Restoring the living skin of the Earth:

Developing a restoration technology based upon biological soil crusts

Matthew A. Bowker, School of Forestry, Northern Arizona University

Why are biocrusts important to soil erosion?

Aggregation of soil….

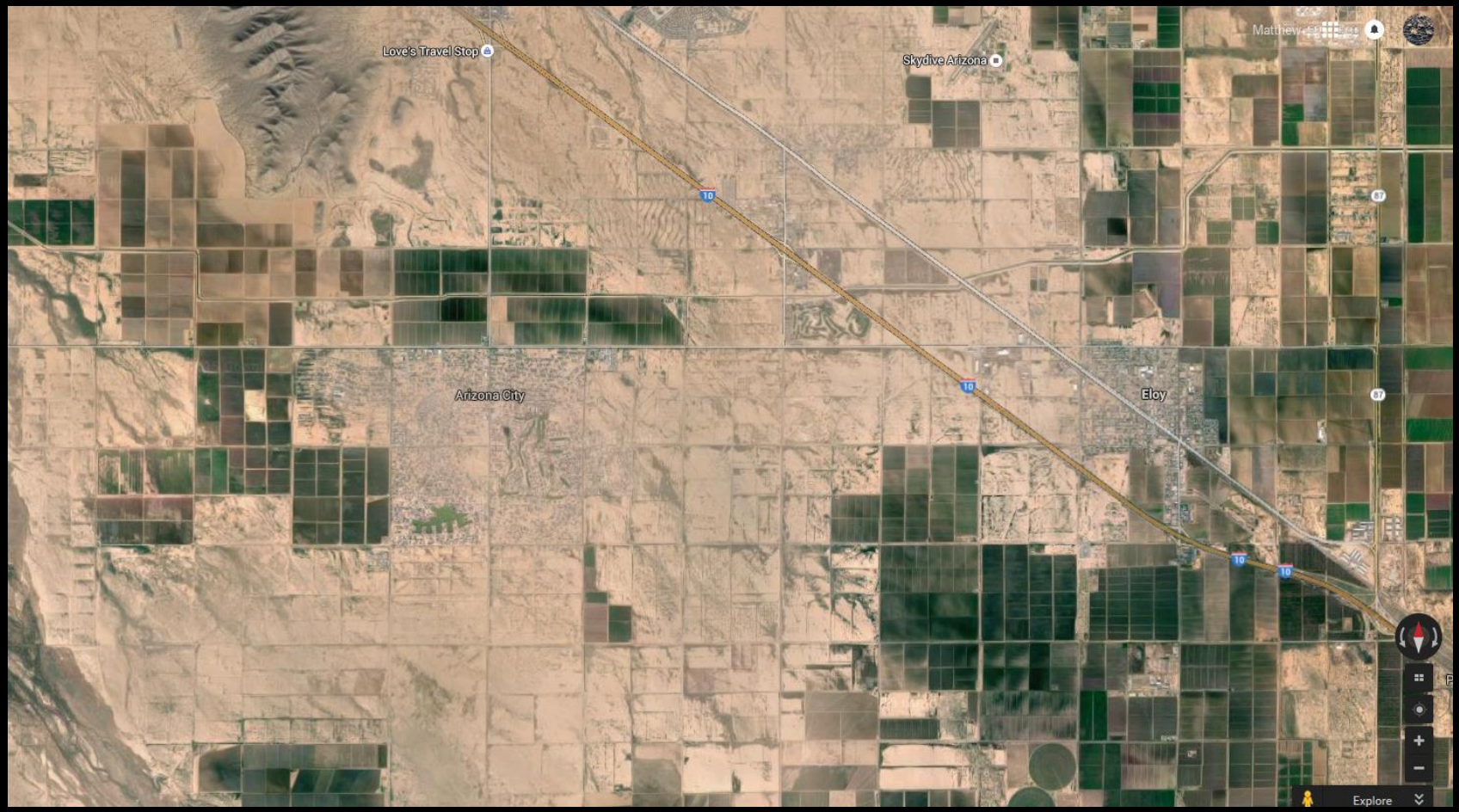
Image: F. Garcia-Pichel

…decreases erodibility

Hydrological effects

Bumpier crusts, common in N. America, favor
water capture & retention
- Due to enhancement of soil surface area, and twisty runoff pathways

The problem: slow natural recovery after disturbances



>56 yrs. recovery time after veg clearing (Kade & Warren 2002)

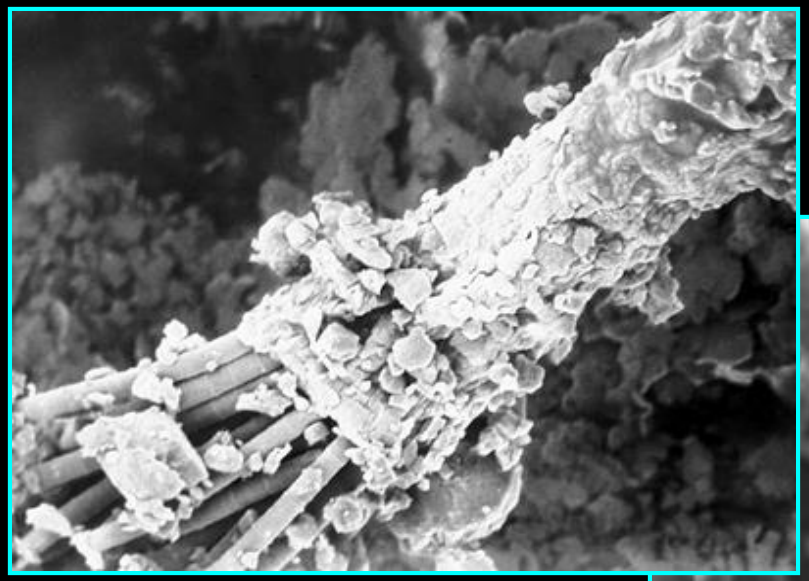
Can we rebuild biocrusts?

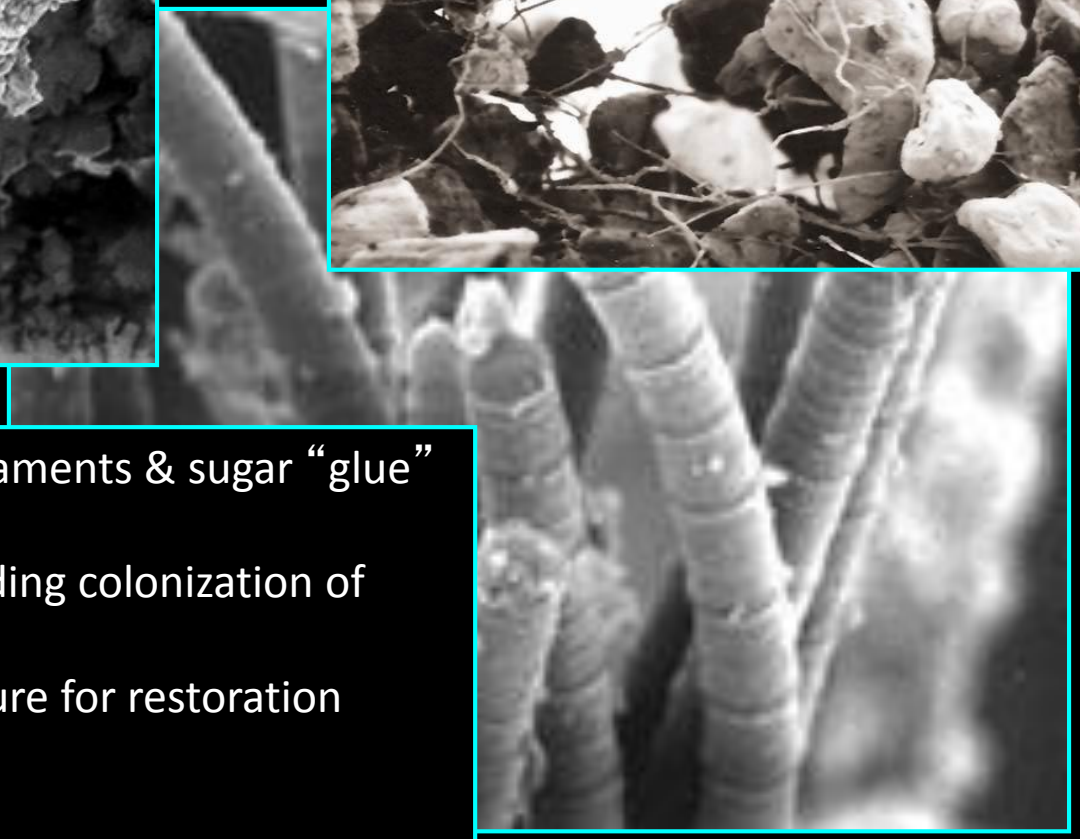
Maybe this is the tool we need to reduce dust emission from hotspots

Such a tool could complement other technologies like revegetation & windbreaks

Let's build a biocrust:

"Stabilizer cyanos"





Wrap up soil with a net of filaments & sugar "glue"
Very early successional
Engineer crust "platform" aiding colonization of other organisms
Most common target of culture for restoration

Microcoleus spp.

Let's build a biocrust:

"Stress reducer & fertility booster cyanos"

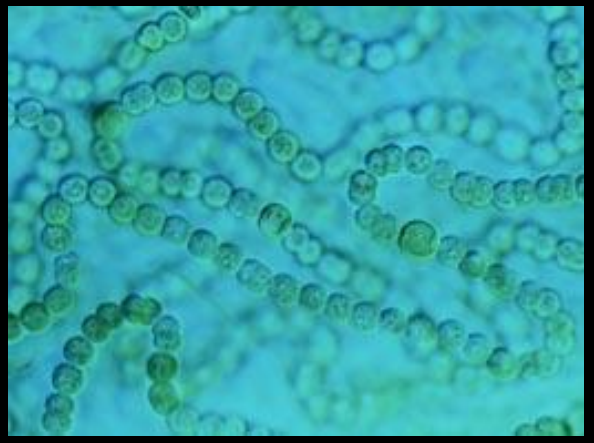
Colonize surface of crust platform, shield it from UV using dark sunscreens

Early - mid successional

Fix nitrogen, improving soil fertility

Sometimes cultured for restoration

Nostoc & Scytonema spp.



Let's build a biocrust:

"Water & carbon harvester mosses"

Early successional - ruderal

Late successional

Soak up water like a sponge, enhance water capture
May be early or late successional…depends on species
may be primary colonizer post-fire
Add the most organic matter

Pterygoneurum spp., *Syntrichia* spp.

Let's build a biocrust:

"Armor lichens"

Mid-successional N-fixers

Late successional

Best possible erosion protection
The best biocrust N-fixers are lichens
May be mid or late successional…depends on species

Collema spp., *Fulgensia* spp., *Psora* spp.

Desirable features of biocrusts as restoration materials

Totipotent clonability

will grow vegetatively

Desiccation tolerance

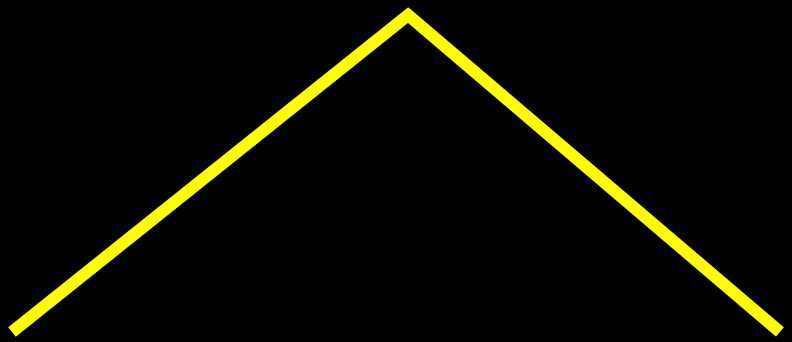
unlike seeds will not die if it stops raining

Long-term dry storage

could retain viability for decades if stored right

May tolerate tough soils

high pH, salinity



Salvage

Taking natural biocrust
form one place,
applying it to the soil surface
in another place

It generally works!
(Belnap et al. 1993,
St. Clair et al. 1986,
Chiquoine et al. in press)

Unsustainable unless: harvest
comes before a planned disturbance

Artificial Culture

Quickly growing biocrust organisms
in artificial environments (greenhouse,
lab, bioreactor), applying it to degraded soil

It has worked (and not),
needs more research effort

Potentially sustainable, and a serious short
cut that might save decades!

Salvaging biocrust materials

Ideally you scrape just the top cm of crust.

With heavier equipment, you'll get a more dilute product. But go as shallow as you can.

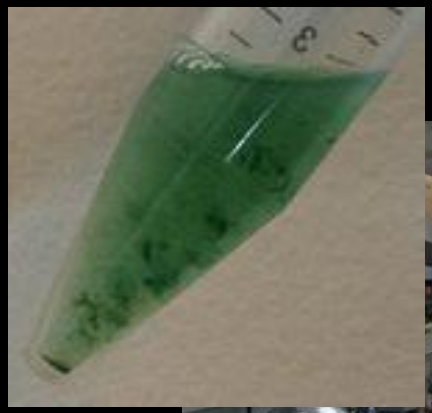
Crumble & reapply at the site you want to treat.

Do so in a cool, relatively wet time season

Or consider watering after application (in winter)

Can we really grow biocrusts?

yes!



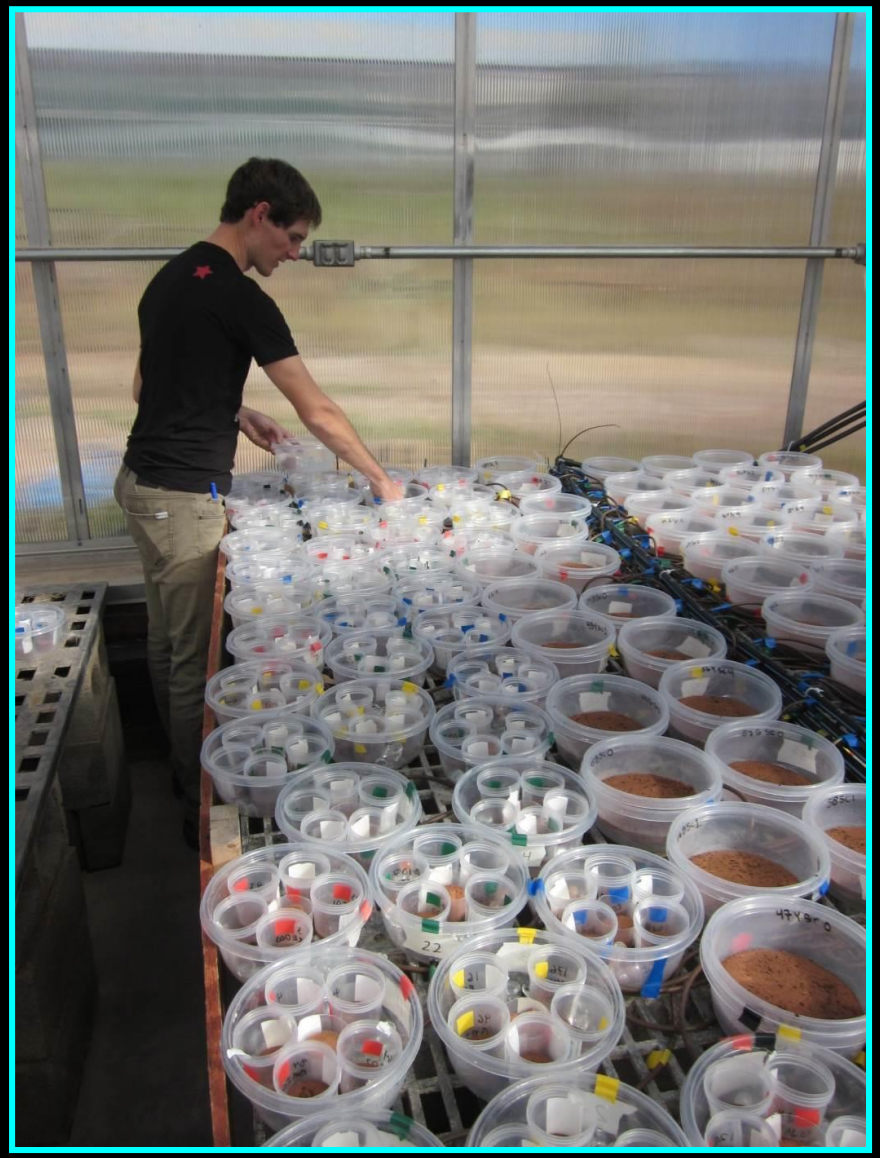
Bioreactors

Outdoor raceway ponds

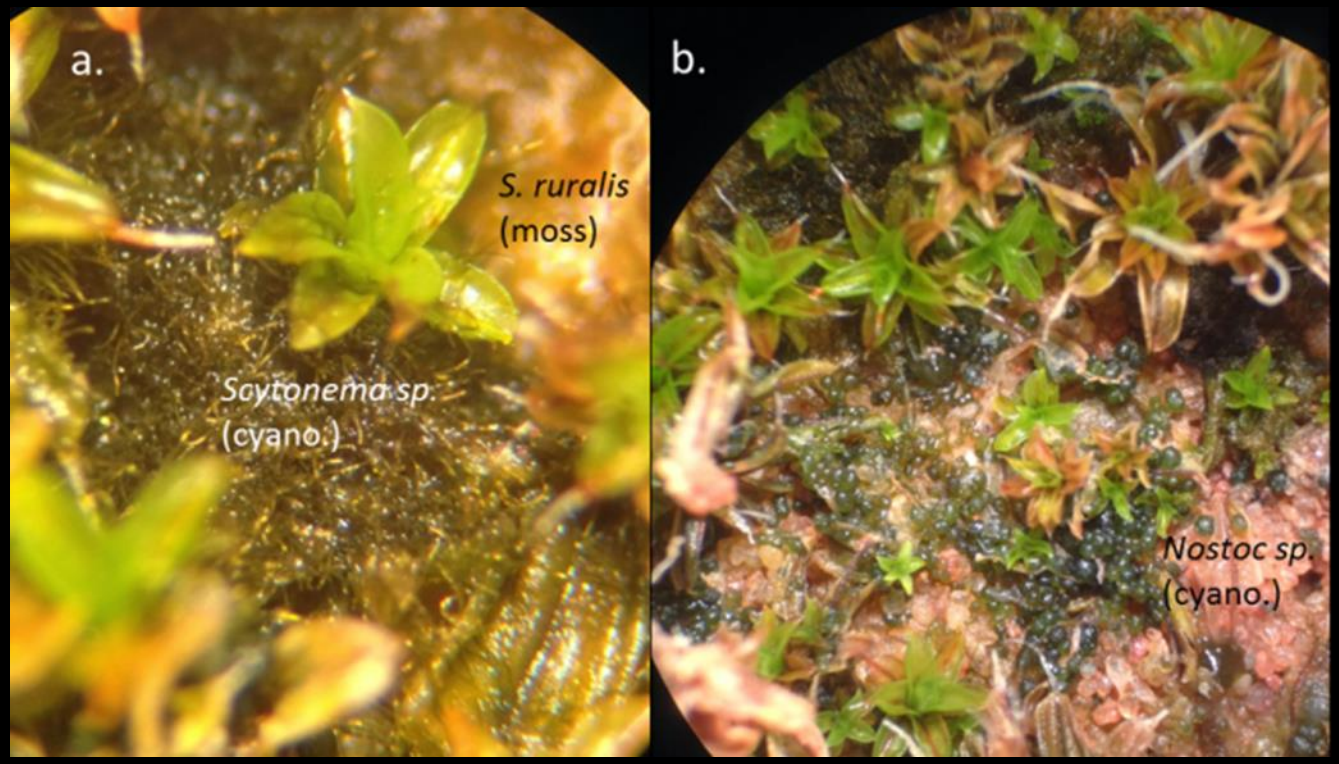
Most research has focused on growing cyanobacteria in liquid culture

Results: the "bryotron"

our system for learning about growing mosses

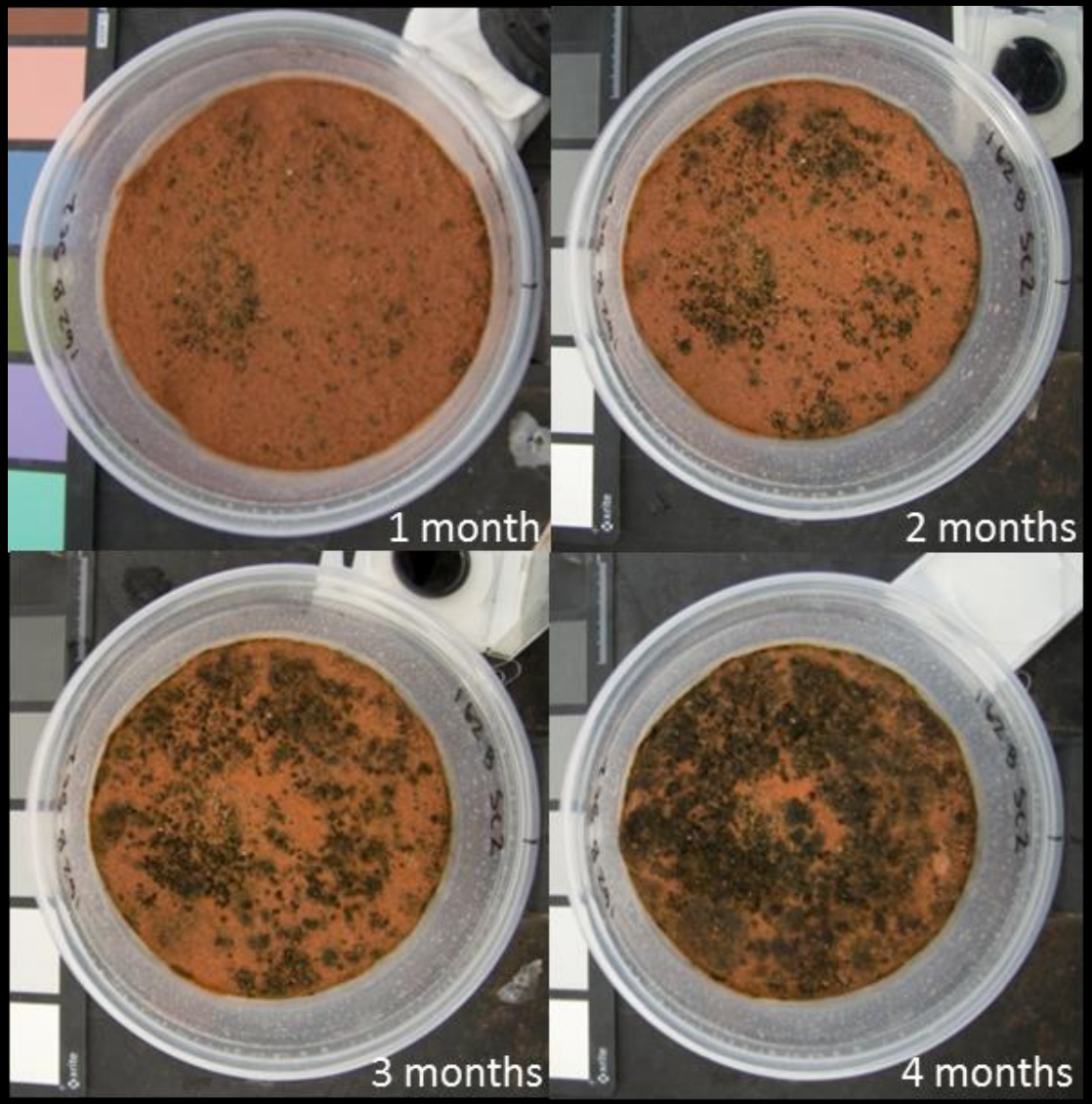


We also (accidentally) grew lots of cyanobacteria



Bonus!

Results after 5 months are amazing!



Although mosses increased,

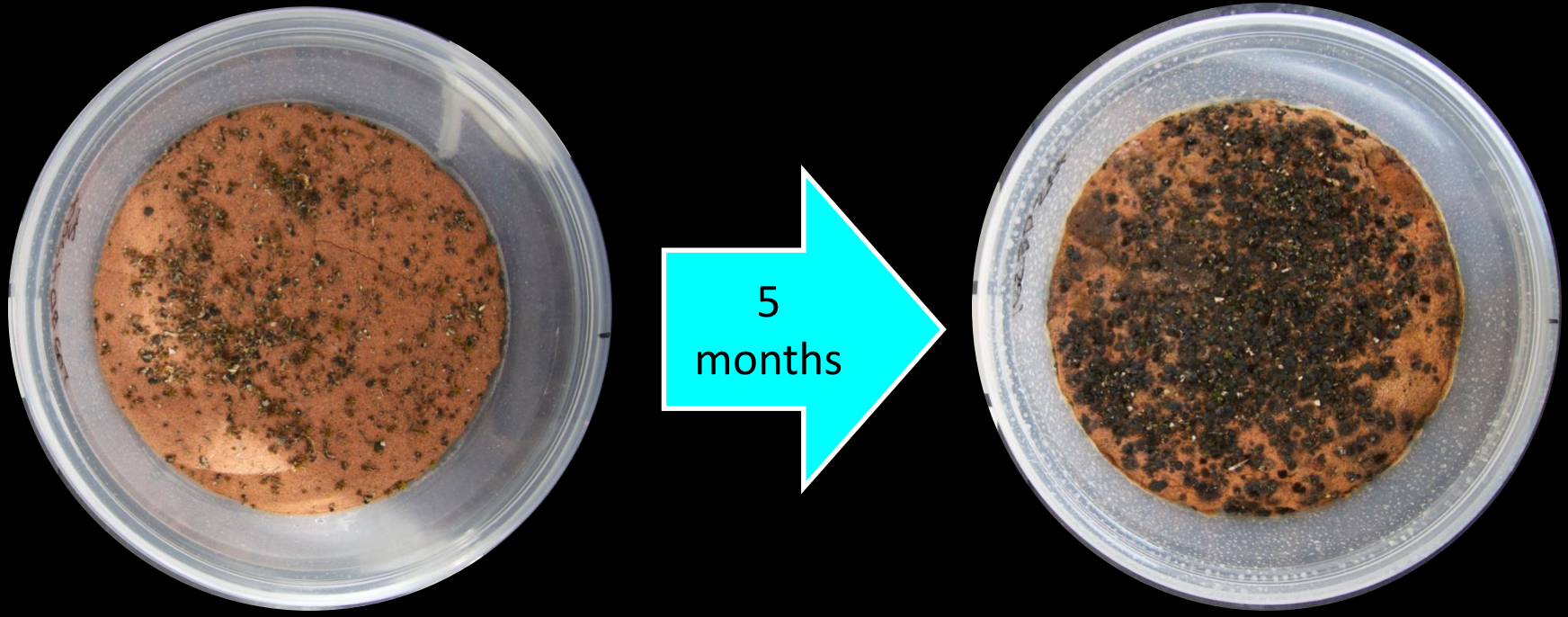
most of what you are seeing are cyanobacteria

total crust cover can reach 100% in 5 months

So we can grow mosses & cyanobacteria

what about lichens?

YES!



We can scale-up to whole greenhouses…

Design: Kyle Doherty

….and we'll be trying outdoor "crust farming" this year

Here is some evidence from China that it can be done in 2 years

Can we do it faster?!

We can grow biocrusts.

But that's not all that's needed to developing a biocrust restoration technology….

1. Develop optimal culturing technique

Grow more biomass faster, cheaper, or in less space

Explore more species

Explore species combinations

We can grow biocrusts.

The Research & Development pipeline

1. Develop optimal culturing technique

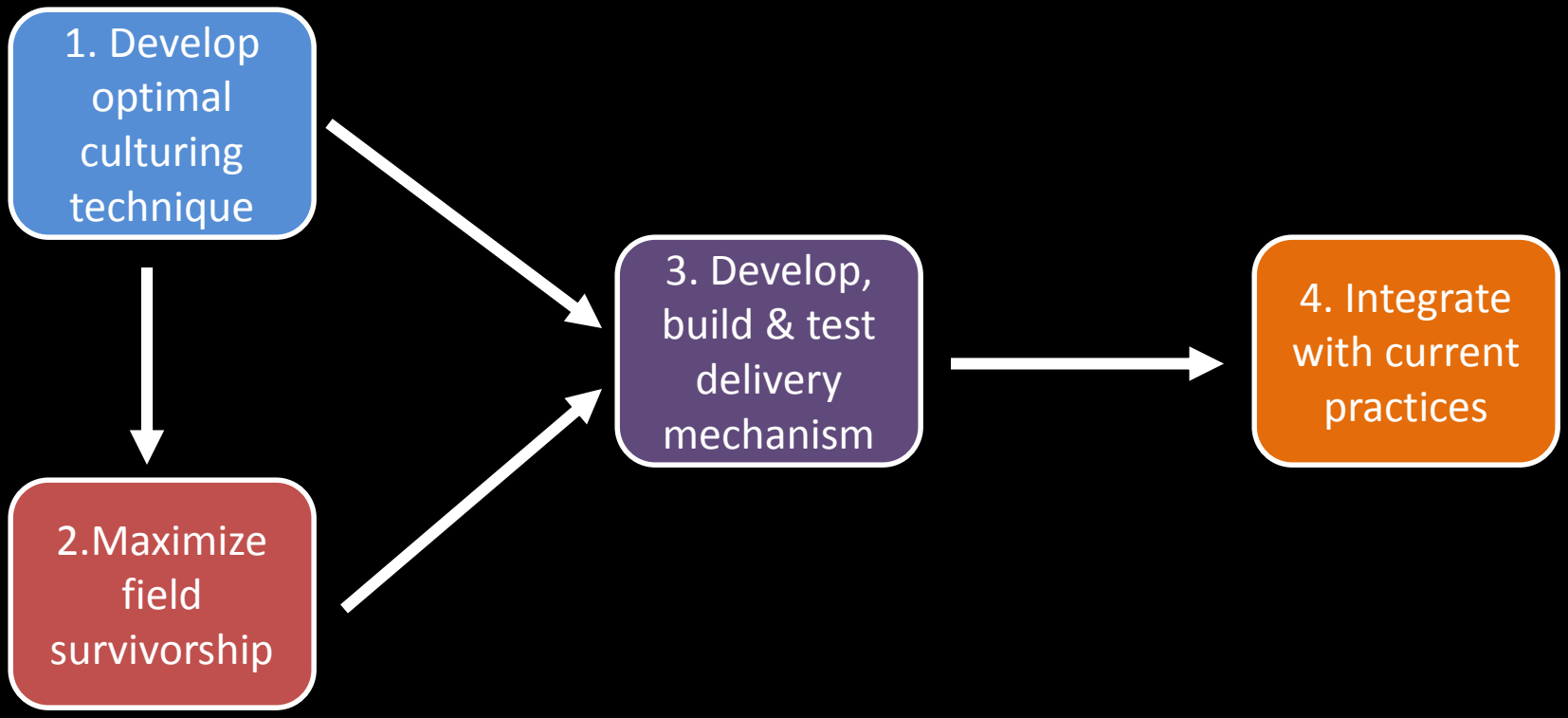
2.Maximize field survivorship

Involves “hardening off” organisms OR
Temporarily make environment more benign OR
Deliver organisms with some form of protection

(This is where many field inoculation efforts fail)

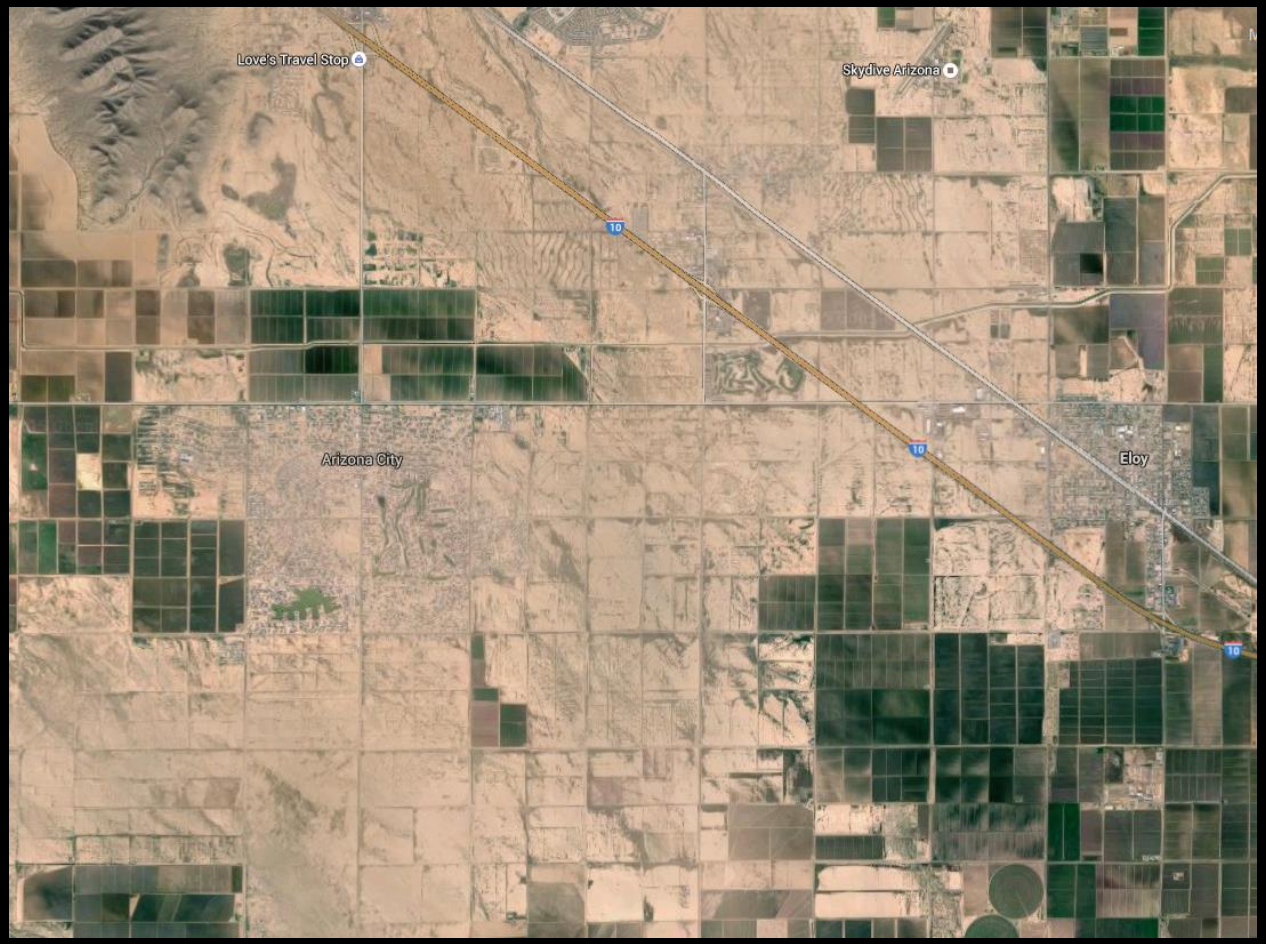
We can grow biocrusts.

The Research & Development pipeline



We've never had this sort of sustained funding & effort in the US

In this setting, the possibility of temporary irrigation is very exciting



2.Maximize field survivorship

Maybe by adding biocrust material,
and watering for a few weeks
the soil surface can be quickly aggregated

Biocrusts have the potential to decrease erodibility of dust hotspots

Can be used in concert with woody vegetation windbreaks

If a salvage site is available, the salvage method can be applied now

Artificial growth of biocrusts is probably the best way forward, but needs more research, trials, funds

Want to help us get there? Let's talk. matthew.bowker@nau.edu

Acknowledgments

Funds: Bureau of Land Management, NAU Faculty Grant Program, Department of Defense, MPG Ranch, National Park Service

Collaborators & Enablers: Anita Antoninka, Kyle Doherty, Kristina Young, Chris Ives, Henry Grover, Nichole Barger, Sasha Reed, Jayne Belnap, Ferran Garcia-Pichel, Mike Duniway, Sergio Velasco, Weibo Wang, Ana Giraldo, Yunge Zhao, Carol Dawson, Craig Allen, Brian Jacobs, Pete Fule, Karl Ford, Wayne Padgett, Bruce Rittenhouse, Philip Ramsey, Rebecca Durham, Dan Mummey, Barry Baker, Ft. Bliss Nat. Resources Staff, Hill AFB Nat. Resources Staff, EnGGen, Jornada Experimental Range & LTER, BLM Utah, Phil Patterson & NAU Greenhouse, Jeff Wright, Amanda Knauf, Kat Smail, all members of Bowker, Johnson & Sanford Labs (NAU), Bandelier National Monument staff, Canyonlands Research Center, Rio Mesa Center