Exploring Biological Solutions to Mitigate Dust near Picacho Peak

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The continued capacity of a soil to function as a vital, living ecosystem that sustains plants, animals, and humans.

USDA NRCS (2012)
Lehmann et al. 2020 *Nature Reviews*

**Fig. 1 | Soil fertility, quality, health and security.** The concepts vary by what relevant spatial scales, functions, ecosystem services and stakeholders they capture (listed as nested concepts on the right of the figure). The concepts also differ in the view of soil rights and assessments. Soil health encompasses a broad range of ecosystem functions, services and actors, impacting a wide array of sustainability goals. The five functions listed here impact overall soil-ecosystem services$^{3,4,6}$. 
Fig. 2. Conceptual illustration showing the increasing number and range of ecosystem functions considered in the historical succession from soil fertility to soil quality to soil health. The boundaries between the various concepts are not always distinct, accounting for variable interpretations of these terms in the literature; for example, some authors see soil quality and soil health as synonymous. We suggest, however, that a strength of the soil health metaphor is that it enfolds an expanded, more qualitative list of socio-ecological functions, not directly considered in earlier terms. Contemplation of soil health, therefore, requires a deliberate, adventurous transdisciplinary approach.
reThink Soil
A Roadmap to U.S. Soil Health

5. Leverage technological innovation to overcome operational hurdles

4. Align incentives between landowners and farmers

6. Provide broader access to products and services supporting soil health

7. Create market signals in sustainability programs for soil health

8. Reward farmers who optimize long-term soil health with lower crop insurance premiums

9. Support policies that enable greater investment in soil health

10. Build a more diverse constituency for soil health policy

POLICY
Improve the policy environment to advance soil health

SCIENCE
Overcome the science and research gap to support expansion of soil health management

3. Advance the science of soil health benefits

2. Develop operational management strategies for adaptively integrating soil health practices and systems

1. Create cost-effective soil health measurement standards and tools

ECONOMY
Overcome economic obstacles by providing the market systems to secure soil health

Increased coordination and investment in the Soil Health Roadmap will lead to tangible economic and environmental benefits for U.S. farmers, businesses and communities.

Working together, committed partners can help ensure a sustainable future for generations to come.

Visit nature.org/soil or email soil@tnc.org.
“Clods”
“Water-Stable Aggregates”
Large Macroaggregate = $> 2000 \mu m$ diameter

Small Macroaggregate = 250—2000 $\mu m$

Microaggregate = 53—250 $\mu m$

Silt & Clay = $< 53 \mu m$
Physical Approaches to Rebuilding Aggregates

- Mechanical treatment (e.g., berms)

Underlying soil structural instability is not fixed; doesn’t operate at appropriate spatial scale
Physical Approaches to Rebuilding Aggregates

- Conservation tillage in croplands

But not always...
Chemical Approaches to Rebuilding Aggregates

- **Gypsum**

![Gypsum structure](image)

It works but is not a long-term solution, and many desert soils already have high Ca.
Chemical Approaches to Rebuilding Aggregates

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

“Tackifiers”

Expensive; Can be toxic; Not guaranteed beyond 3 years; Do not promote plant growth
But what about microbial “glues?”

- Bacterial “Biofilm”
- Fungal Hyphae
- Strands of Algae (Cyanobacteria)
- Bacterial Extracellular Polymers
- Biological Soil Crusts (“Biocrusts”)
Phase 1: Laboratory

“Rhizoboxes”

Phase 2: Field Plots

1x1 m plots with 5 replicates of 4 treatments: Control, Microbial Inoculant, Plant Seeds, Combo

3 Native Plant Species:
- Bush muhly
- Low woollygrass
- Fourwing saltbush

3 Microbial Inoculants:
- Cyanobacteria
- Mycorrhizal fungi
- EPS-producing bacteria

Soil health indicators:
- Water-stable macroaggregates
- Microbial/plant EPS “glues”
- Other organic metabolites
- Metagenome
- Nutrients
- Plant/root biomass
- Dust production

3 Microbes - Soil - Plant

1. Plant
2. Microbe
3. Soil

ARIZONA INSTITUTES FOR RESILIENCE
RESEARCH, INNOVATION & IMPACT
Effect of microbial inoculants on water-stable soil macroaggregates across all plant treatments (none = no inoculant)

**Conclusion:** The cyanobacterial inoculant was the best soil aggregator
No statistically significant effect of cyanobacterial inoculant on soil macroaggregates under field conditions ($p = 0.37$), but headed in right direction (+9%).
Ground truthing soil dust emission using portable wind tunnel

• Measures dust production at various “wind” speeds
• Determines mass of dust produced and threshold friction velocity

** But can’t sample over plants
Example raw data from portable wind tunnel

Control

+ Cyanobacteria
Although native grasses did not perform well under field conditions, we found using the portable wind tunnel that plots with cyanobacteria had a threshold friction velocity (TFV) two times greater than the plots without the inoculant, indicating a much lower potential for dust emission from soils with added cyanobacteria. The existing degraded soils at the site began producing substantial dust at wind speeds between 12 and 16 mph. However, the soils we inoculated with cyanobacteria more than 2 months earlier did not begin producing substantial dust until wind speeds between 24 and 29 mph. As far as we know, this is the first study to show the full mechanism and potential for a soil microbial inoculant to decrease dust emission.
In conclusion...

Soil Microclimate

LONG-TERM DUST MITIGATION

Microorganisms
Native Plants