Biological soil crusts
National park design, management, and policies

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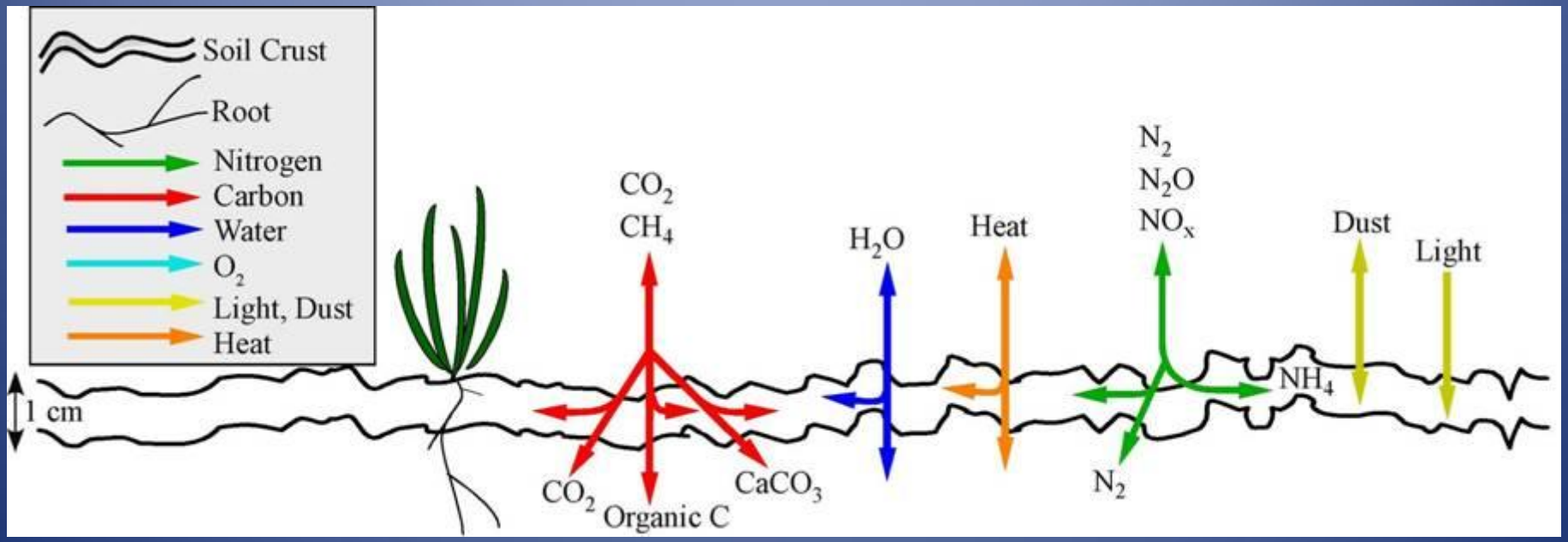
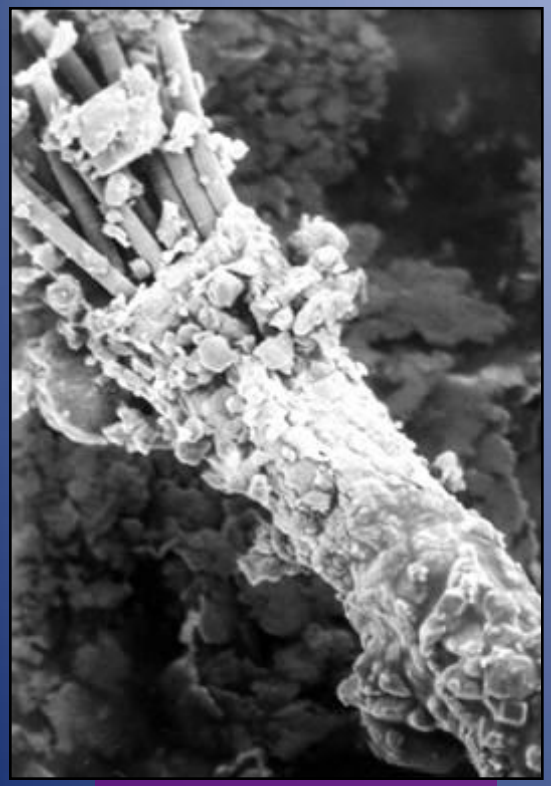
US Geological Survey

Biocrusts can be a dominant controller of ecosystem processes and thus function in areas where they cover large amounts of soil surfaces



Generic knowledge, as very little is known about tropical biocrusts

Each component influences ecosystem function differently



Cyanobacteria

Lichens

Mosses

Ecological role dependent on external morphology

Flat
(0 cm)

Rugose
(2.5 cm)

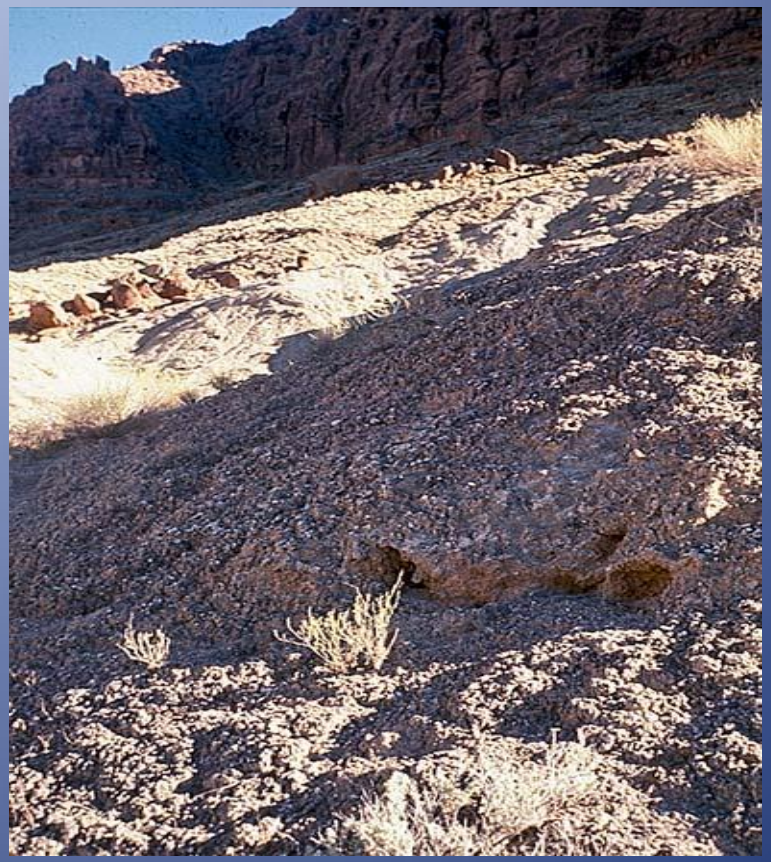
Pinnacled
(15 cm)

Rolling
(7.5 cm)

Soil Stability

Sparse vegetation

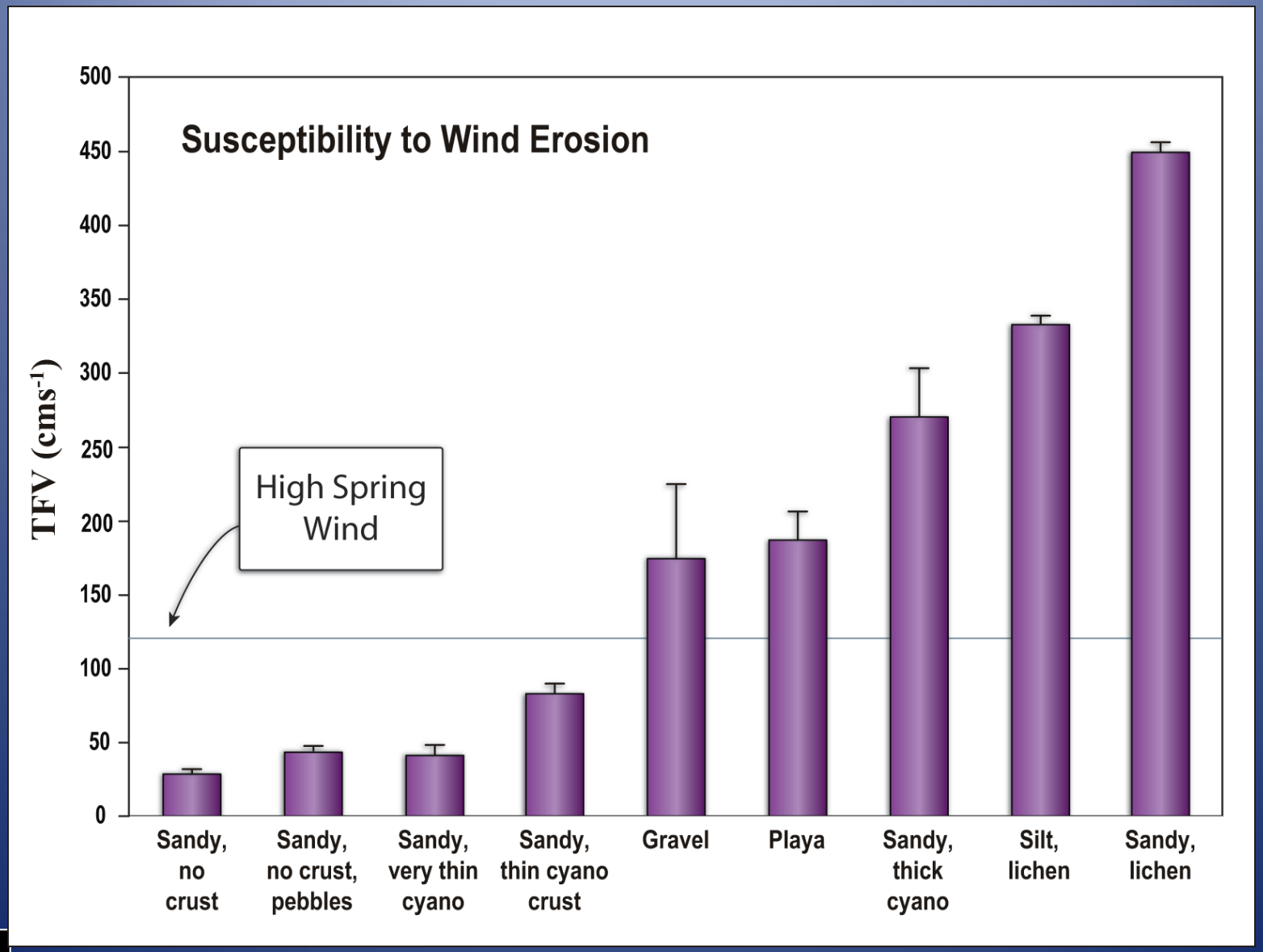
But soils do not erode

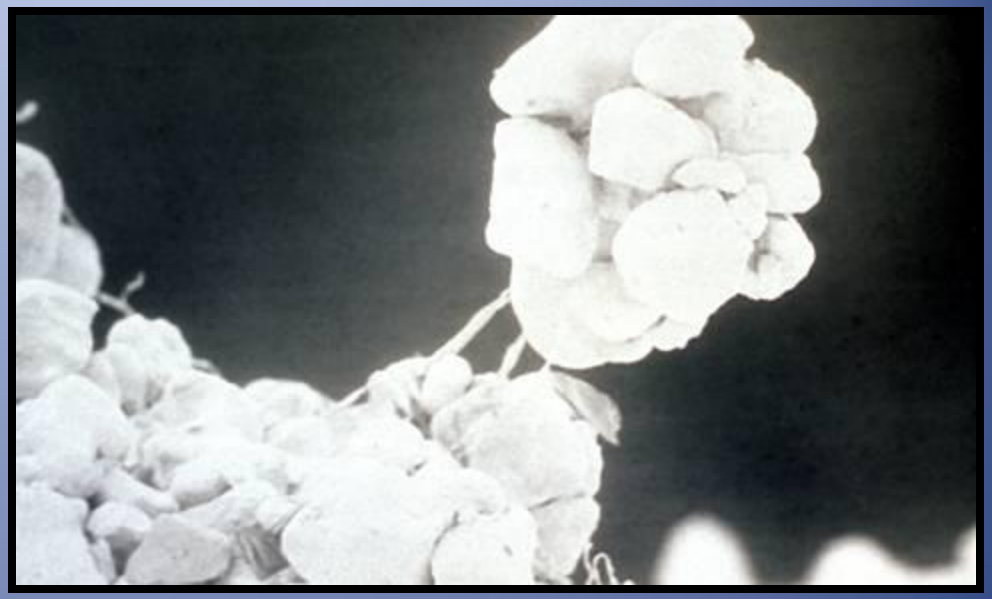


Hill slopes

Soils held beyond angle of repose

Wind Erosion (water too)

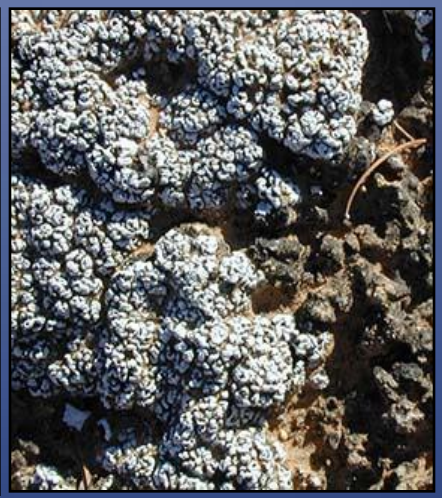




Crust flora influence soil permeability

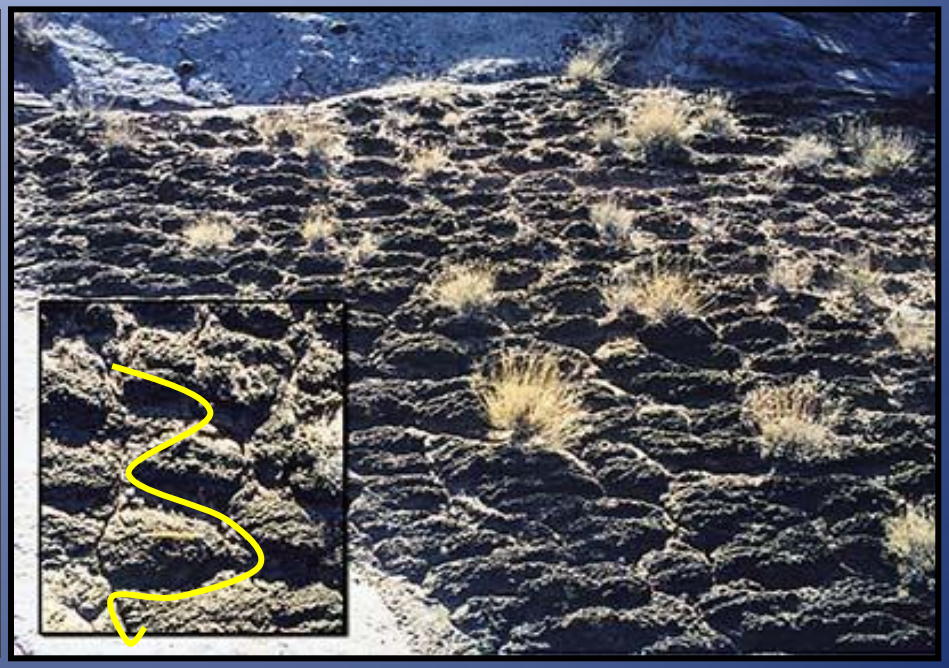
bare > light cyano > dark cyano >

patchy lichen > continuous lichen > moss



Retention Time:

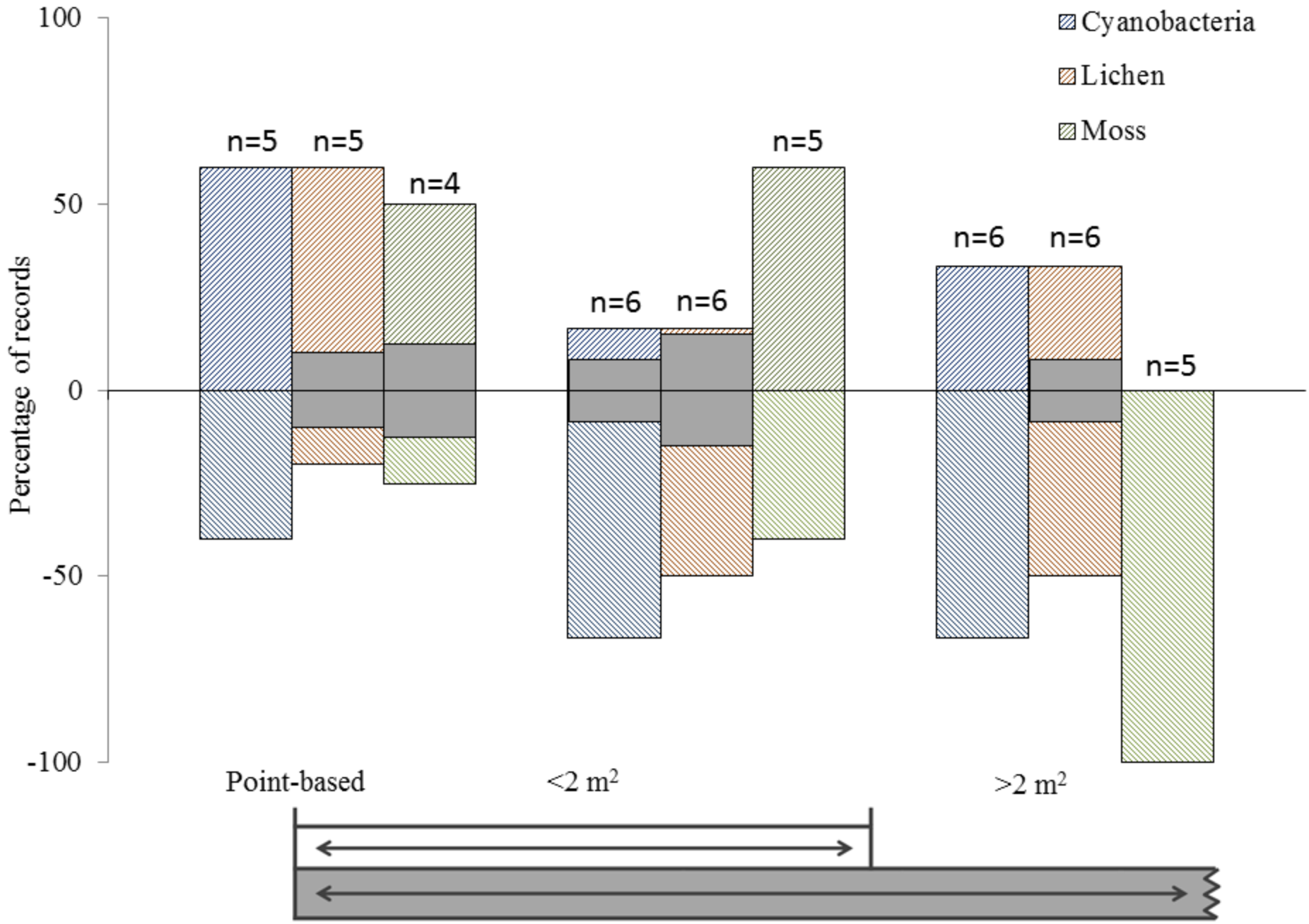
Path Connectivity/Surface Roughness



Hot deserts (smooth surface) = less retention

Cool deserts (rough surface) = greater retention

(Mounds can direct water to or from plants)


Cyanobacteria
Lichen
Moss
Percentage of records
100
50
0
-50
-100
n=5
n=5
n=4
n=6
n=6
n=5
n=6
n=6
n=5
Point-based
<2 m²
>2 m²

Soil Fertility

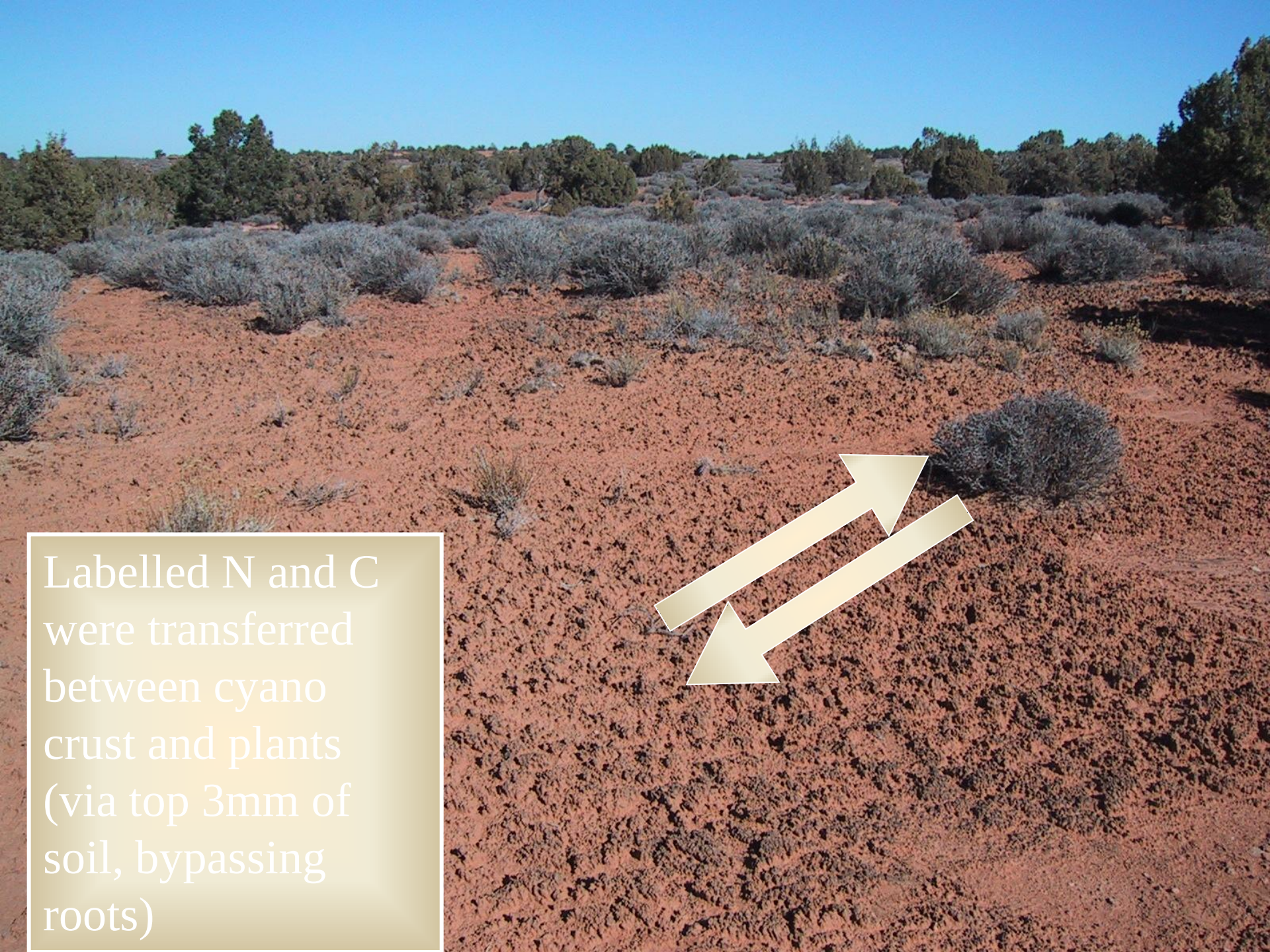
Collema tenax, a cyanolichen

- Cyanobacteria (free and lichenized) fix N and leak it!
- All fix C
- Many desert soils are very low in N, C, and P, especially in plant interspaces

Rock varnish , tree leaves, plant litter also fix N!!!

Role in phosphorus cycling is not understood, but may be essential, as biocrusts secrete phosphatases. P, rather N, likely limit tropical productivity

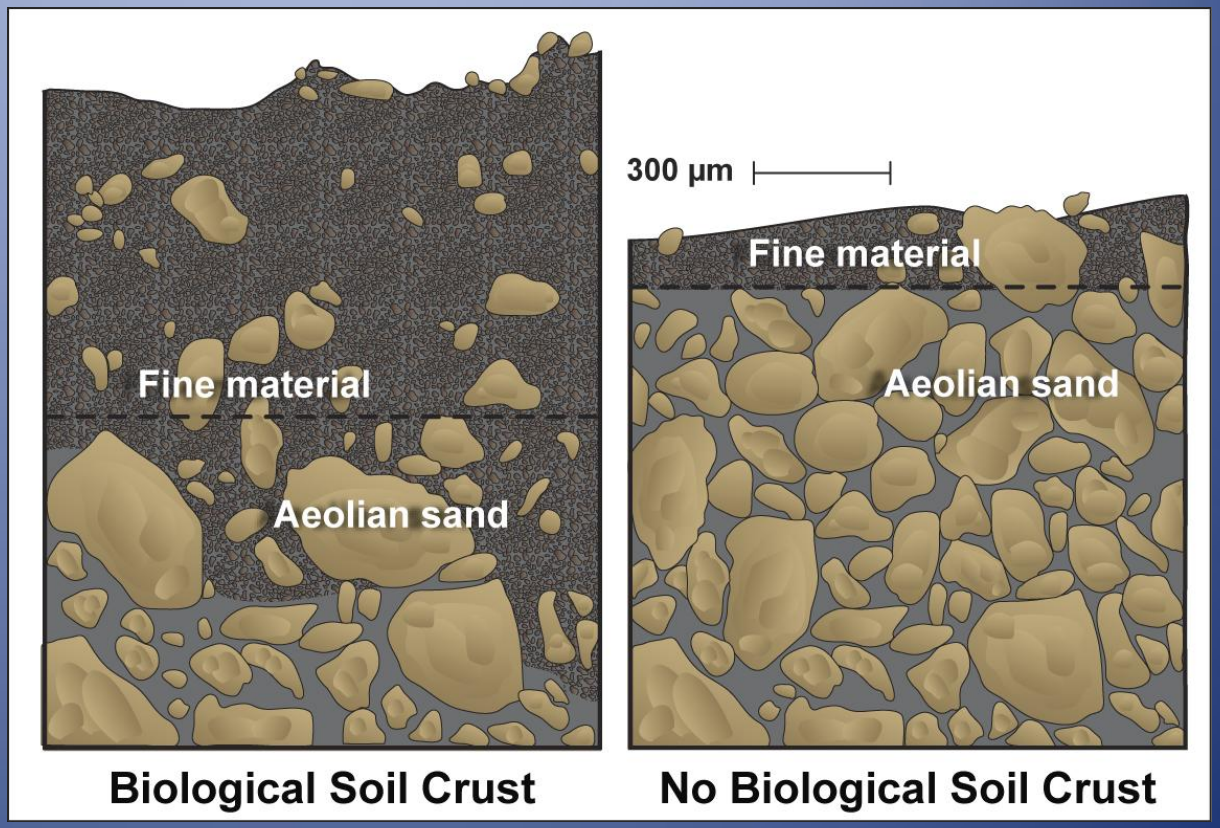
Interaction of N and P inputs from biocrusts and C cycling is not understood, but C production often N and P limited



Labelled N and C were transferred between cyano crust and plants (via top 3mm of soil, bypassing roots)

Dust Capture

- Dust contains high levels of nutrients
- Rougher surfaces, more (sticky) organisms retain more dust
- Small particles hold more moisture



Colorado Plateau, Sandy Soils								
Enrichment (x)								
P	K	Mg	Na	Ca	Mn	Zn	Cu	Fe
2.6	1.2	4.6	4.3	1.3	2.1	2.7	1.4	1.6

Albedo/Soil Temperature; vascular plant establishment

Dark crusts are up to 9C warmer than light crusts in winter

Amoebae, Flagellates, Ciliates, Nematodes

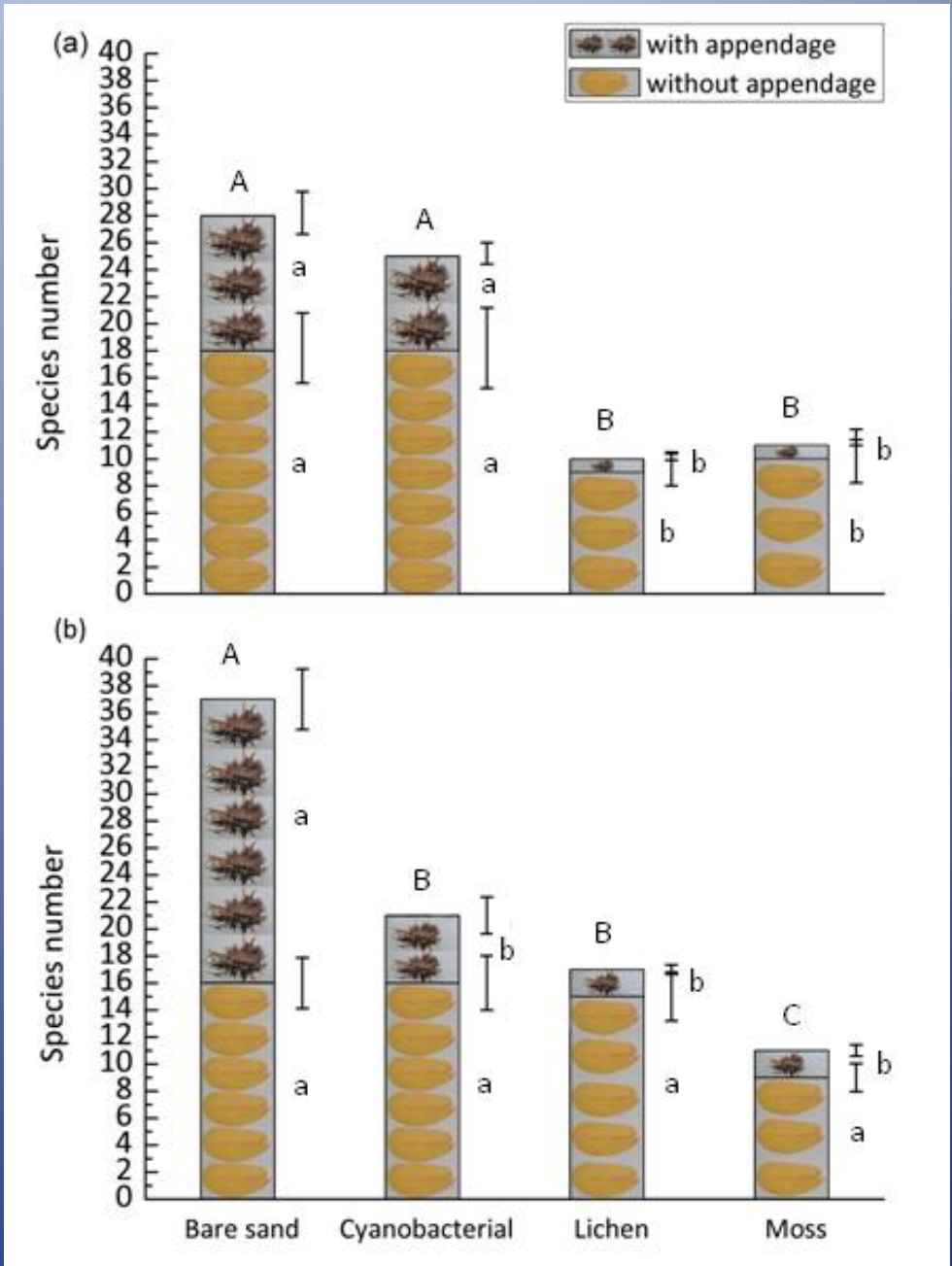
More developed crusts, surface soils = > abundance, > richness

Effects of biocrusts on plant nutrition

USGS
science for a changing world

Seed bank

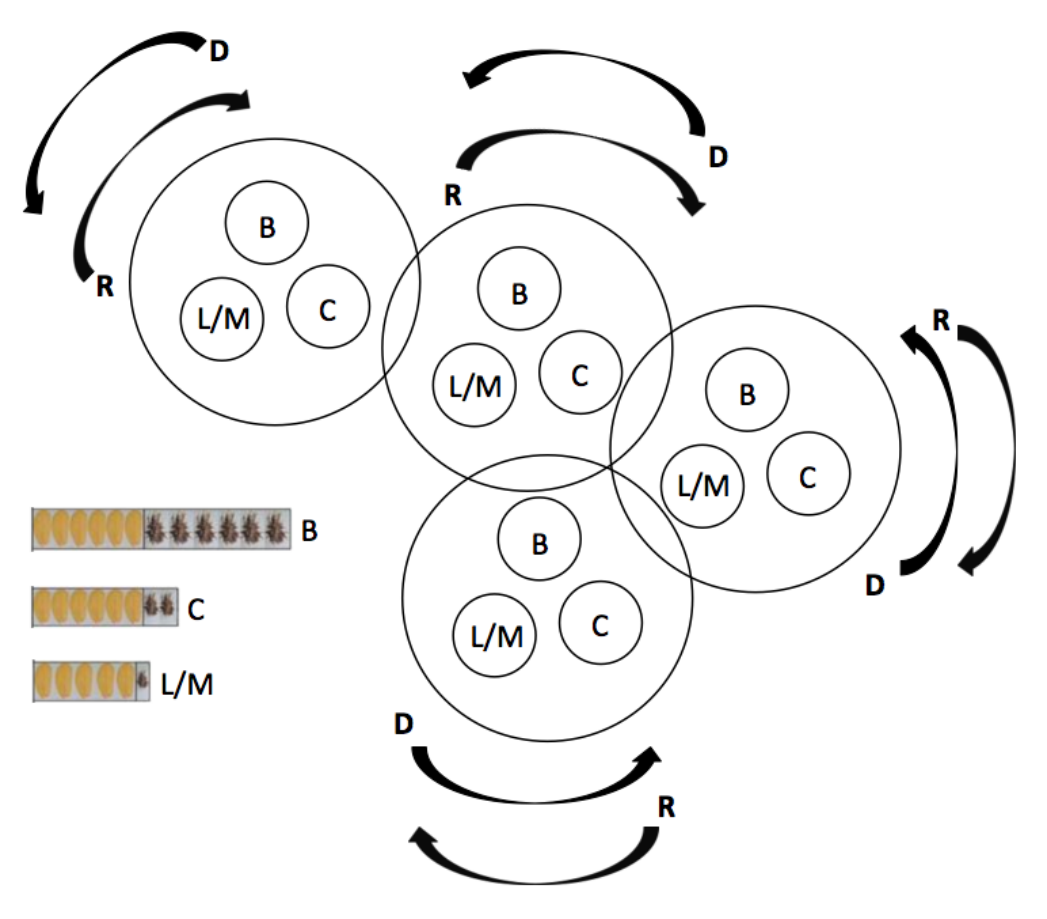
Plants



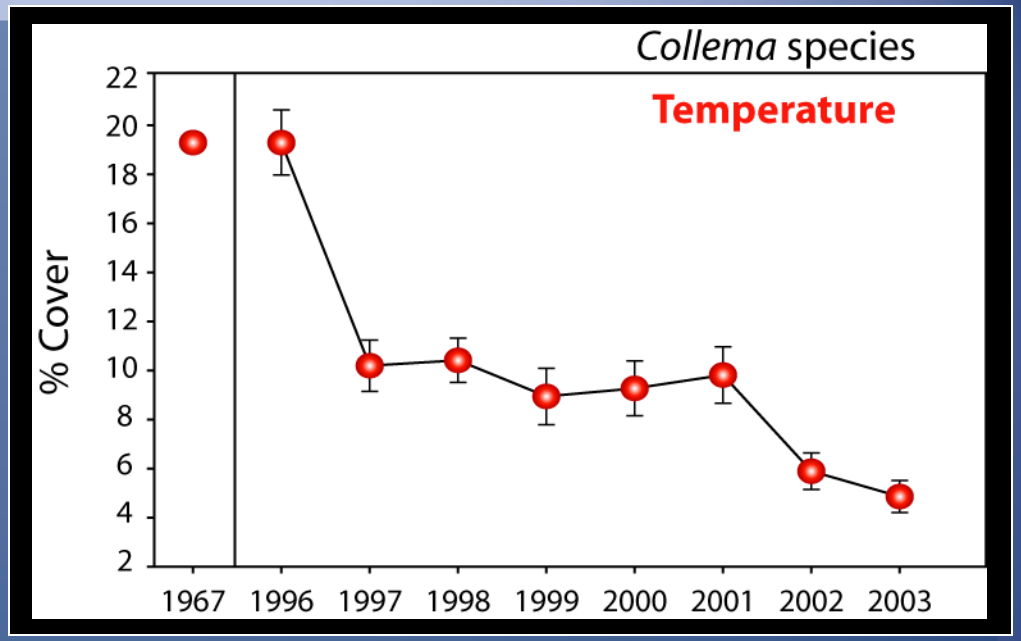
530 plots; Zhang and Belnap

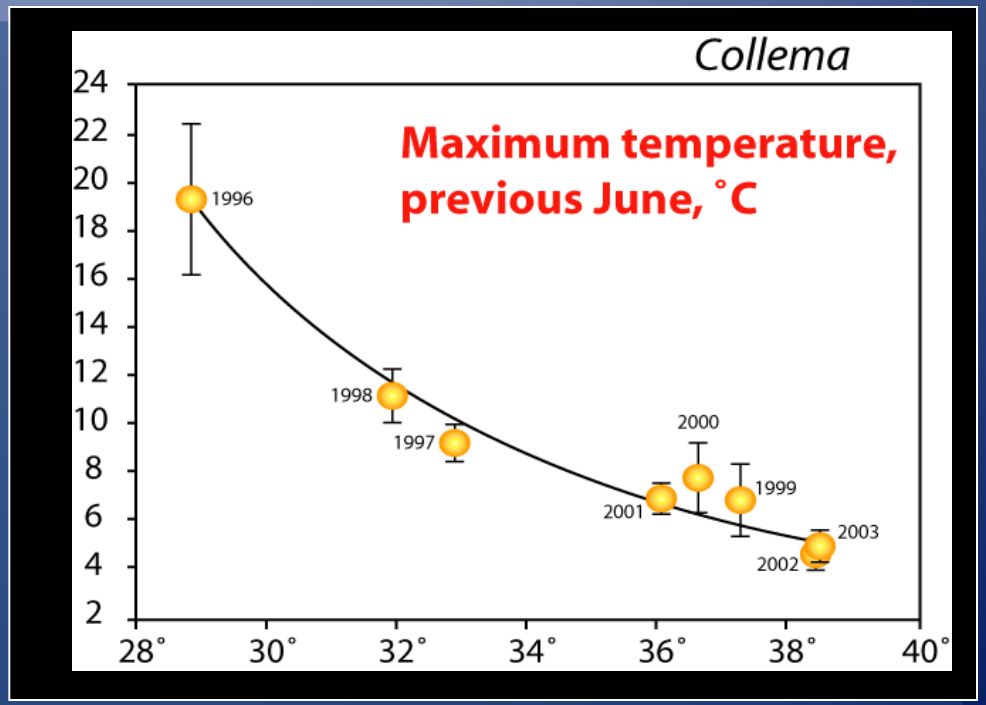
Long noted that invasive annual grasses with large appendages have difficulty germinating in biocrusted soils

Thus, biocrusts may structure plant communities in space and time. Is this universally true?



Increasing temperature

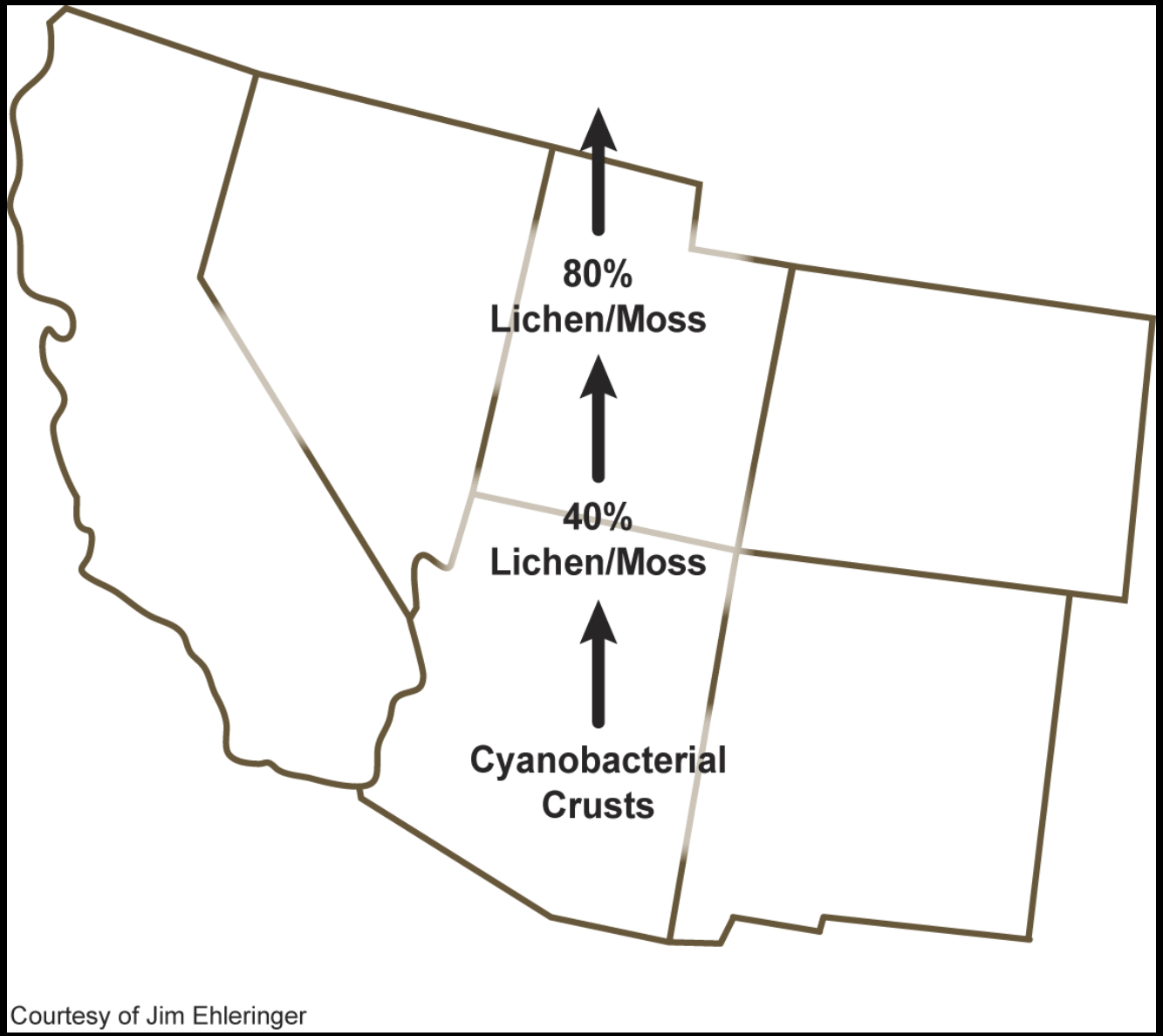




What does it mean for other species? Ecosystem function?

USGS science for a changing world

With climate change, species shift pole-ward



Courtesy of Jim Ehleringer

Biocrust Research Needs

- Unknown species composition
- Role in N, P, C cycling; hydrology; stability; vascular plant community composition
- Highly vulnerable to trampling: how does this alter species composition, function
- Vulnerable to climate change, will alter species composition, ecosystem function
- Increasing temperature will change species composition, N and C fixation
- Recovery rates will decrease with less soil moisture
- Unknown effectiveness of rehabilitation techniques

National park design and management policies: each step with scientist/stakeholder/public engagement

*Setting management goals is the first step:

Conservation of what? Natural, cultural, archeological resources? The more specific, the better the outcome as they can be very different. Examples:

Cultural: people living within the protected area

Natural: day use, wilderness, to zapovedniks

Archeological: guided, very restricted

*Mgmt policies: what type, timing, intensity of uses can be allowed and still reach goals? Identify data needed

*Restoration of degraded areas: is it feasible? Where and when can it be done? Identify data needed.

Monitoring of ecosystem function (not just biodiversity) is essential (!!!) to inform management policies to assess condition relative to management goals.

***Develop indicators**

Soil nutrients
Biological soil crust cover
Ground cover
Compaction
Soil surface strength
Plant spacing
Vegetation cover and composition
Soil aggregate stability
Infiltration

***Triage according to resources; (what ecosystem properties are most important to monitor?)**
***Develop monitoring plan**

The most important step is Adaptive Management

Monitoring results are communicated to stakeholders, management, and public. These then inform management policies. If management goals are not being met, some aspect(s) of use need to be altered or goals may not be realistic. Policies need to be adapted accordingly.

A big challenge: getting local farmers involved in monitoring efforts so they are invested in sustainable use. Develop simplified monitoring techniques. It can work!! (Kenya, Mongolia, Mexico)

Develop ways for people to get money from park