The Use of Terrestrial cyanobacteria for the Rehabilitation of Arid Soils: Not just another good idea

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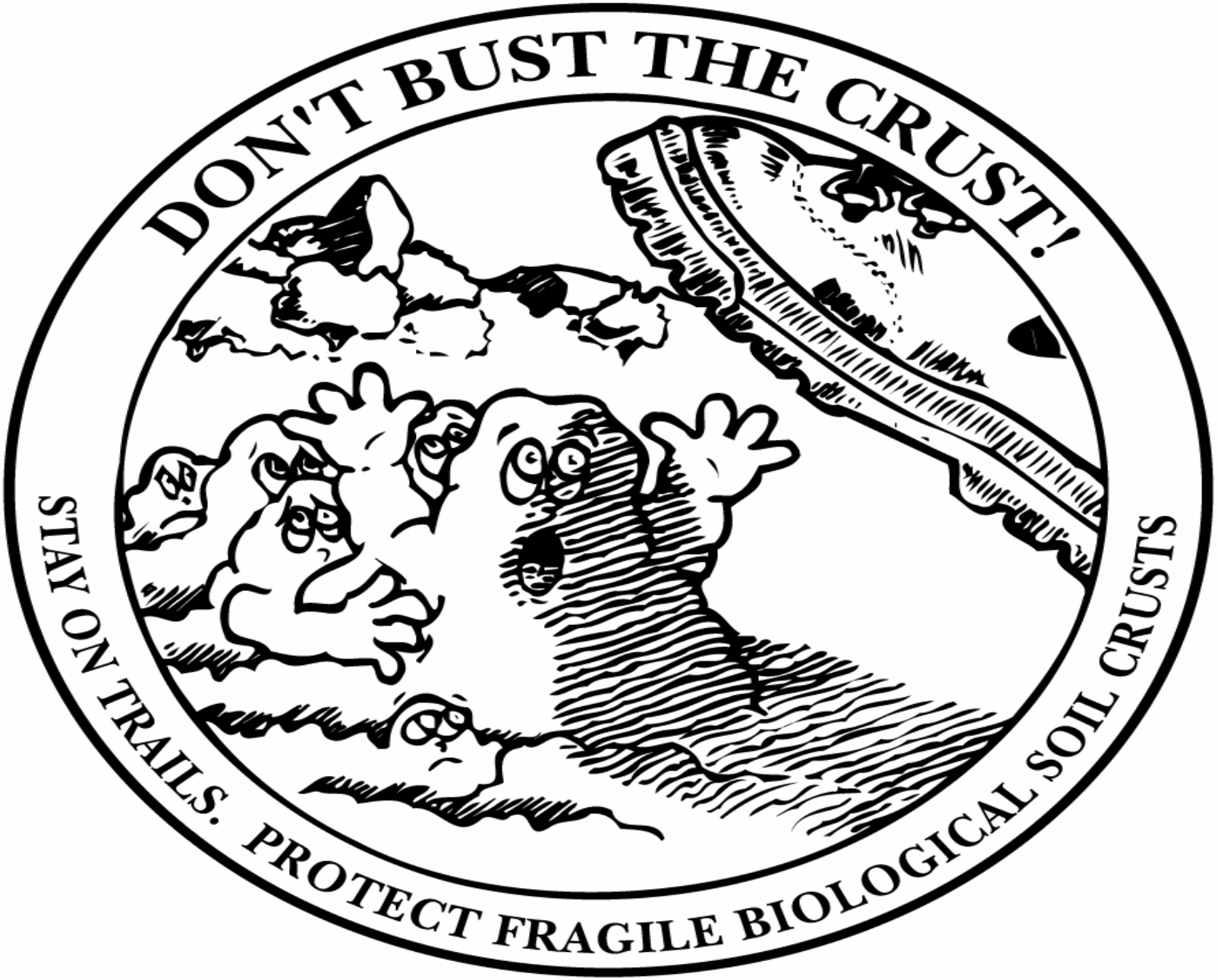
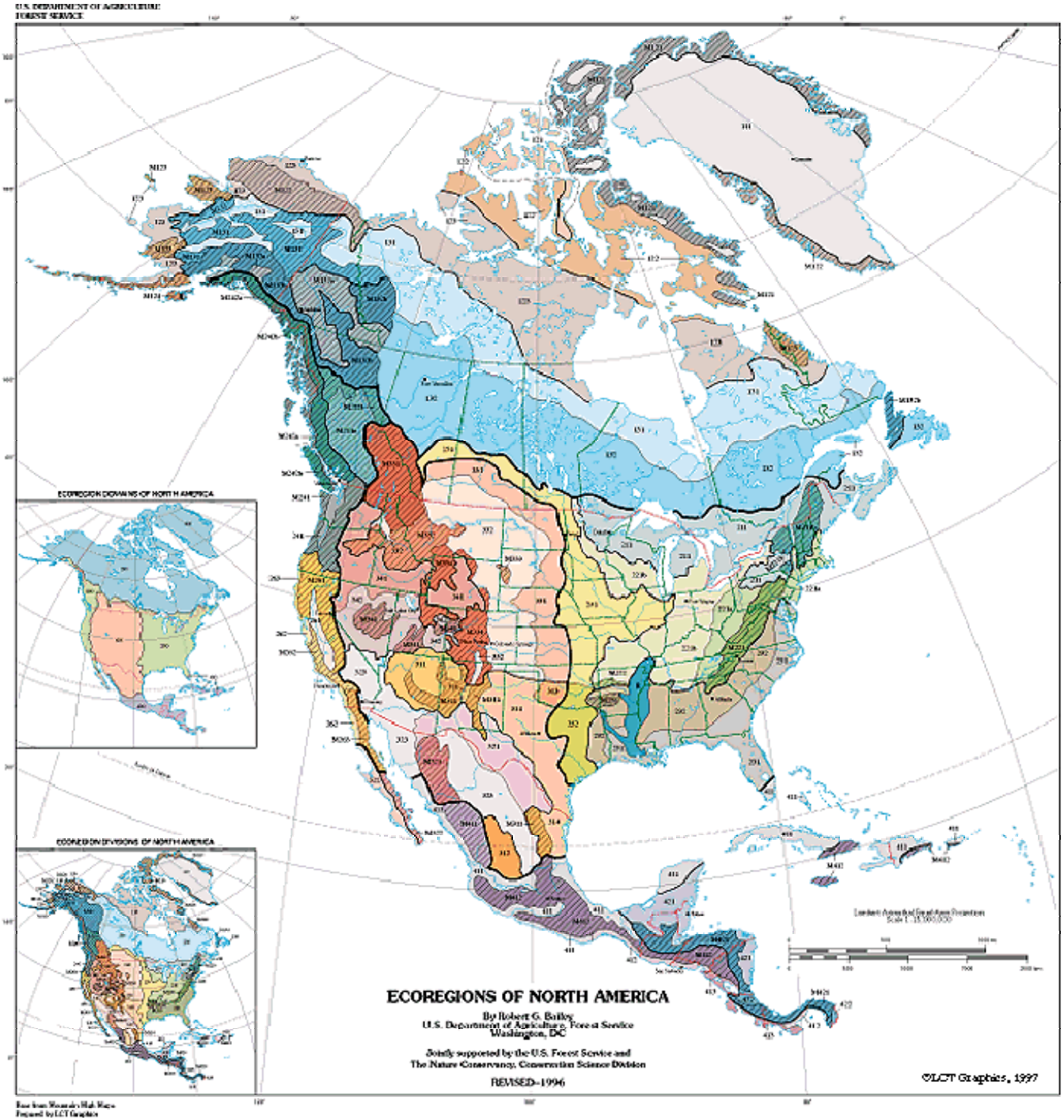
It's Alive!
Please don't walk on it. Stay on trails!
La sol vit!
Der Boden lebt!


DON'T BUST THE CRUST!
STAY ON TRAILS. PROTECT FRAGILE BIOLOGICAL SOIL CRUSTS



35% of world is arid (= 5.2×10^9 ha)

40% of US

Evaporation exceeds precipitation

Ecoregion	Annual precipitation (mm)	Moisture: Season/Form	Mean annual temperature range (°C)	Vegetation type
Hot Deserts				
Sonoran	75 – 255	Summer/rain Fall/rain	15 – 24	Mixed thorn scrub
Mojave (low elevation)	50 – 150	Winter/rain	10 – 24	Scrubland
Mojave (High elevation)	150 – 610	Winter/rain	3 -10	Scrubland
Chihuahuan	205 – 245	Summer/rain	10 – 18	Scrubland
Cool Deserts				
Colorado Plateau	205 – 510	Winter/snow Spring/rain Summer/rain	4 – 13	Scrubland Woodland
Great Basin	130 – 490	Winter/snow Spring/rain	4 -13	Sagebrush steppe Salt-desert shrub
Columbia Basin	260 – 635	Winter/rain Spring/rain	4 – 14	Perennial grassland
Great Plains	490 – 740	Spring/rain Summer/rain	4 – 18	Prairie grassland
Coastal Chaparral				
California Chaparral	175 – 635	Winter/rain	15 – 18	Chaparral grassland

Background

- **Arid environments are dominated by microbial communities** (Cyanobacteria, algae, Lichens, Fungi, Bacteria, and Mosses)

- **Cyanobacteria**
  - Photosynthetic, Azototrophic (fix nitrogen)
  - Active when wet, dormant when dry → Desiccation tolerant
  - 70% of ground cover, 99% of nitrogen input
  - Cyanobacteria are first to colonize new substrates.

What's in a name? Biological Soil Crusts (BSCs)

- Also known as "cryptogamic soils", "cryptobiotic", "microbiotic", or "microphytic" crusts
- Different from "Physical crusts"
- See www.soilcrust.org

Crust-Stabilized Slope

Slope Close-up

The BSC microbial community: “Terrestrial Pondwater”

- Cyanobacteria
- Lichens (cyanolichens and phycolichens)
- Fungi
- Bacteria
- Eukaryotic algae
- Bryophytes (mosses and liverworts)
- Protozoa (single celled animals)
- And a host of others

Soil Crust Community

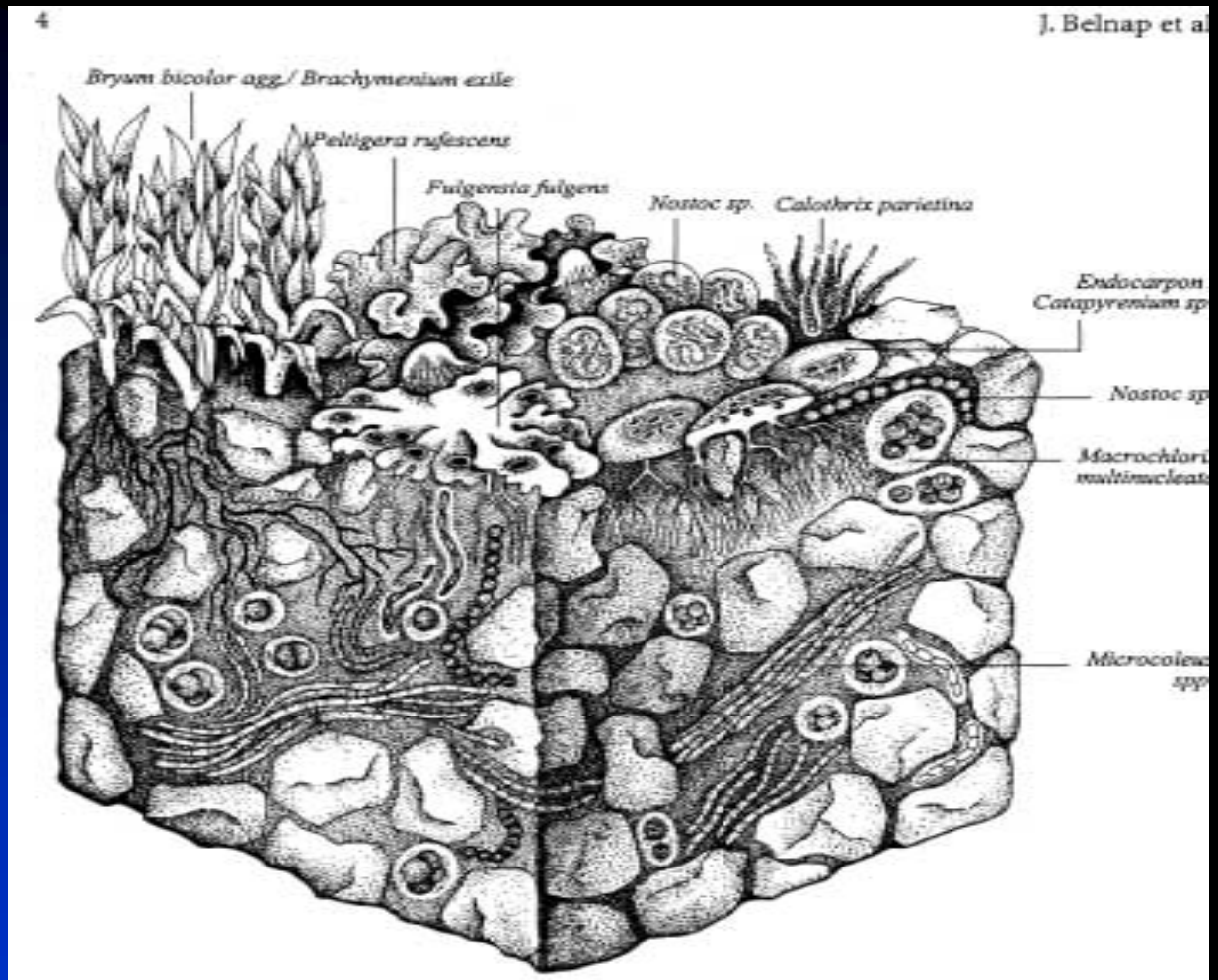
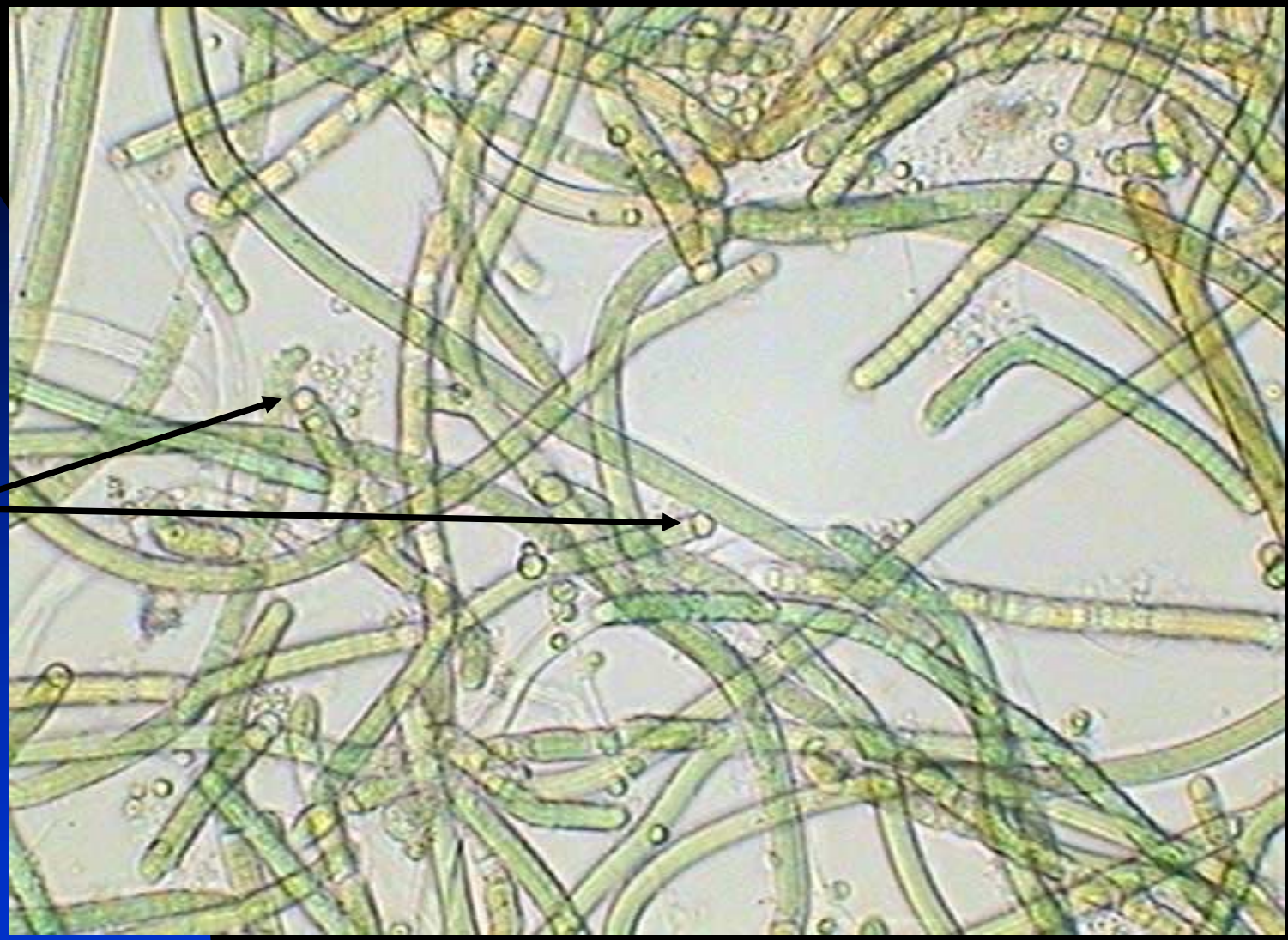


Fig. 1.1. Schematic block diagram of a biological soil crust with typical colonizers
Thickness of the layer about 3 mm, organisms not drawn to scale. (Illustration Renate
Klein-Rödder)

3 mm^3

Tolypothrix sp.



Trichormus sp. (=Anabaena)

Nostoc colony

Lichens: Fungal-Algal Symbionts

- Phycolichen:
  - Eukaryotic “green” algal partner
  - Stratified thallus
- Cyanolichen:
  - Prokaryotic cyanobacterial partner
    - ★Nitrogen-fixing
  - Non-Stratified gelatinous thallus

Collema tenax

BSC = TPS

(terrestrial pond scum)

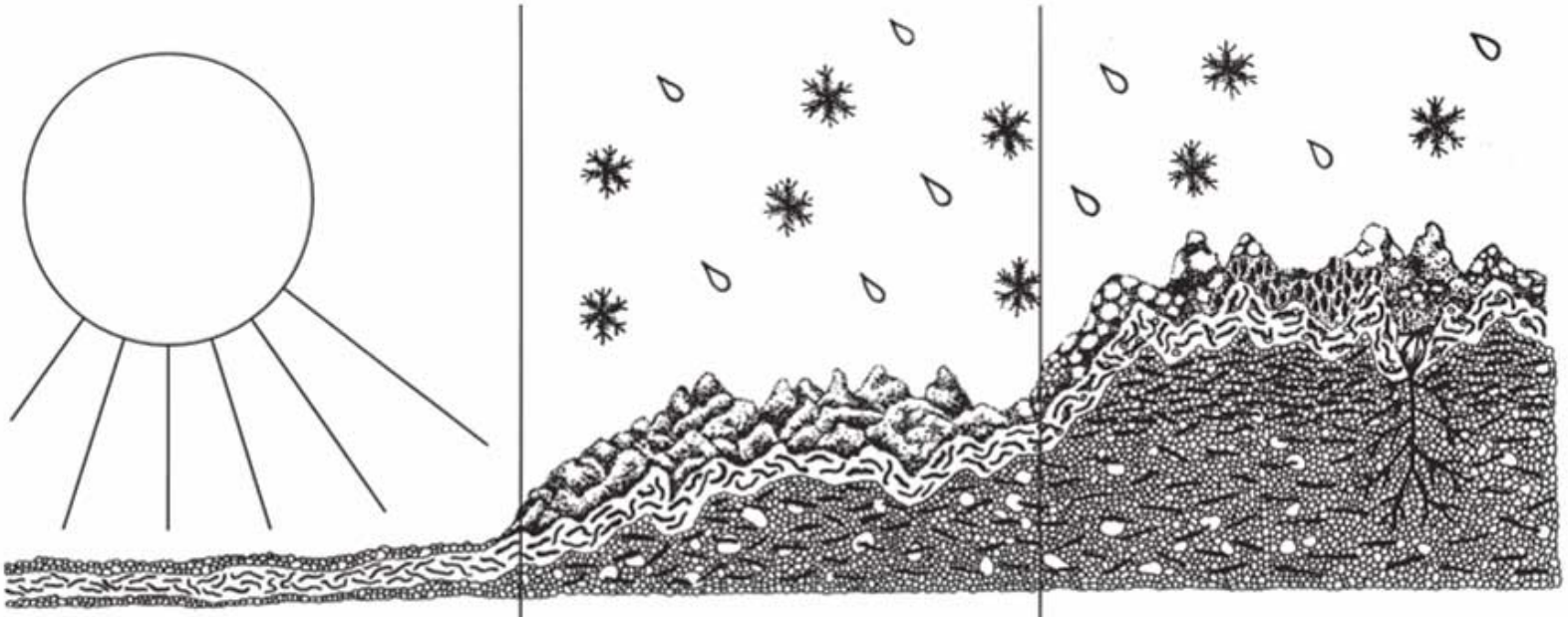
Amoeba- 1000x

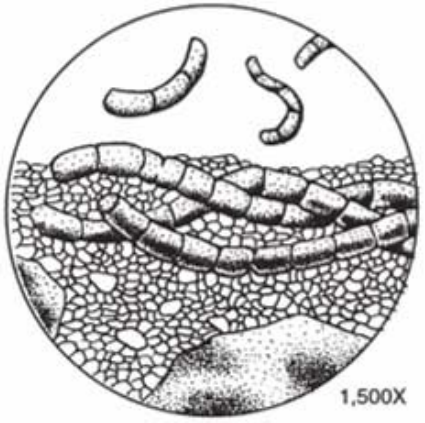
Hormogonia and *Vorticella*

hormogonia and vorticella 1000x.avi

Vorticella – 1000x

vorticella 1000x.avi





Young Cryptos: 0 to 3 Years
Cyanobacteria float through air and fall to the ground, crawl across the surface, or are carried by bugs and animals. They remain on the surface to catch sunlight and photosynthesize for their life processes.

Mid-life Cryptos: 3 to 10 Years
Cyanobacteria secrete sticky sheaths that stick to sand particles. When buried by soil, the cyanobacteria move to the suface. With frost heaving, sheaths form a contorted surface.

Mature Cryptos: 10+ Years
Lichen, mosses, fungi grow on surface; water debris and seeds become entrapped in pockets, seeds root which further strengthen soil.

Crust-Mediated Erosion Control: What's holding the place in place?

- Up to 70% of the vegetative cover in deserts
- Slime covered filaments bind soil particles together
- Frost heaving in cool deserts → water infiltration
- Organic matter → water holding capacity
  - → Carbon Sequestration
- Creates mechanical barrier that prevents the establishment of exotic weeds (Cheat Grass)

Crust and Soil Fertility

- Secretes nitrogen (10 kg • ha^{-1} • yr^{-1})
- Chelates micronutrients
  - (Fe, Mn, Co, Ni, Zn, etc.)
- BSCs contribute soil organic matter:
  - Improves water holding capacity
  - Provides energy for bacteria and fungi
    - ➲ facilitates biogeochemical cycles

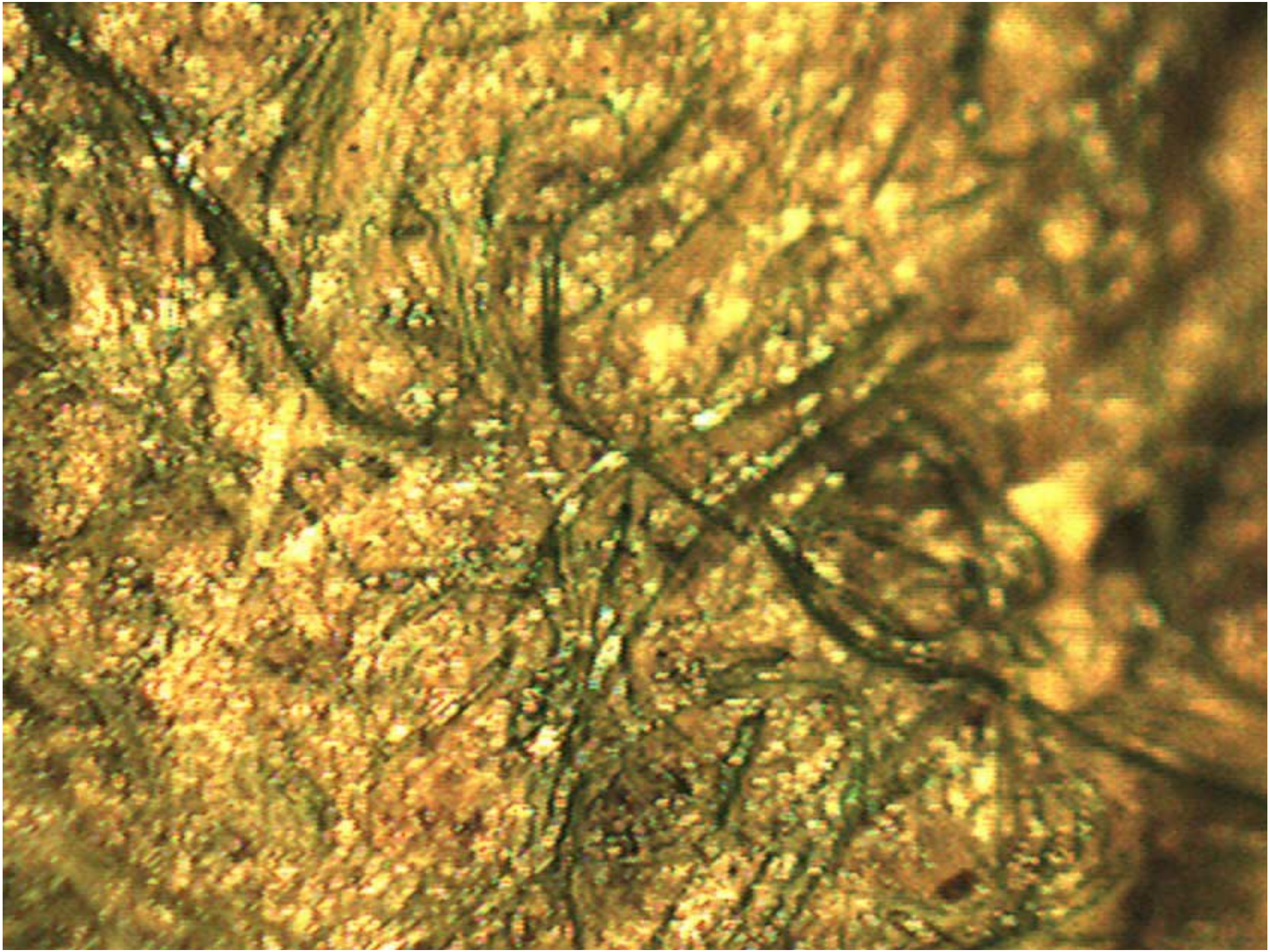
Working Photobioreactor

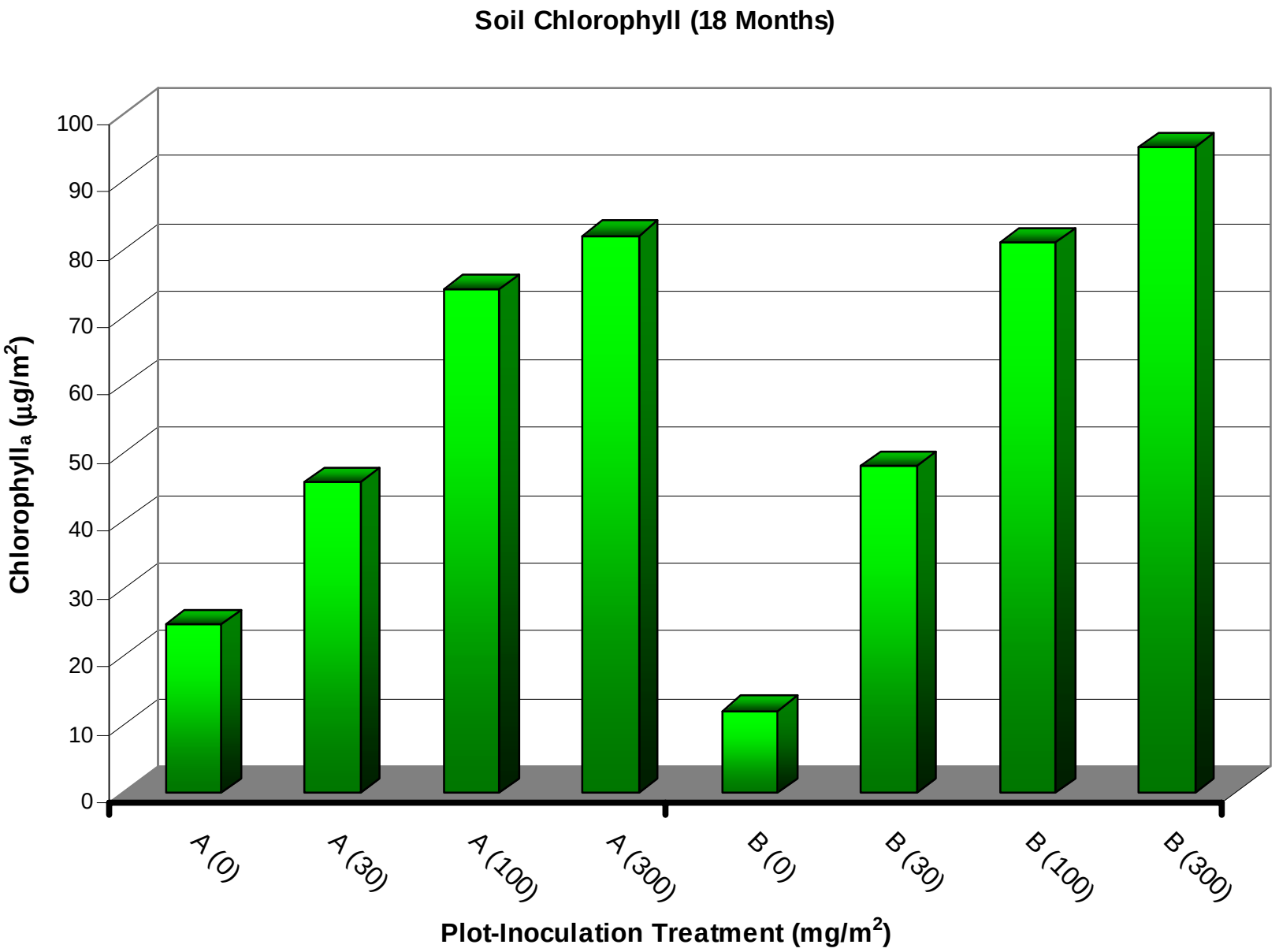
Coyote Gulch Demonstration Unit

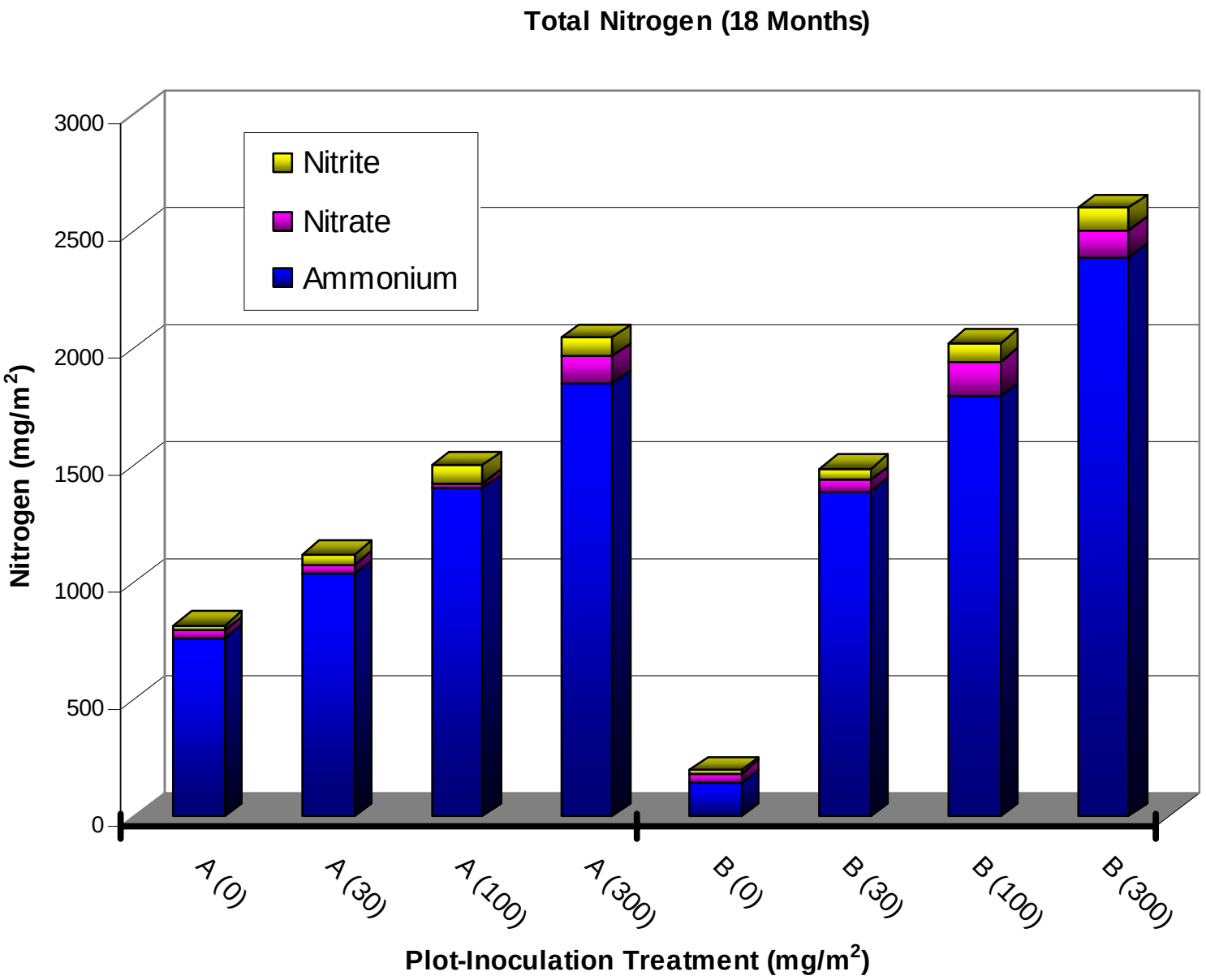
320 lbs (dry equivalent) of harvested biomass ready for oil extraction


GeoDerm™

Home-made Crust (First Generation)



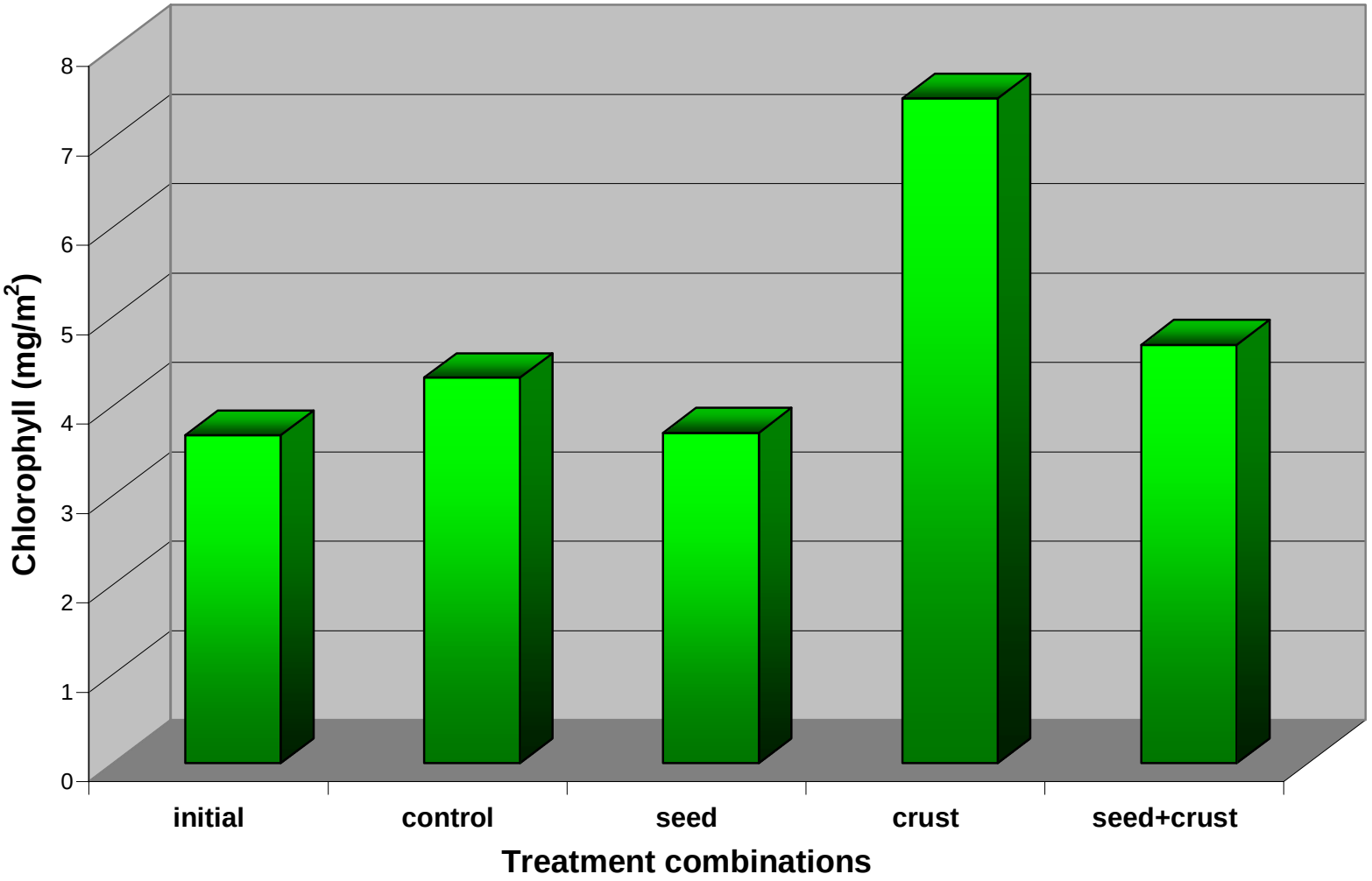

Soil Chlorophyll (18 Months)
Chlorophyll$_a$ (µg/m^2)
100
90
80
70
60
50
40
30
20
10
0
A (0)
A (30)
A (100)
A (300)
B (0)
B (30)
B (100)
B (300)
Plot-Inoculation Treatment (mg/m^2)


Total Nitrogen (18 Months)
Nitrite
Nitrate
Ammonium
3000
2500
2000
1500
1000
500
0
Nitrogen (mg/m2)
A (0)
A (30)
A (100)
A (300)
B (0)
B (30)
B (100)
B (300)
Plot-Inoculation Treatment (mg/m2)


Norwood-
post fire

Norwood Post-Fire (6 months)

Figure 1: Soil Cholorphyll



Norwood Post-Fire (6 months)

Figure 2: Soil Nitrogen

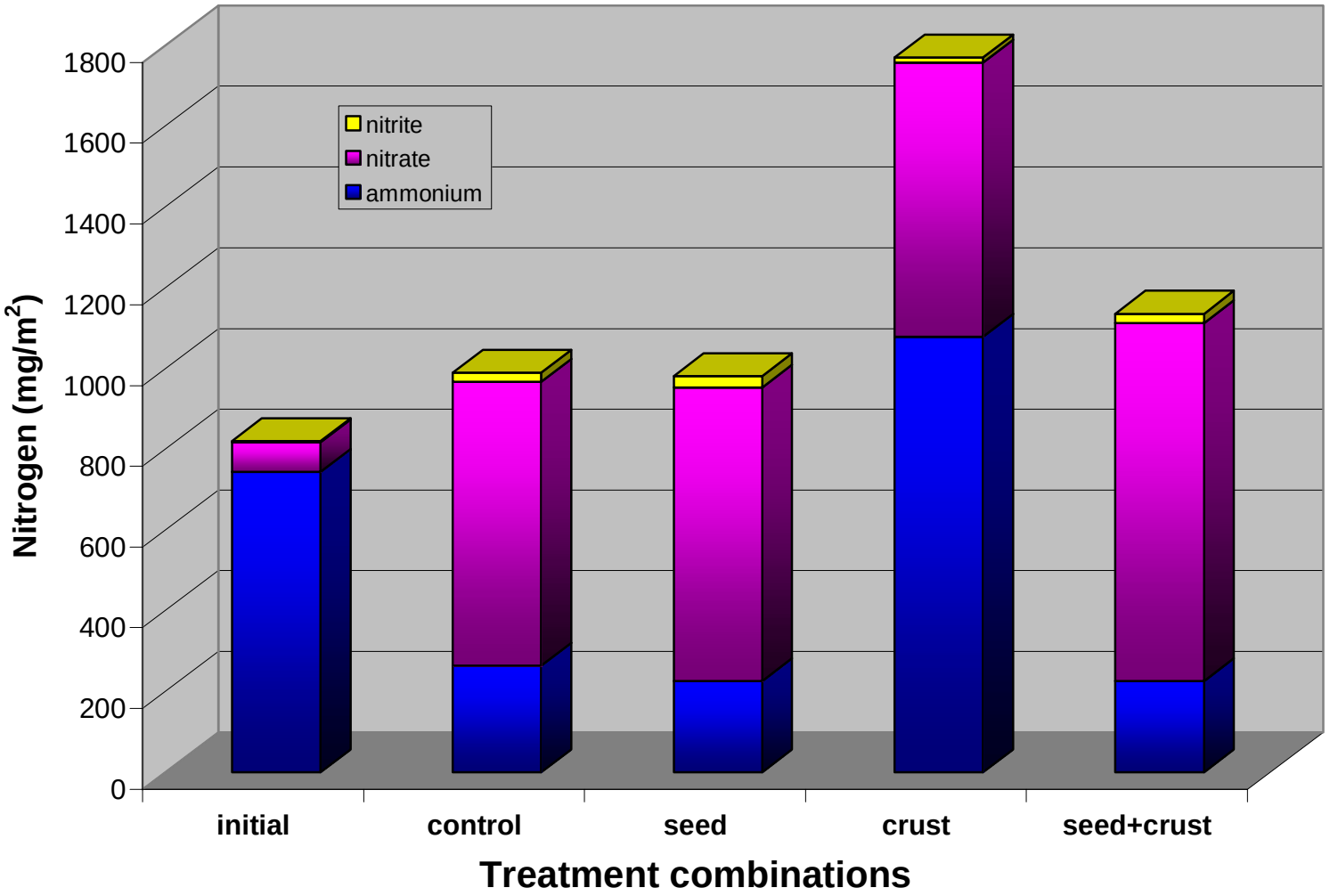


Figure 2: Chlorophyll- 14 month total incubation (winter interval)

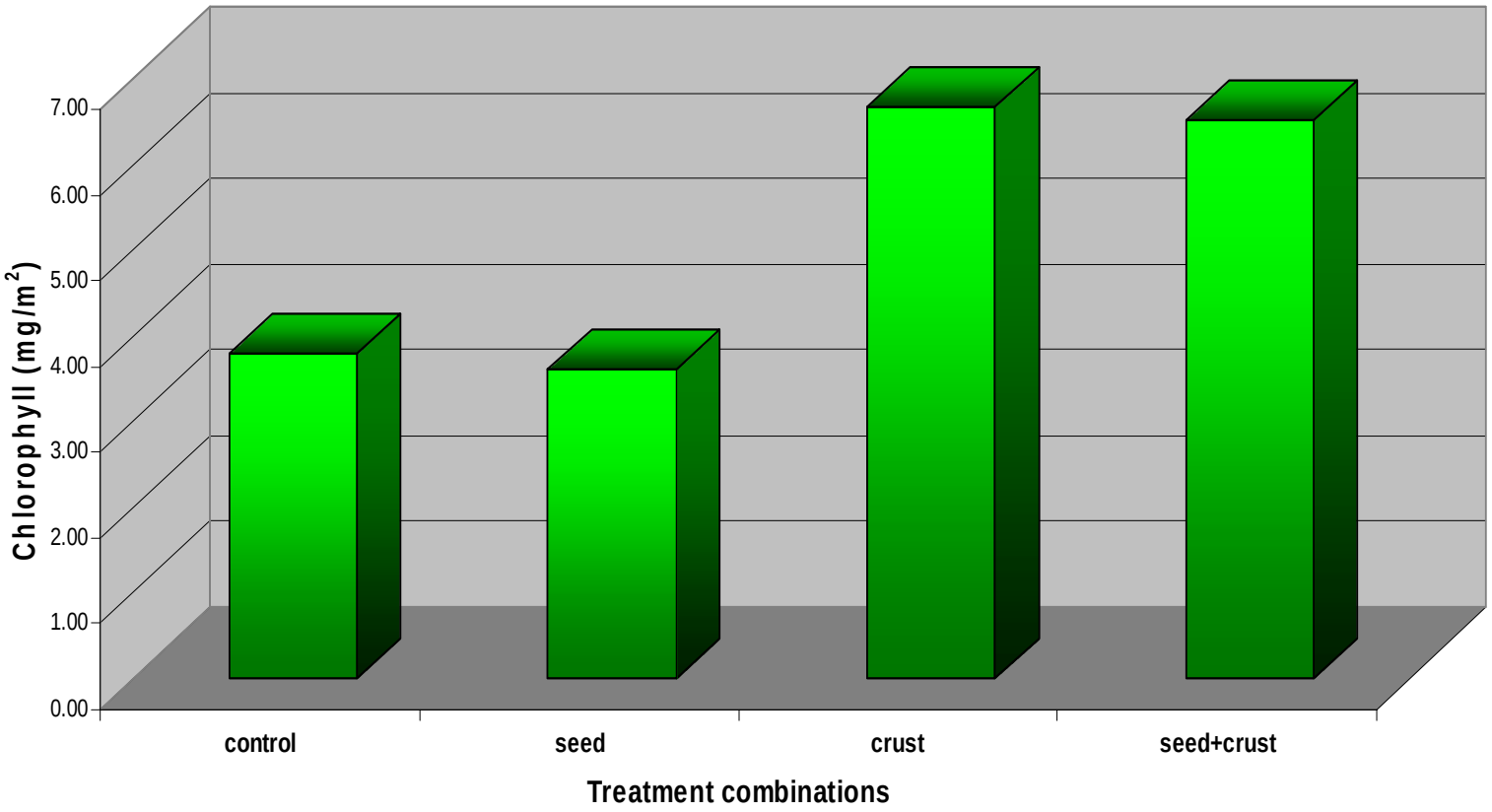
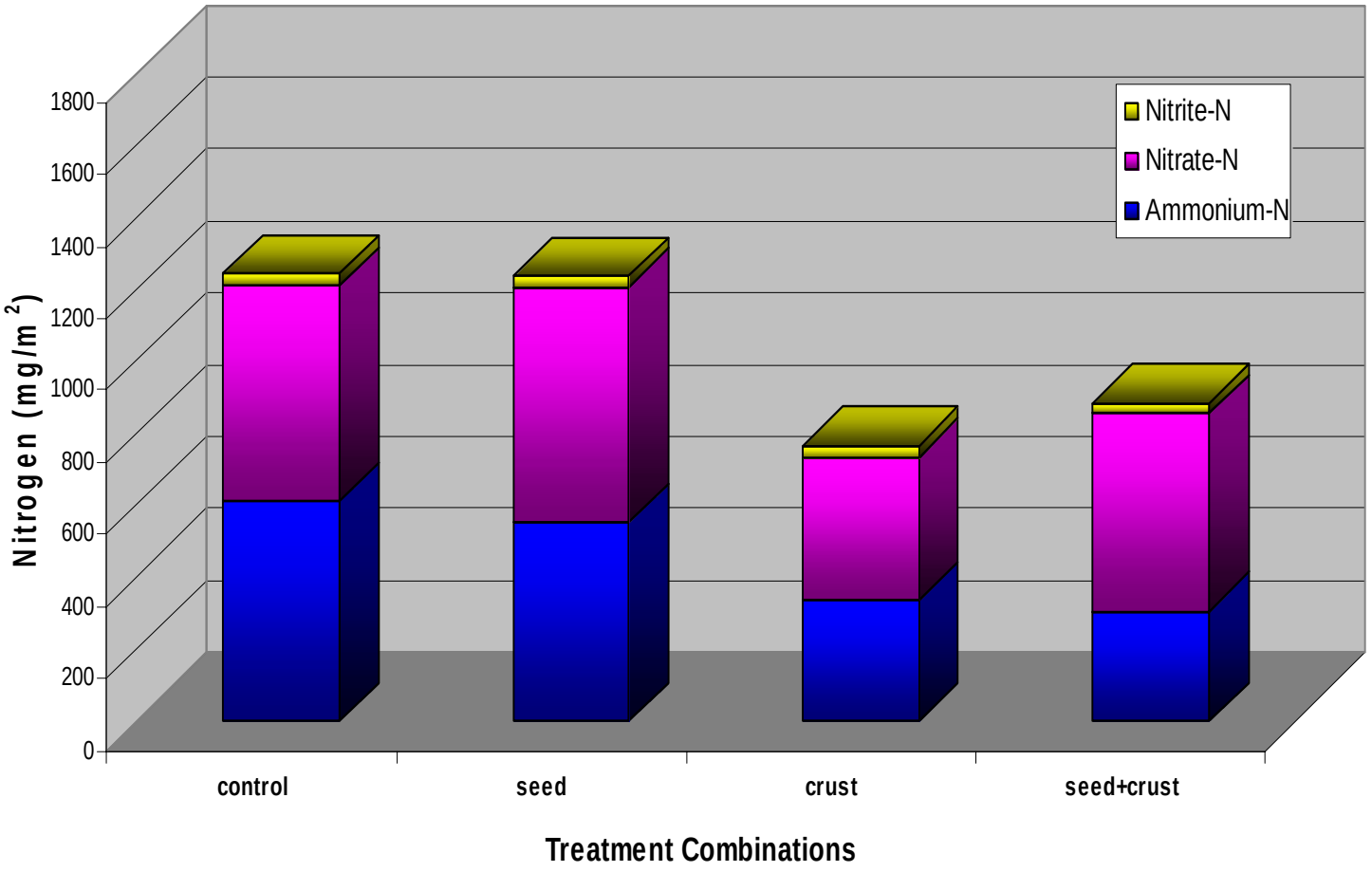


Figure 4: Nitrogen- 14 months total incubation (winter interval)



EnCana

March 2009

Thank You

PRIMORDIAL SOLUTIONS INC

SOLIX

ALGAE TO ENERGY