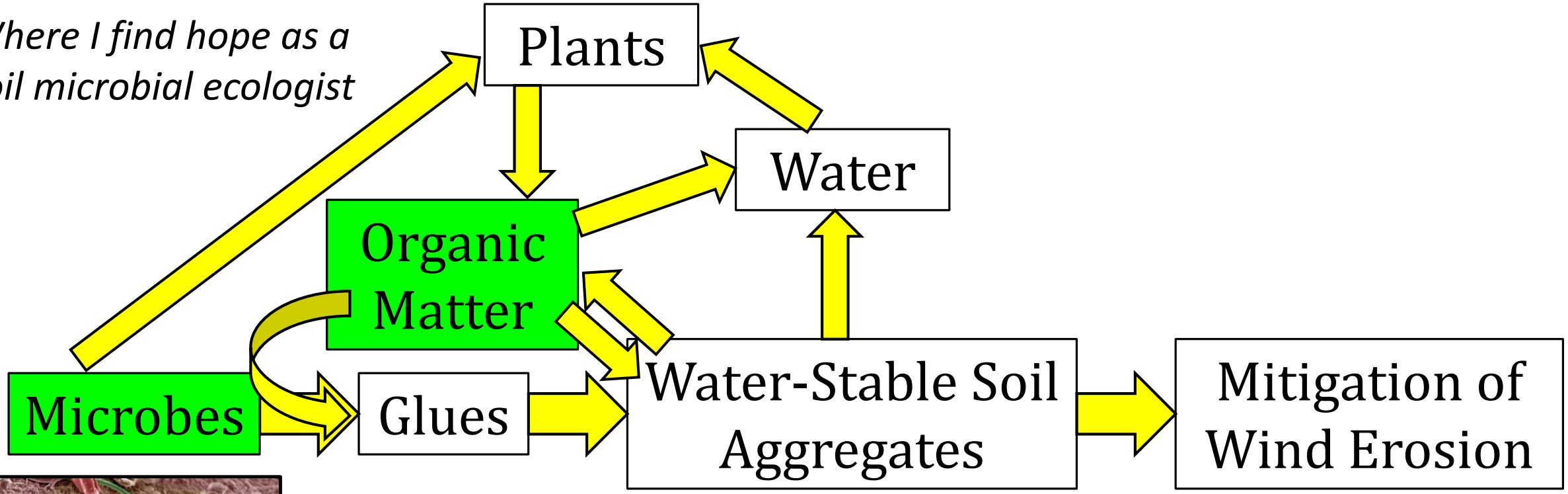
Obligatory Box & Arrow Diagram

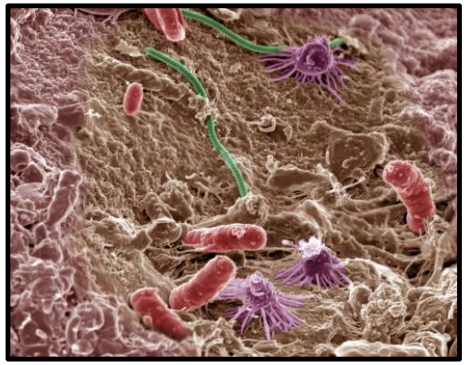




Obligatory Box & Arrow Diagram

Where I find hope as a soil microbial ecologist





Benefits of Using Organic Amendments in Dust Mitigation Projects

- ❑ Promotes **soil structure** directly
- ❑ **Improves microclimate** by covering soil and slowing H_2O
- ❑ **Carbon source** for carbon-starved soil microbes
- ❑ **Nutrient source** for potentially nutrient-starved plants



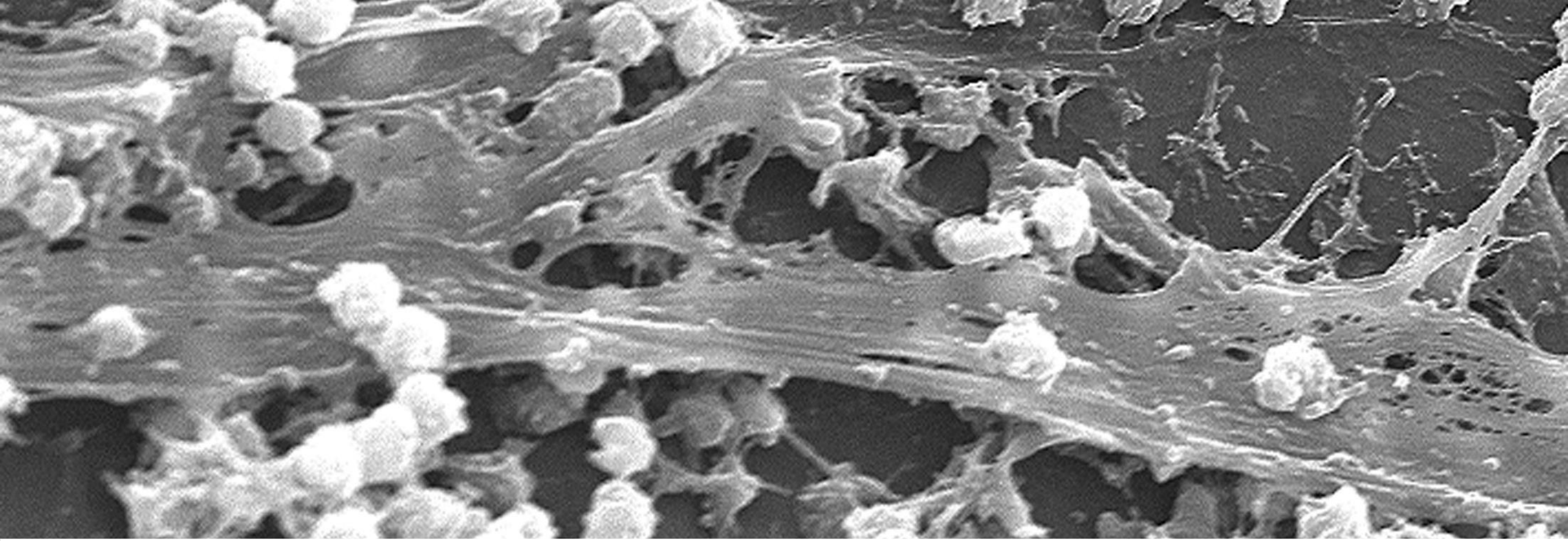
Wood Mulch

Compost + Mulch

Compost + Biochar

Augmenting the Soil Microbiome Directly

- ❑ Managing existing soil microbes
- ❑ Boosting with probiotics



Managing Existing Soil Microbes for Water-Stable Aggregate Formation

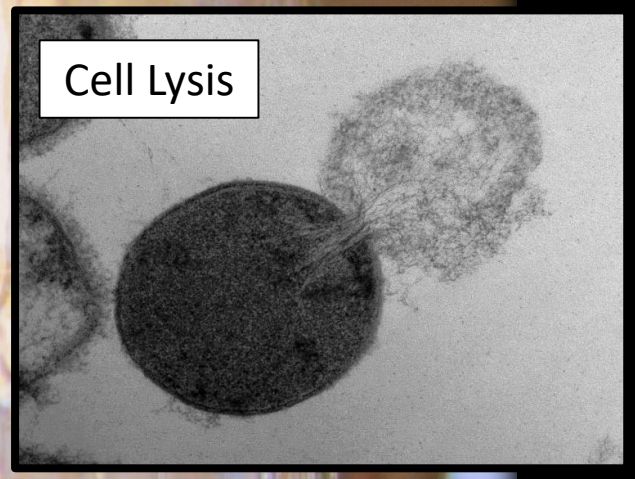
Microaggregates,
Silt, and Clay

DRY **MOIST**

5% 10% 15% 20%

(% of water-holding capacity)

Chloroform Sterilization



Soil

Chloroform ($CHCl_3$)

Blankinship et al. (2014) *Soil Biology & Biochemistry*

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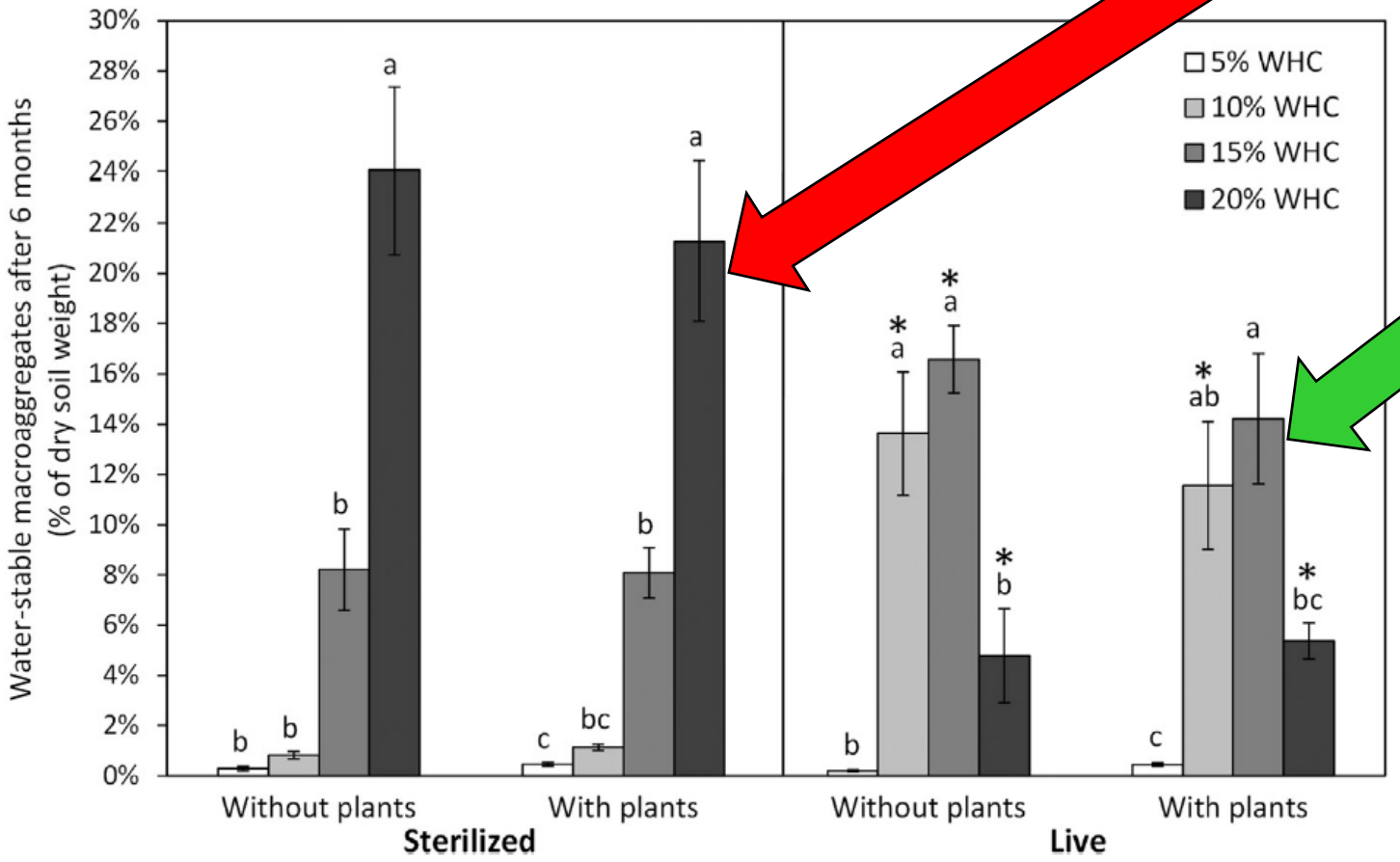
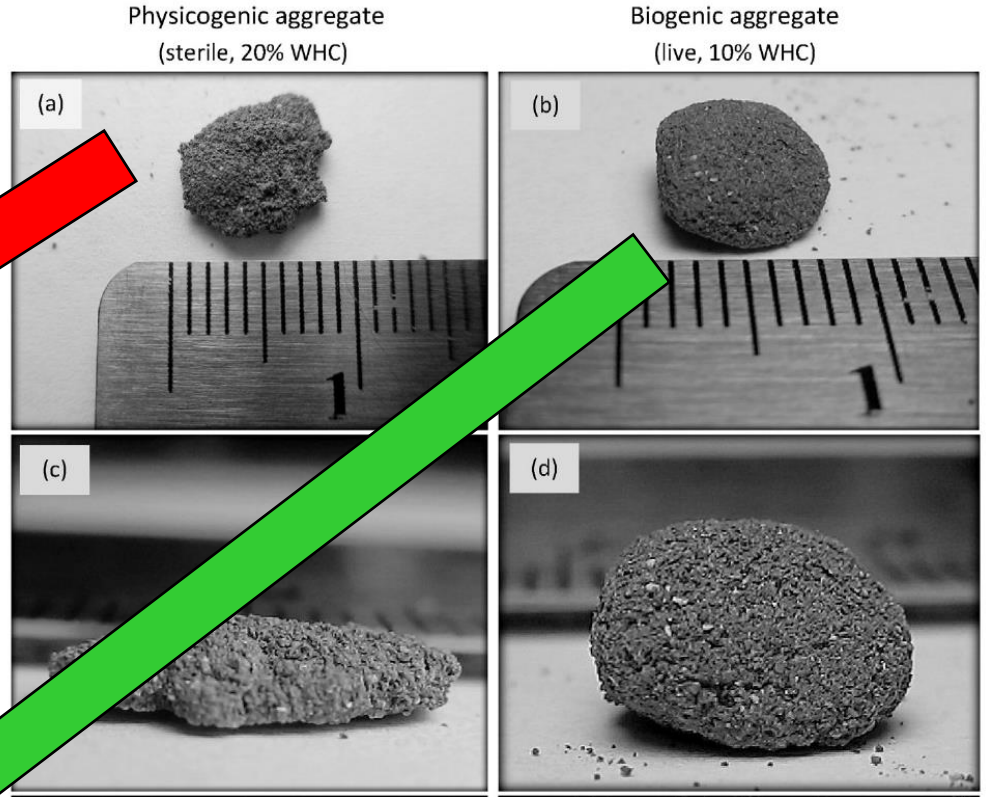
journal homepage: www.elsevier.com/locate/geoderma

Plant versus microbial controls on soil aggregate stability in a seasonally dry ecosystem

Joseph C. Blankinship [a,*], Steven J. Fonte [b,c], Johan Six [d], Joshua P. Schimel [a]



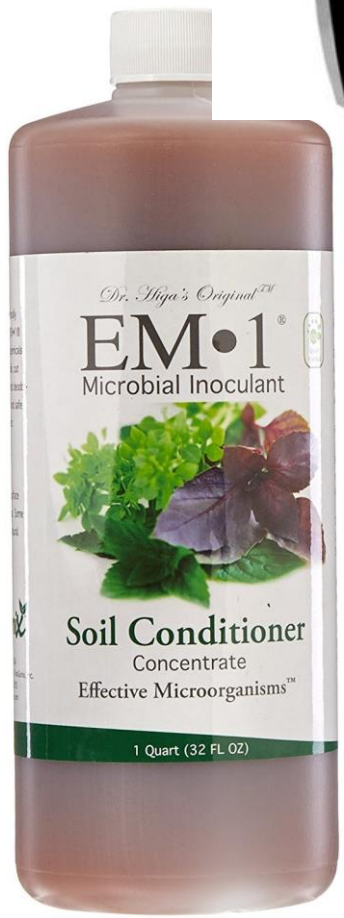


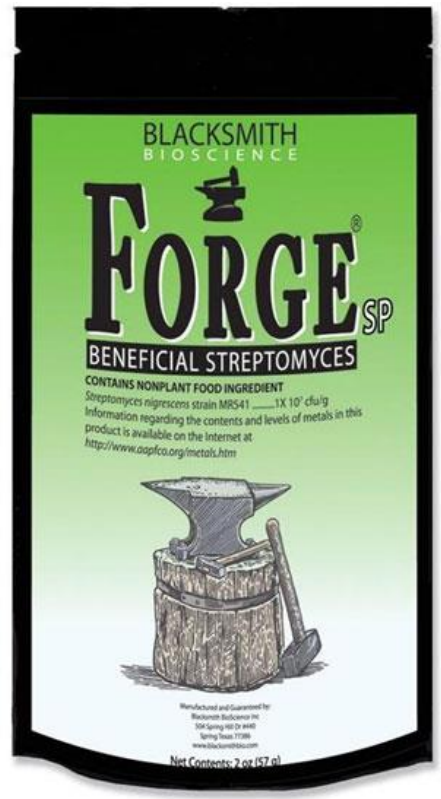
Boosting the Soil Microbiome with Probiotics

- ❑ Inoculation with commercially available products

BACTIFEED
SOIL TREATMENT SYSTEM

MICROP
OMRI LISTED
NATURE'S BIO-FERTILITY PROGRAM





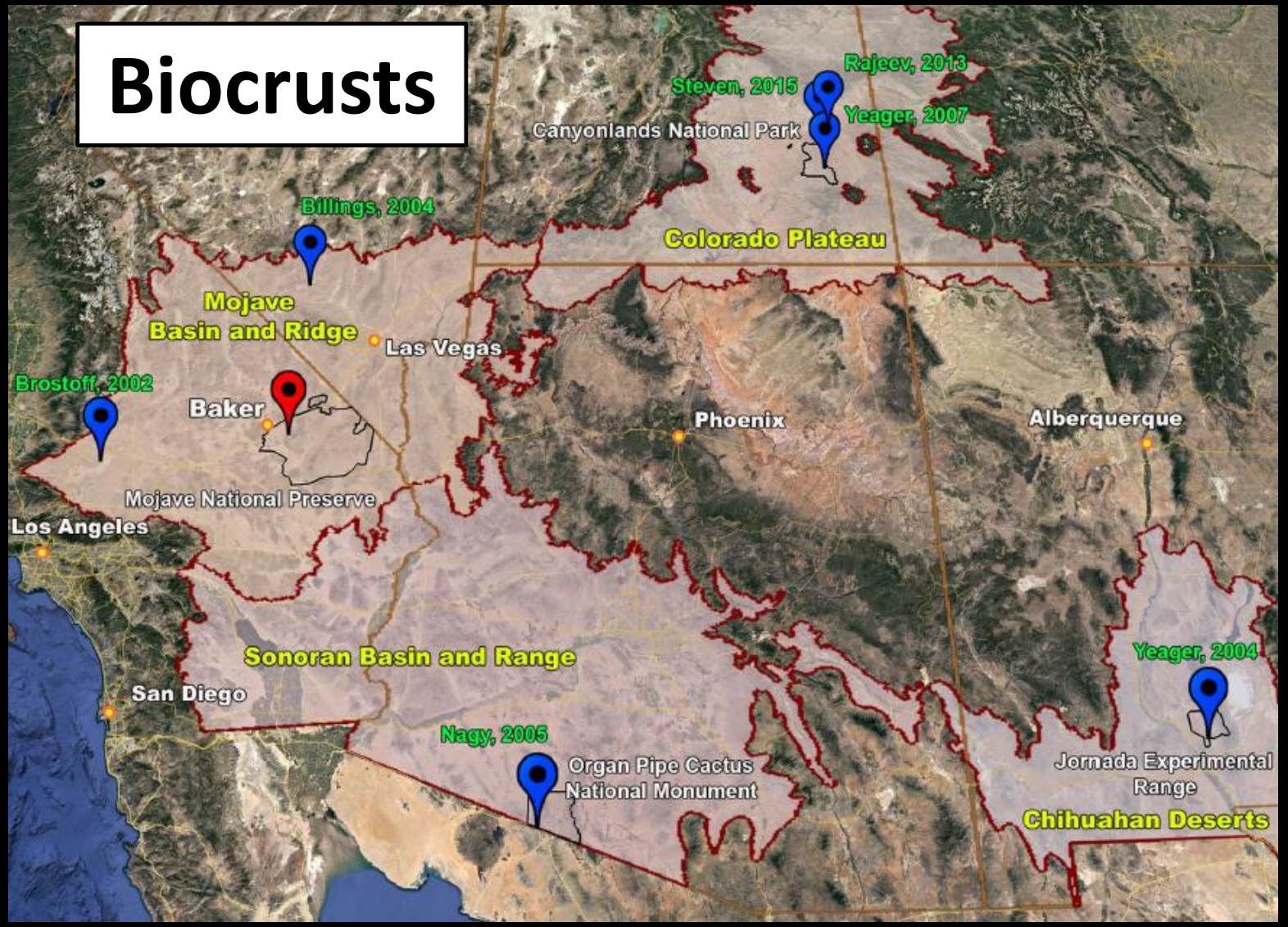
Boosting the Soil Microbiome with Probiotics

- **Inoculation with commercially available products**
  - Which ones work best for “bioengineering” soil aggregates?
  - Which ones promote plant growth in barren ecosystems?
  - Which products are economically viable?
  - How much/often to apply?
  - What time of year to apply?

Boosting the Soil Microbiome with Probiotics

- ❑ Inoculation with commercially available products
- ❑ **Bio-crust “farming”**

Biocrusts



Mogul et al. (2017) *Frontiers in Microbiology*

Pointing & Belnap (2012)
Nature Reviews Microbiology

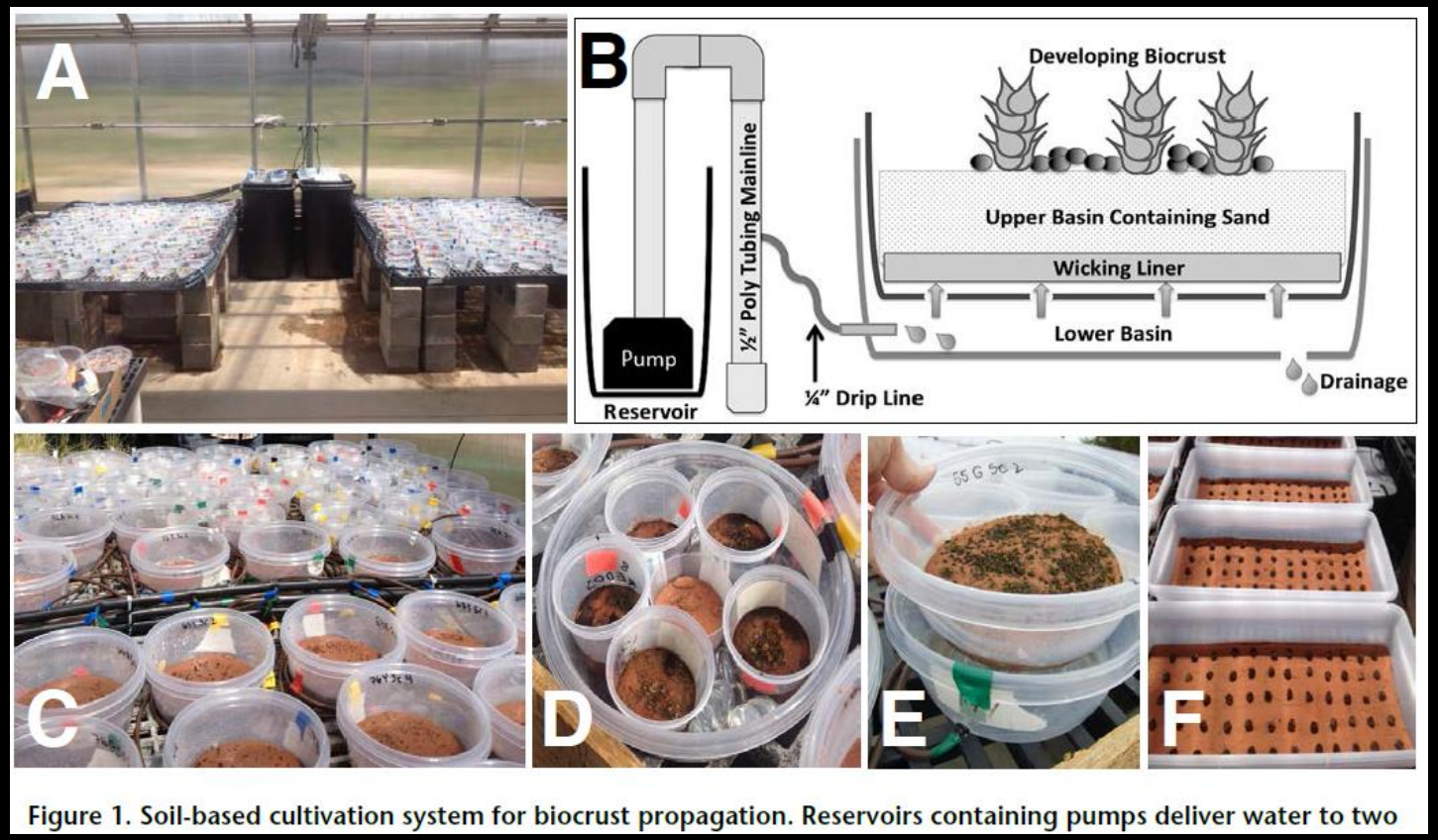


Figure 1. Soil-based cultivation system for biocrust propagation. Reservoirs containing pumps deliver water to two

Doherty et al. (2015) *Ecological Restoration*

Bowker et al.

Connections to Wind Erosion Handbook

Chapter 5. Controlling wind erosion

A. **Farmland**

iii. Abandoned cropland

1. Long-term abandonment
2. Short-term drought mitigation

B. **Rangeland and Natural Areas**

i. Revegetation

ii. Bio-crusts

iii. Mulching