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Novel approaches to dryland reclamation enhance vegetation cover and soil stability at a former uranium mine

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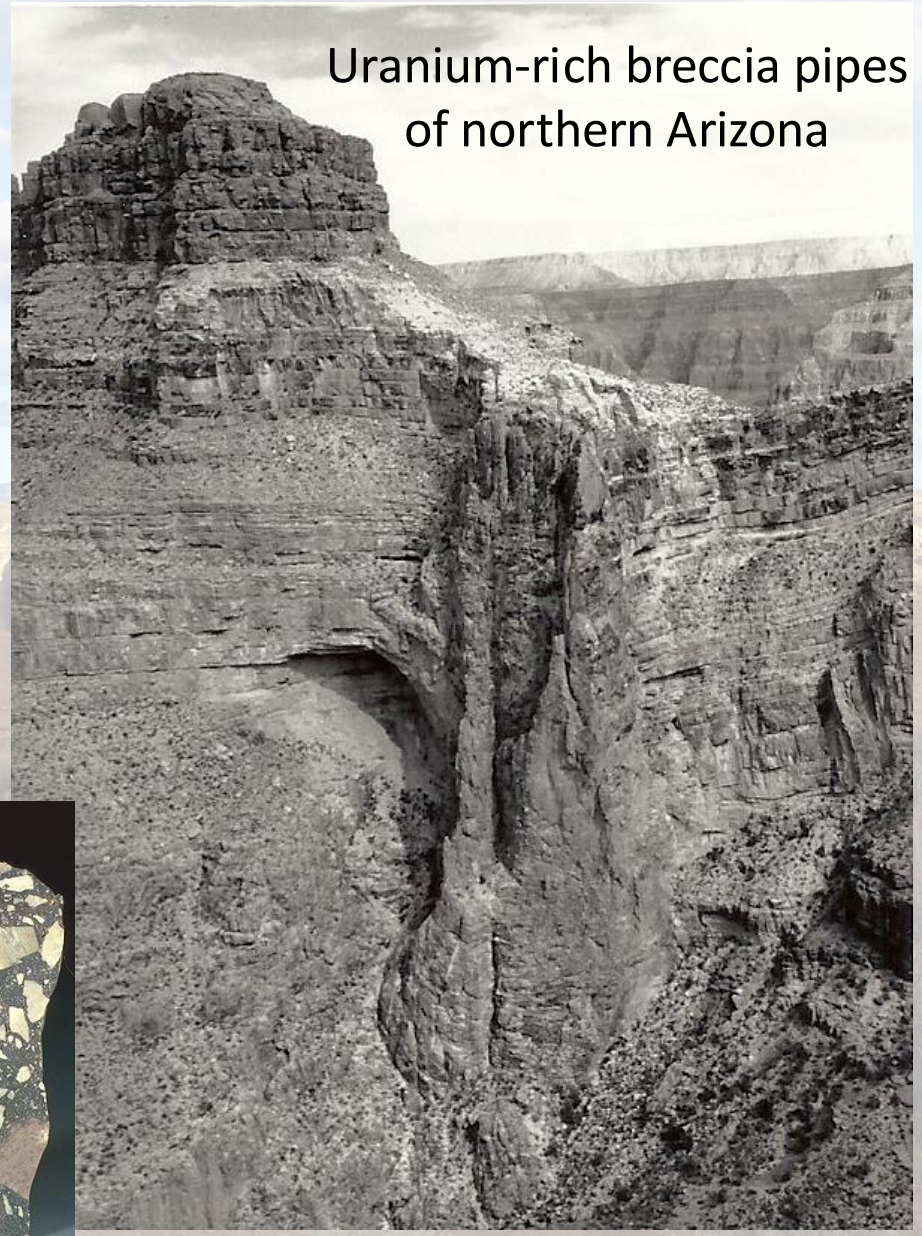
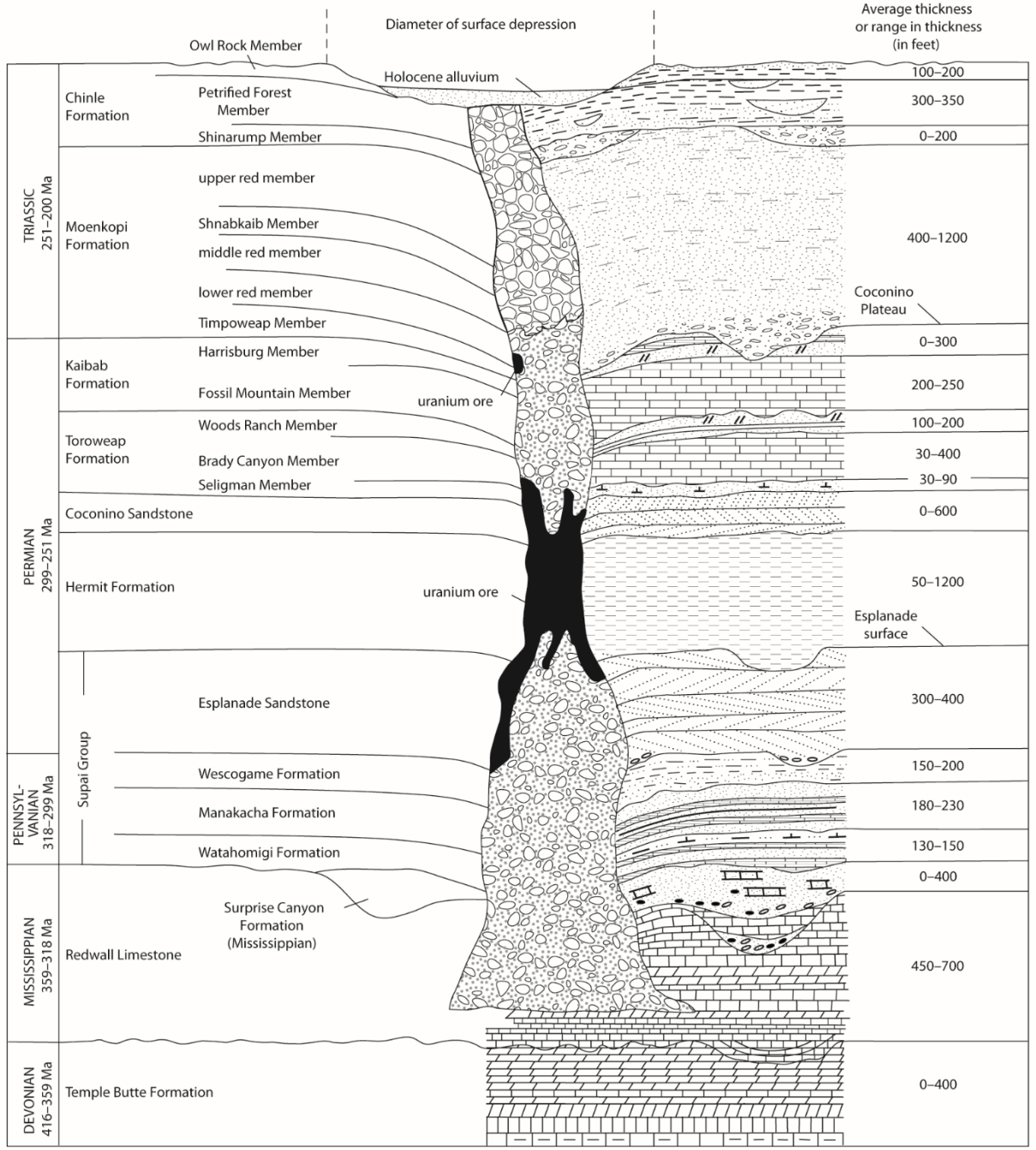
[5]Natural Hazards Mission Area, Reston VA

Grand Canyon

Grand Canyon Uranium: Breccia Pipes



U, As, Cu,
Fe, V, Zn,
Pb, Ag, Mo,
Ni, Co, Se



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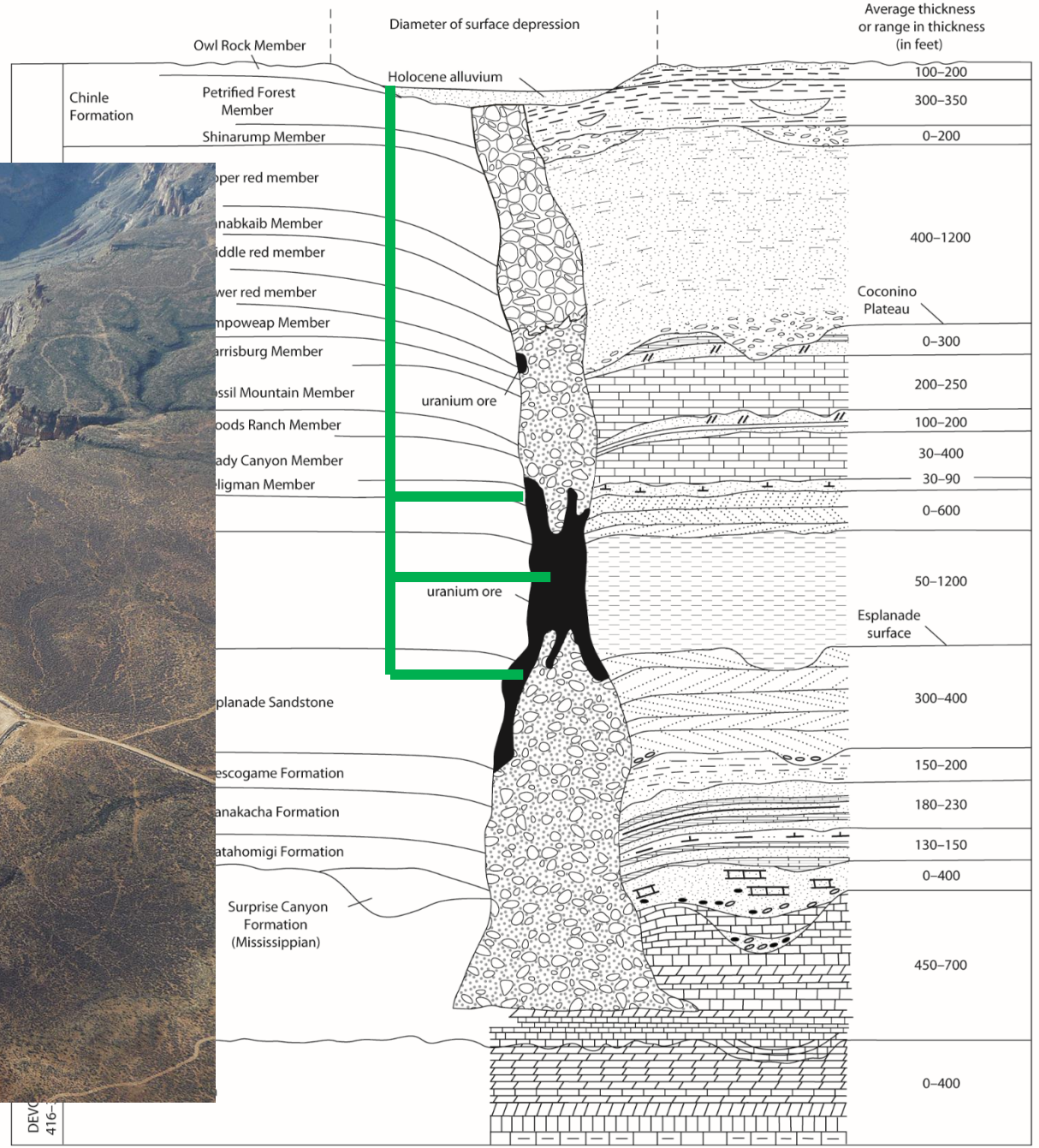
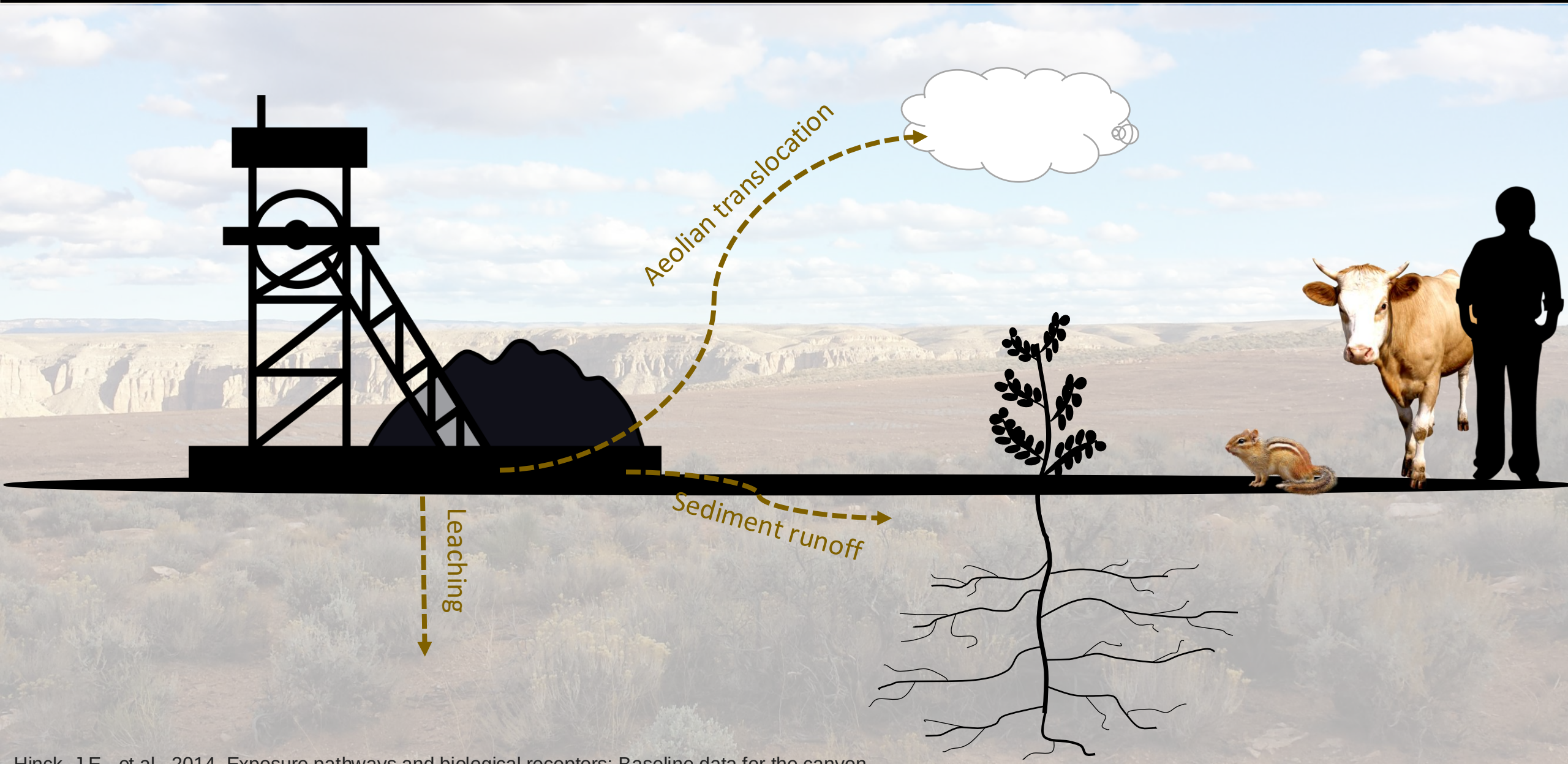


Mining in an environmental context

Mining in an environmental context: Translocation pathways



Hinck, J.E., et al., 2014. Exposure pathways and biological receptors: Baseline data for the canyon uranium mine, Coconino County, Arizona. *Journal of Fish and Wildlife Management*, *5*(2), pp.422-440.

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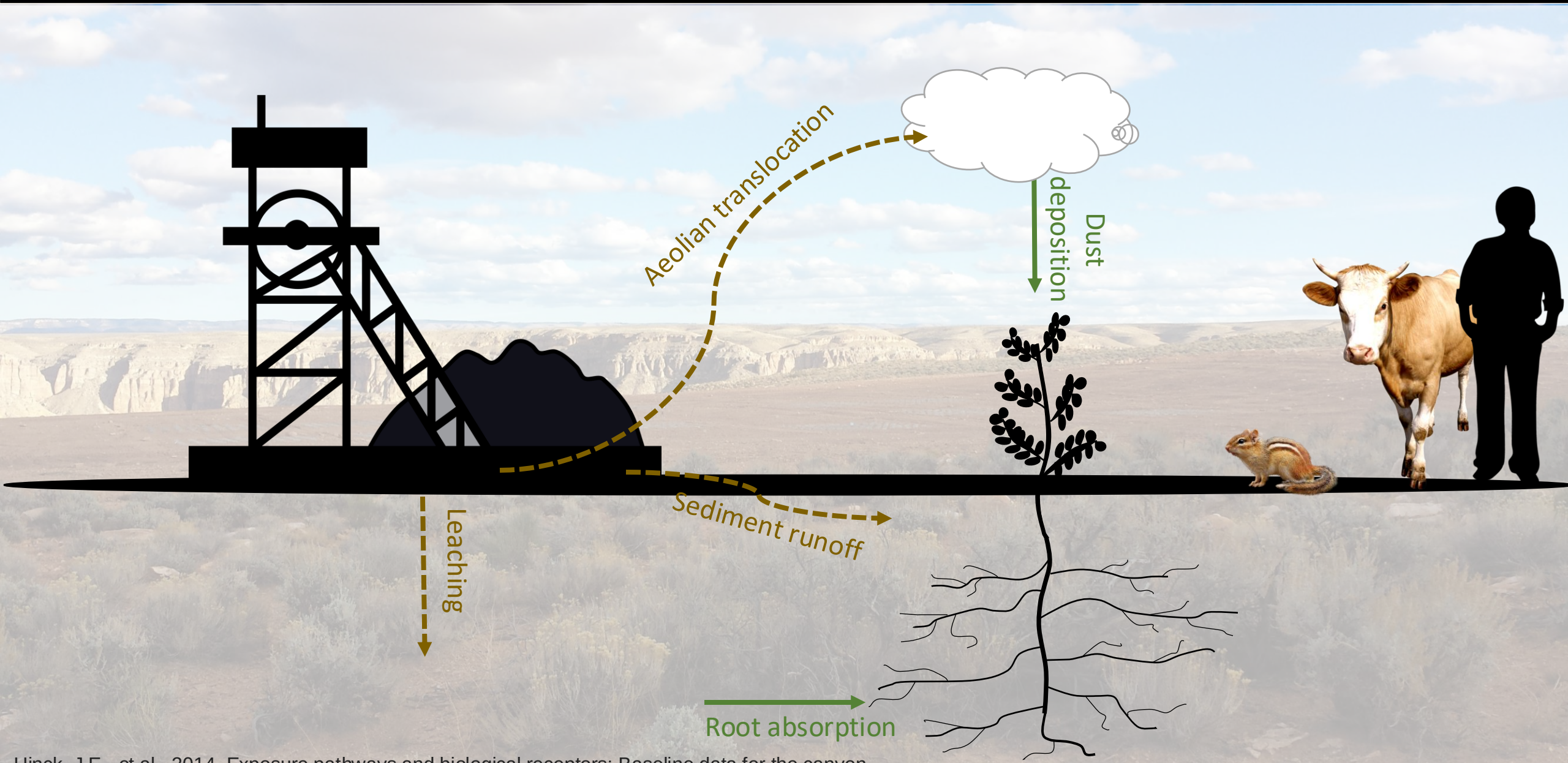

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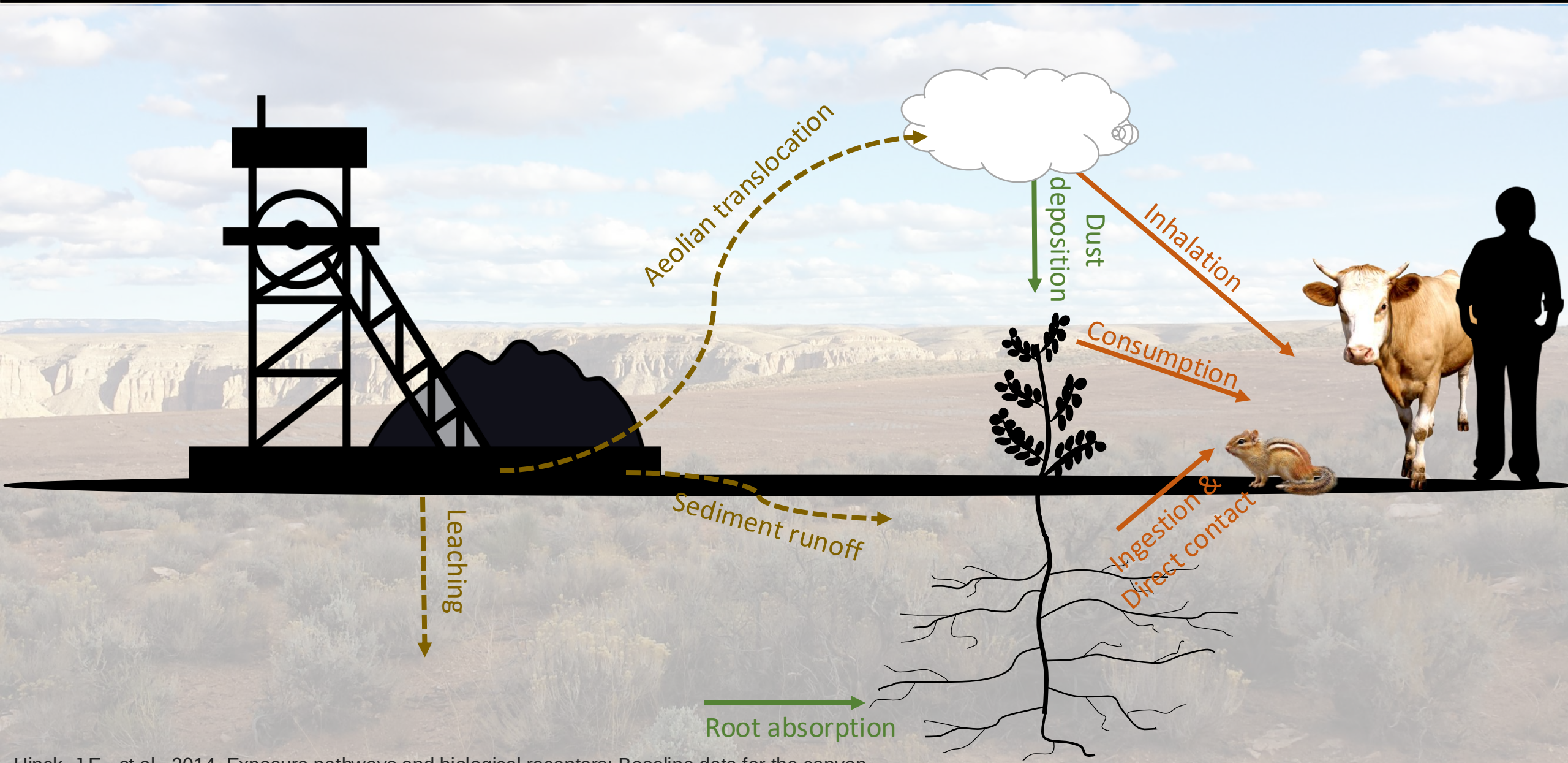

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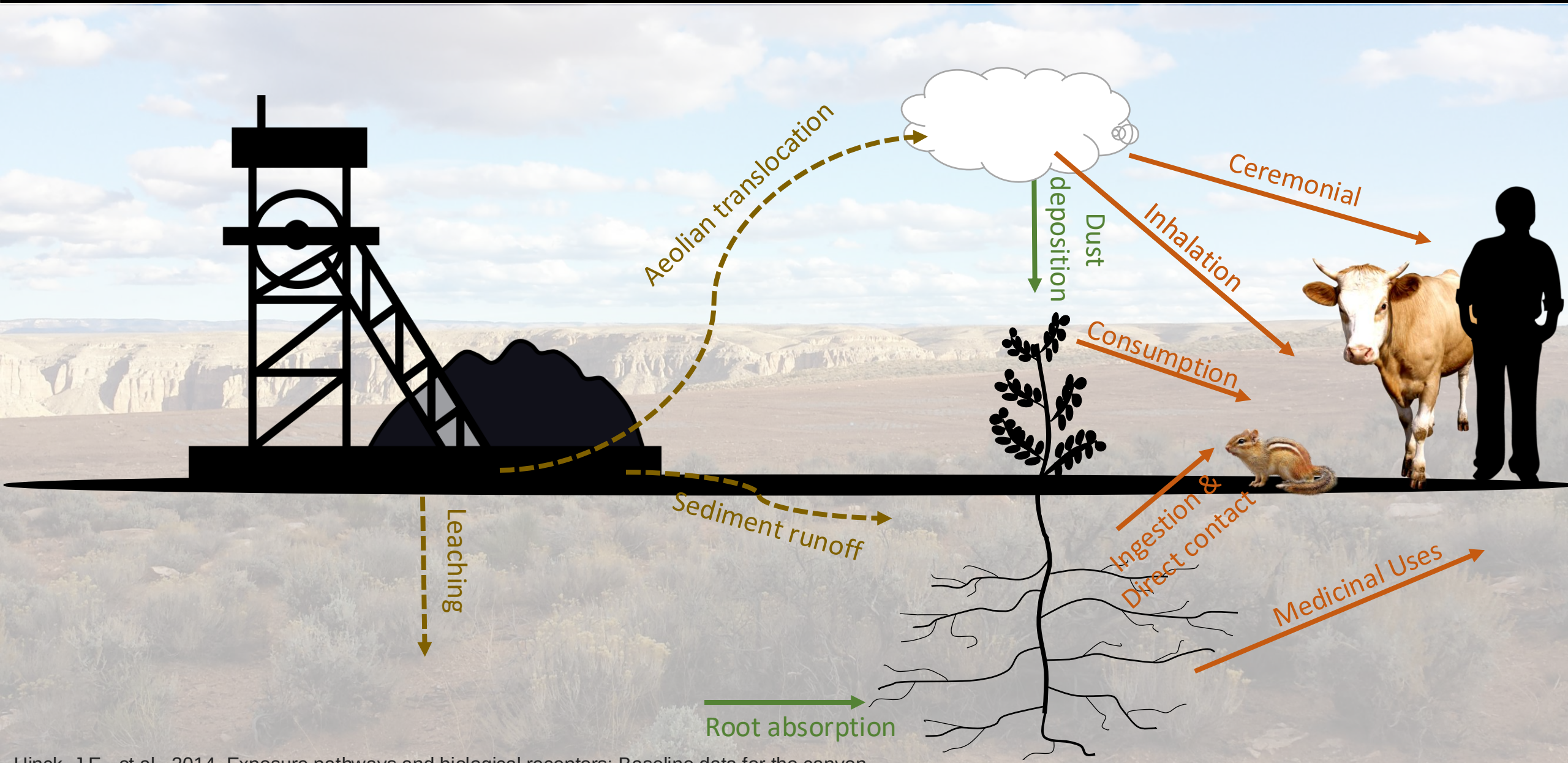
Mining in an environmental context: Indigenous translocation pathways



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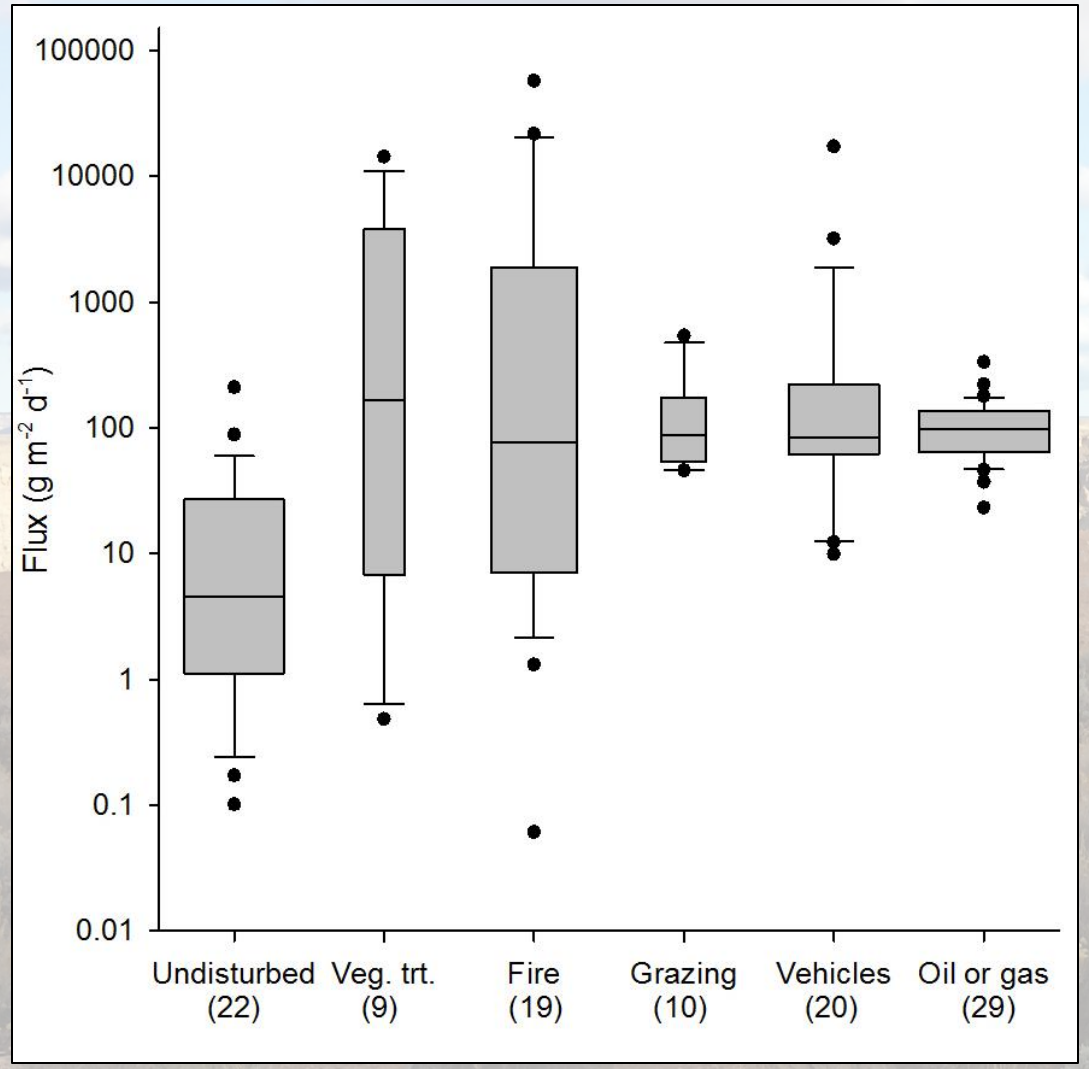
Mining in an environmental context: Aeolian transport



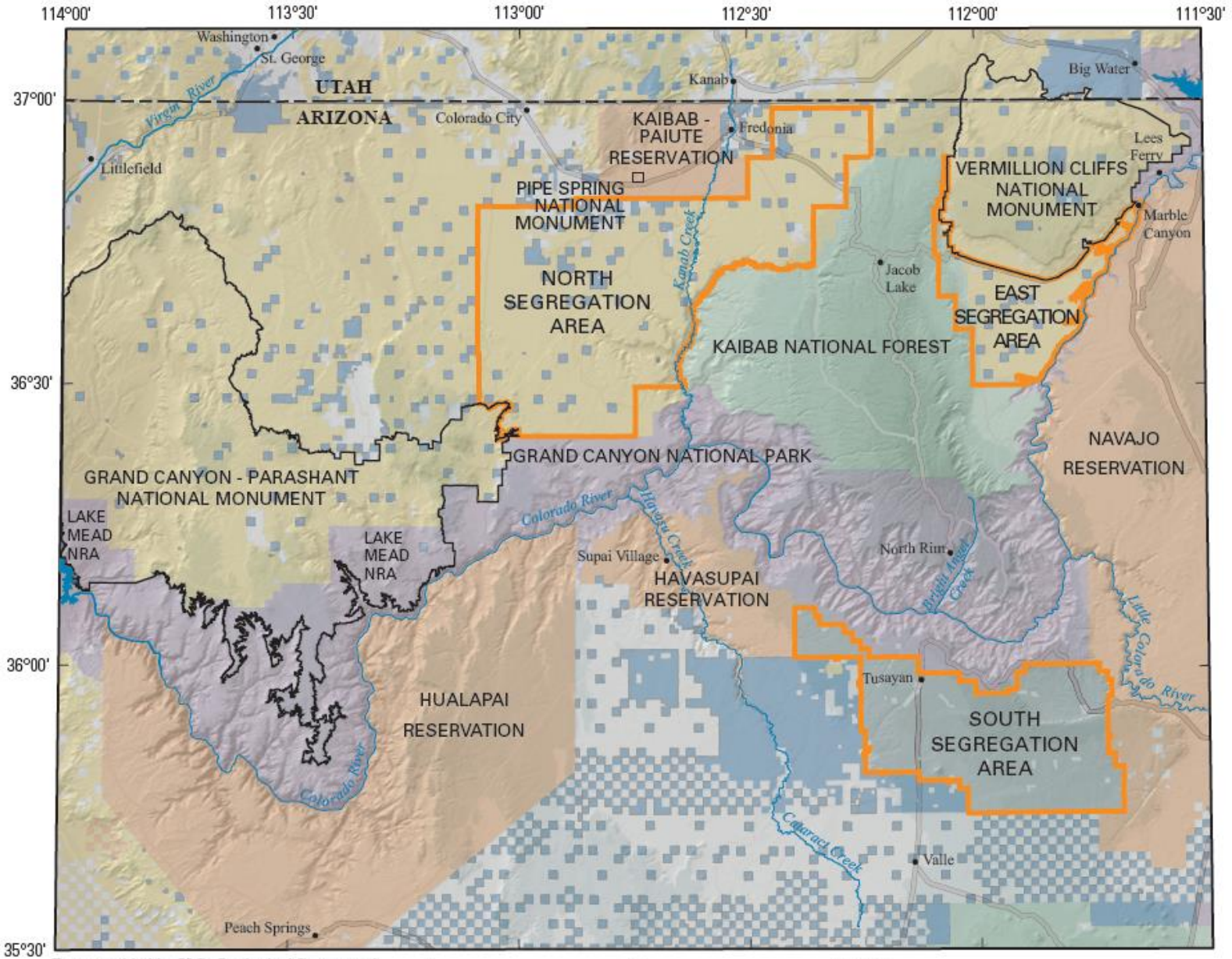
Duniway et al. 2019 Ecosphere

Arizona 1 Mine
June 2014
Dust Transport

Grand Canyon Uranium

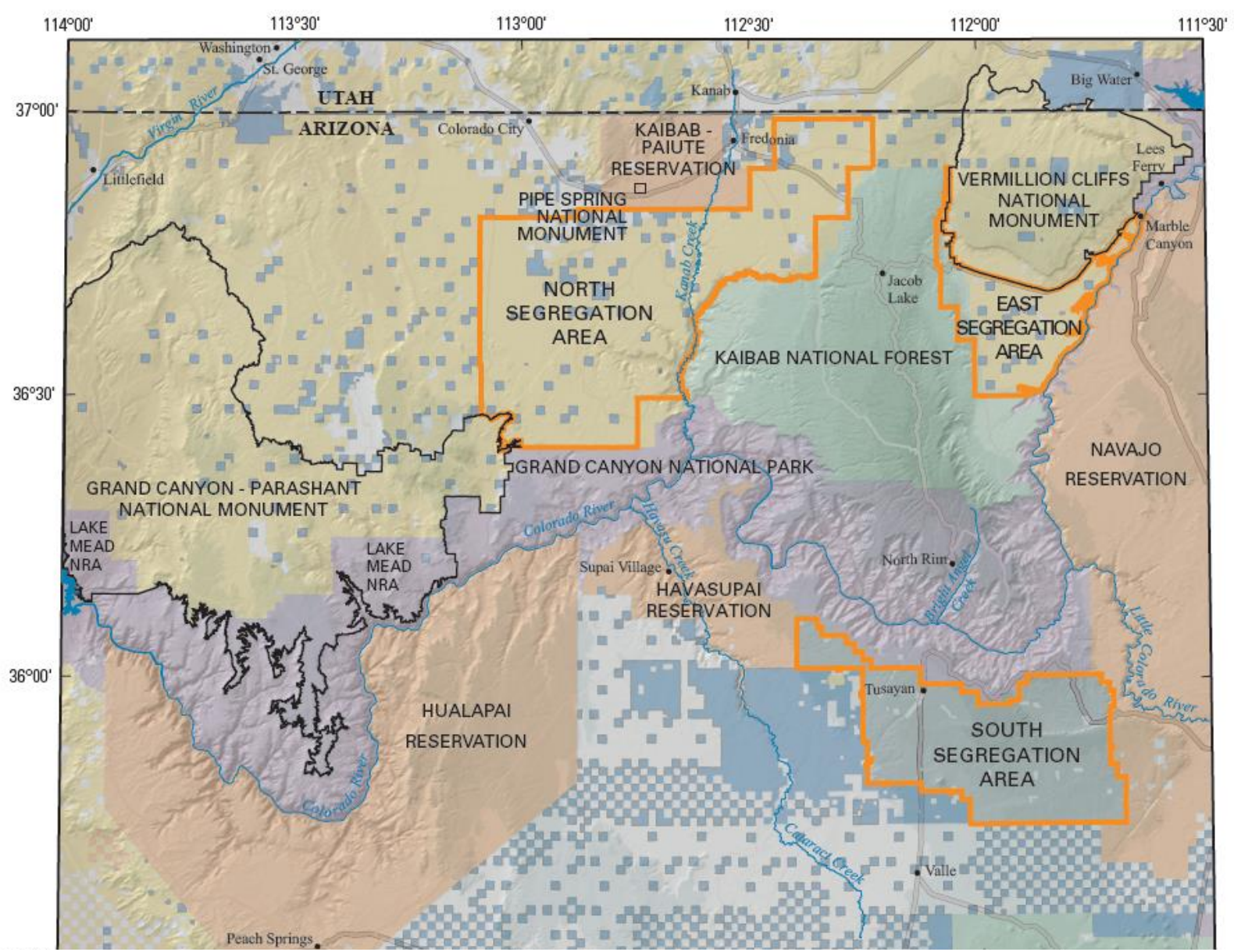
EXPLANATION

- U.S. Bureau of Land Management
- U.S. Forest Service
- Tribal land
- National Park Service
- State land
- Private land
- Segregation area—Boundary
- National Monument—Boundary



SEGREGATION AREAS
(Proposed mineral withdrawal areas)

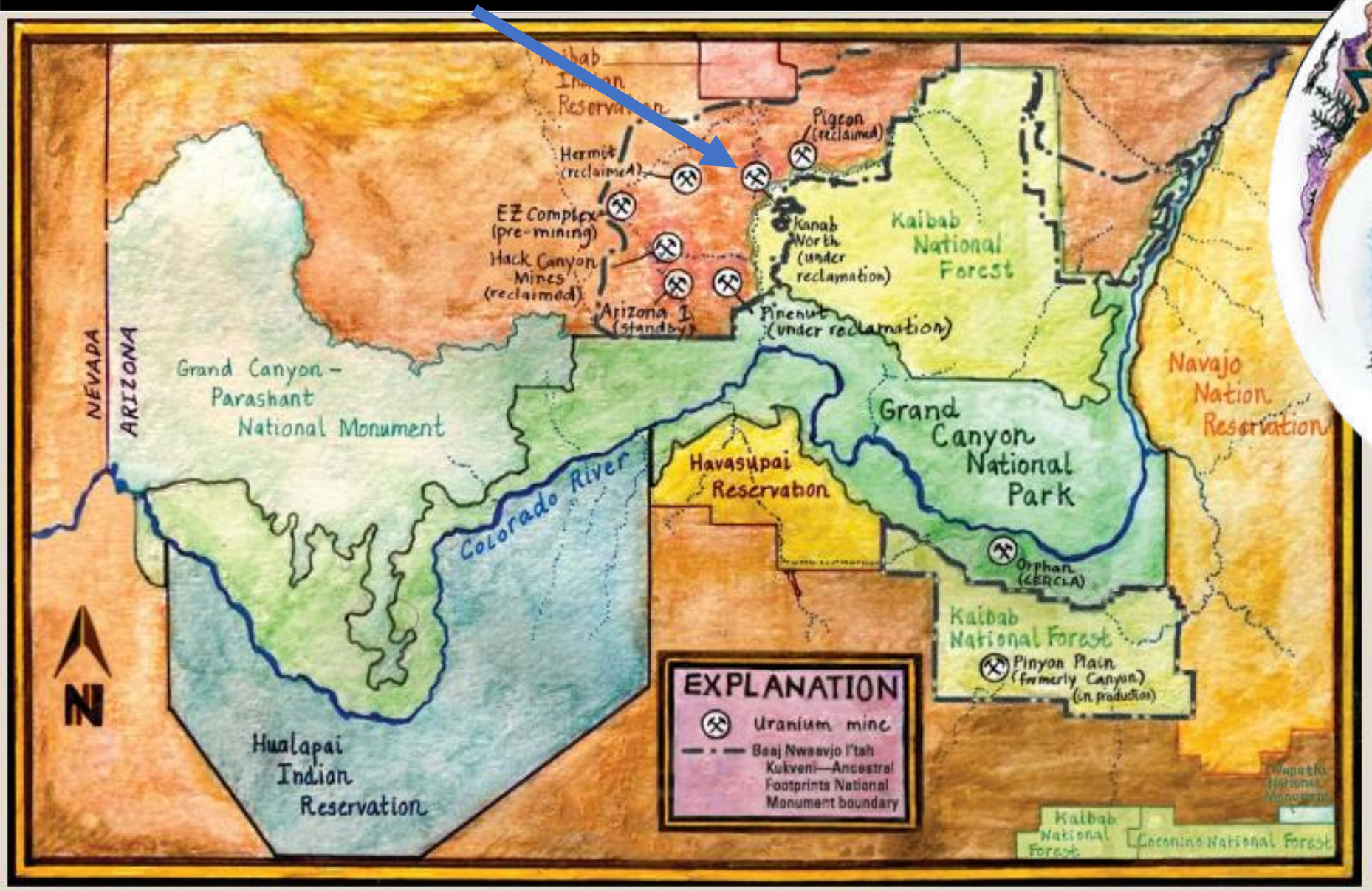
Grand Canyon Uranium



Ancestral Footprints National Monument

Established: Aug 2023

Grand Canyon Uranium Mines



Big Picture: What is the potential for translocation of inorganic constituents from Uranium mines in the Grand Canyon region, through various phases of their operation?

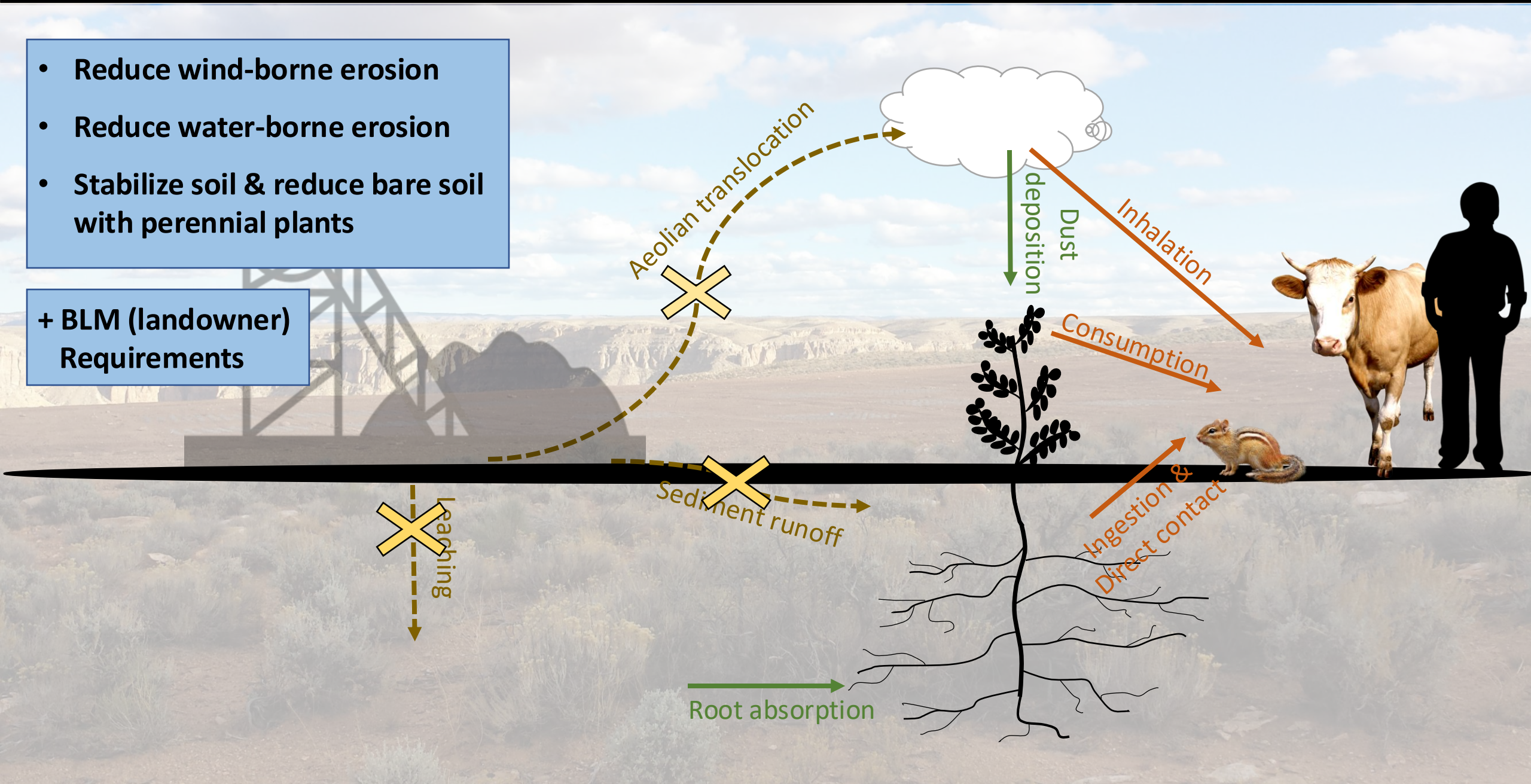
Our Focus: **Reclamation at the Kanab North Mine**

Figure 1. Illustration of the Grand Canyon region in northwestern Arizona showing major land holders and locations of some of the uranium mines in the region. Mine status and Tribal land names current as of March 2024.

Mining in an environmental context: Reclamation Goals

- **Reduce wind-borne erosion**
- **Reduce water-borne erosion**
- **Stabilize soil & reduce bare soil with perennial plants**

+ BLM (landowner) Requirements



Dryland Reclamation: Challenges

Biotic Challenges

- Depleted seed bank
- Depleted soil organisms
- Intense competition

Physical Challenges

- Soil movement and loss
- Nutrient-depleted topsoil
- Altered hydrology
- Lack of shelter



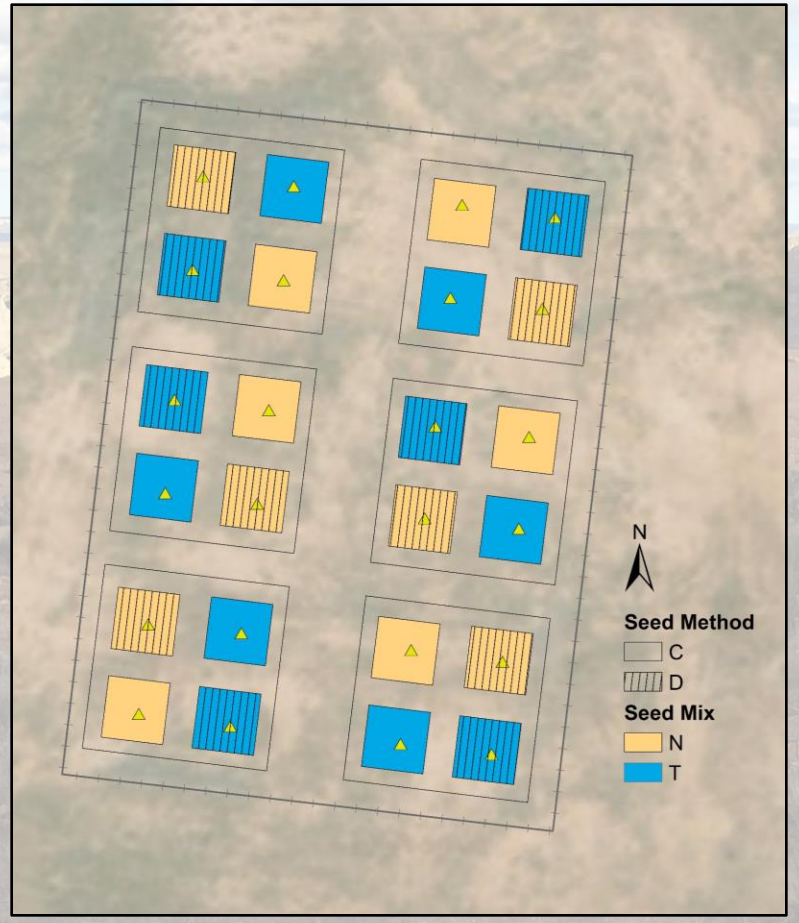

Don Pillmore

Kanab North

Experimental Design: Large-scale

1991: Mining completed -> **2017:** Reclamation study initiated

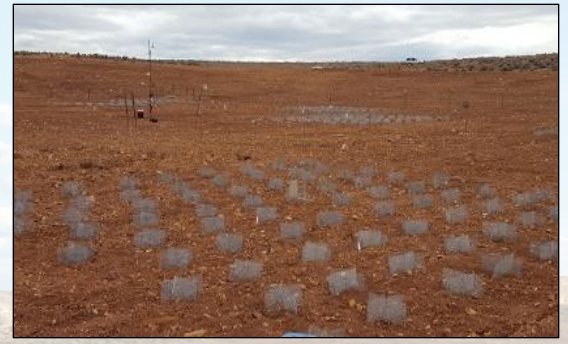
Randomized Complete Block design:
Seed Method * Seed Mix



Seeding Method

Traditional : Drill Seeding

Novel: ConMods



X

Seed Mix (comprised of six species)

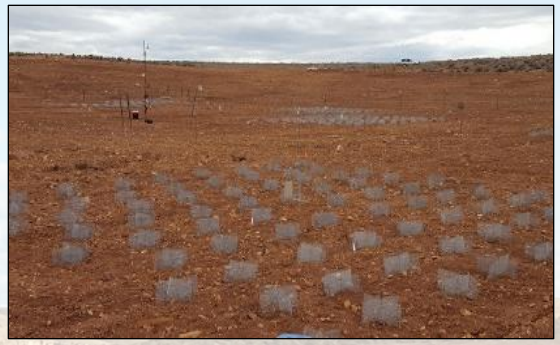
Traditional : with non-natives

Crested wheatgrass ~ Forage Kochia ~ Burnett
Ricegrass ~ Galleta Grass ~ Sand Dropseed

Novel: all native species

Thickspike wheatgrass ~ Fourwing saltbush ~ Globemallow
Ricegrass ~ Galleta Grass ~ Sand Dropseed

Novel: ConMods



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Experimental Design: Large-scale

Experimental Design

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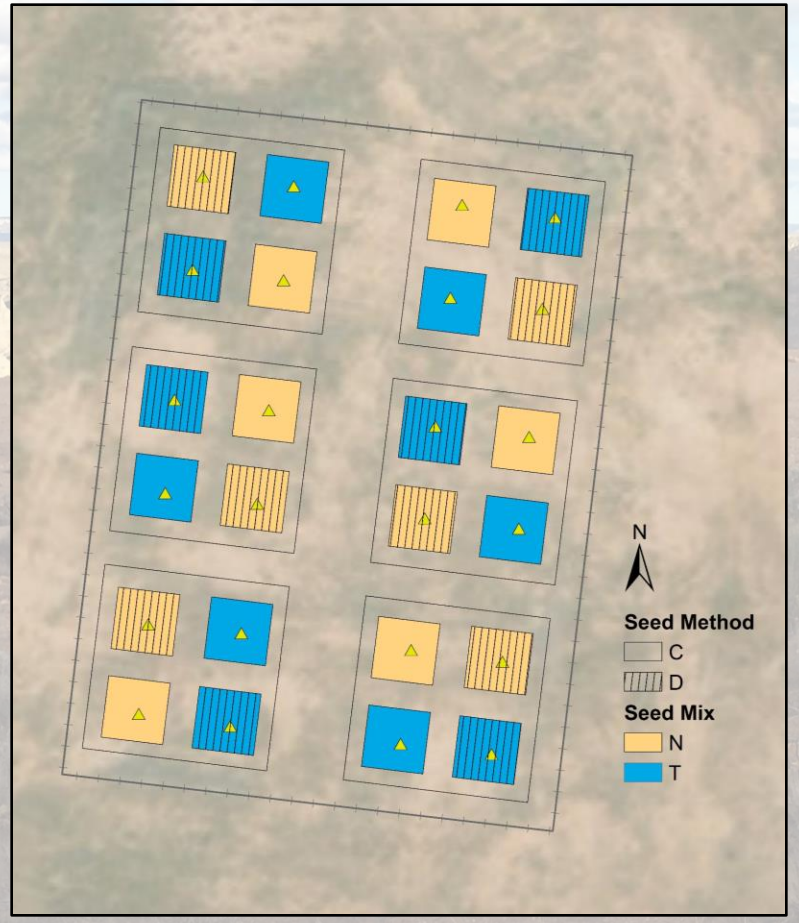

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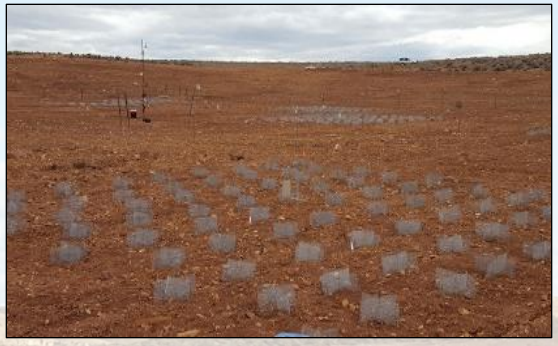

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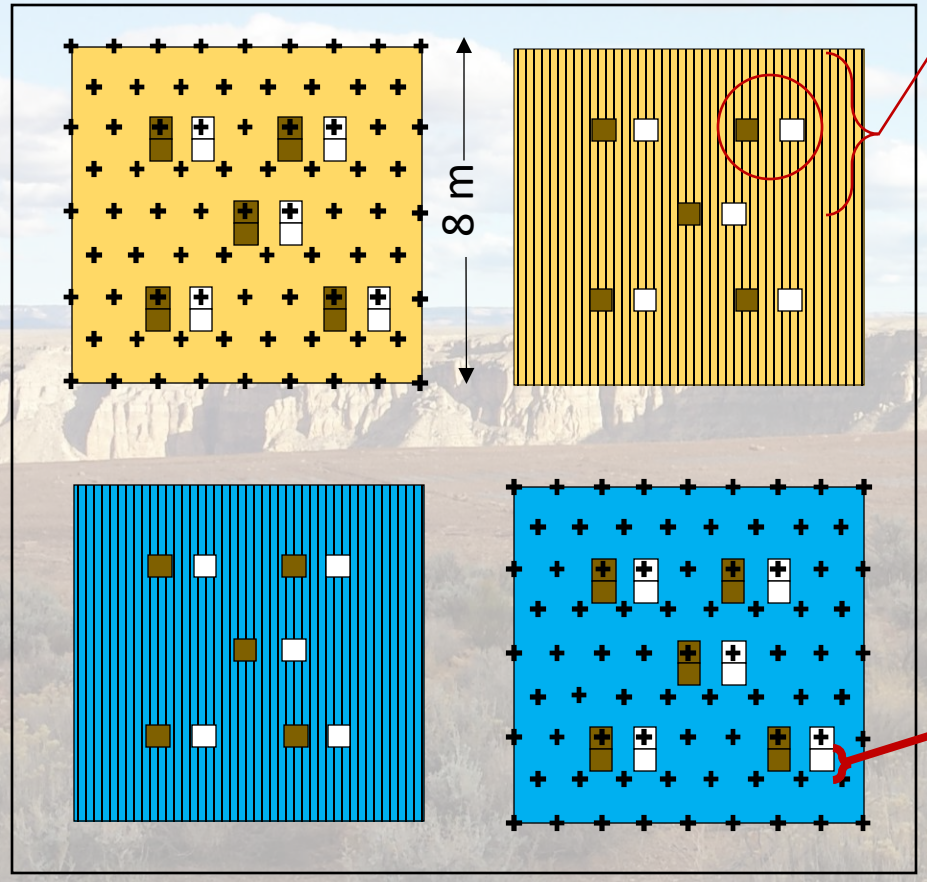
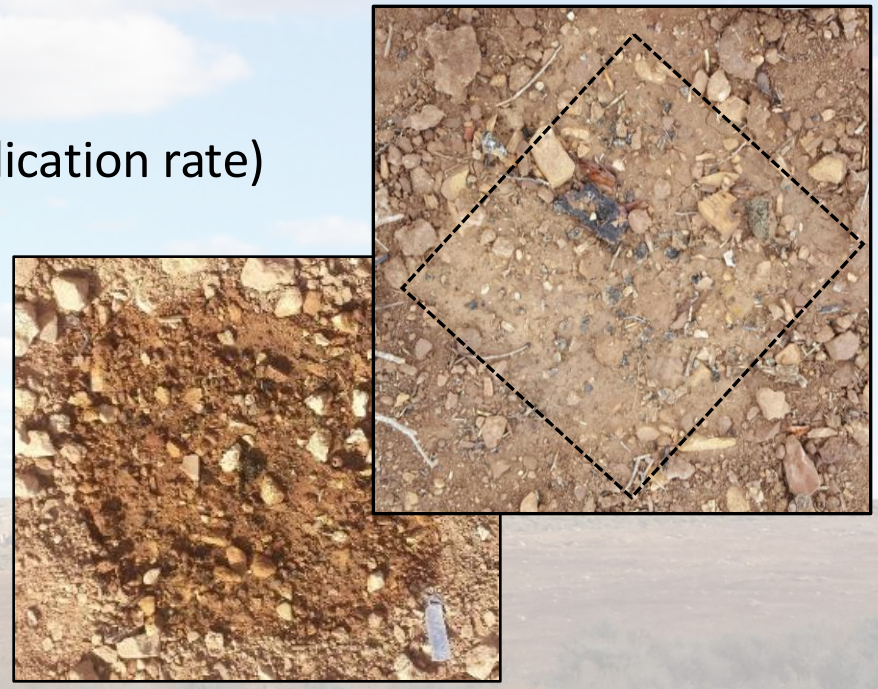
Experimental Design: Small-scale

Experimental Design



Biocrust Subplots

- Inoculated (30% application rate)
- Control (no biocrust)



ConMod Interspaces

Area between ConMod

Questions: Large-scale vs Small-scale

Large-scale

- ✓ *Across 64 m^2 plots*
- ✓ *ConMods vs Drillseed methods*
- ✓ *Native vs Traditional seedmix*

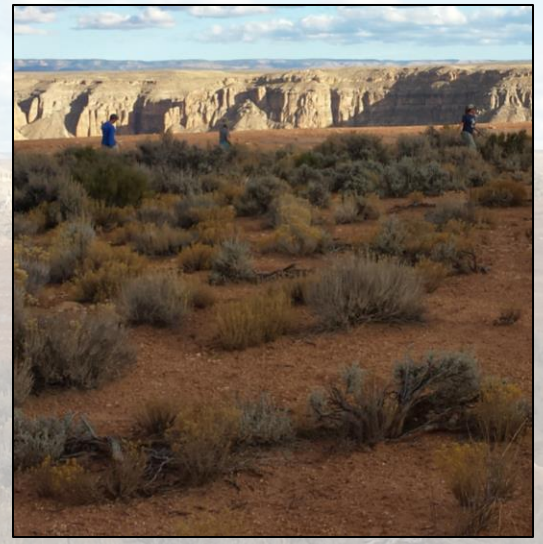
Small-scale

- ✓ *Nested withing large-scale*
- ✓ *0.1 m^2 quadrats*
- ✓ *Biocrust inoculation*
- ✓ *ConMod Interspace*

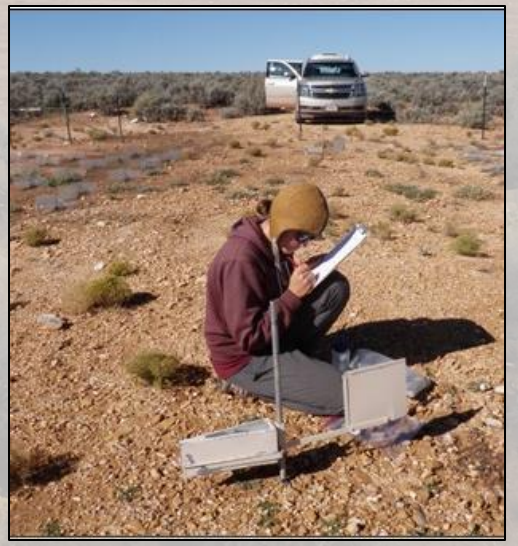
First five years of reclamation

Monitoring: Large-Scale

Plant & Surface Cover
Line-Point Intercept

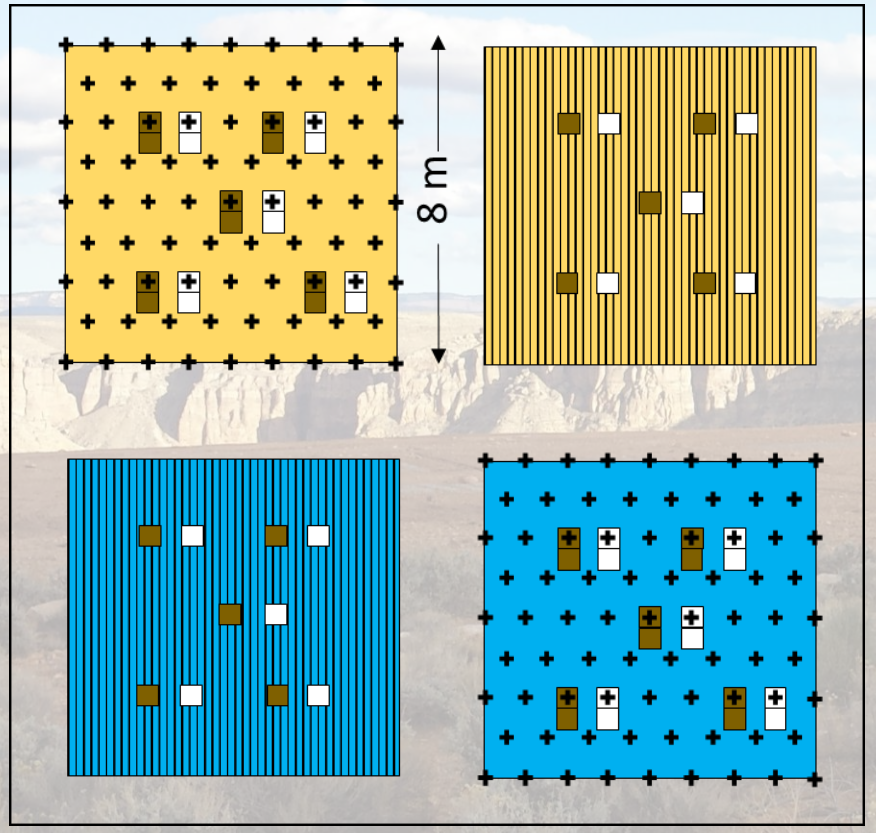


Soil Exposure
Canopy gap

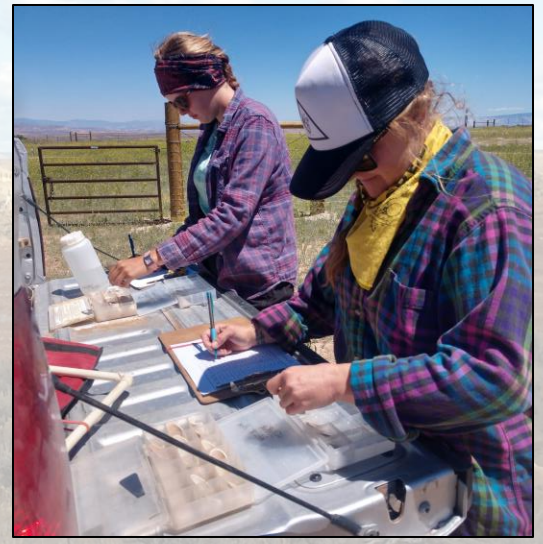


Aeolian Sediment Flux
BSNE Dust Traps

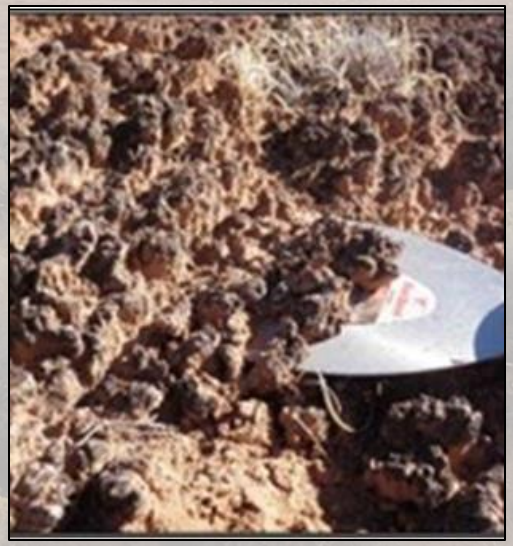
Monitoring: Small-scale



Plant & Surface Cover
20-point frames

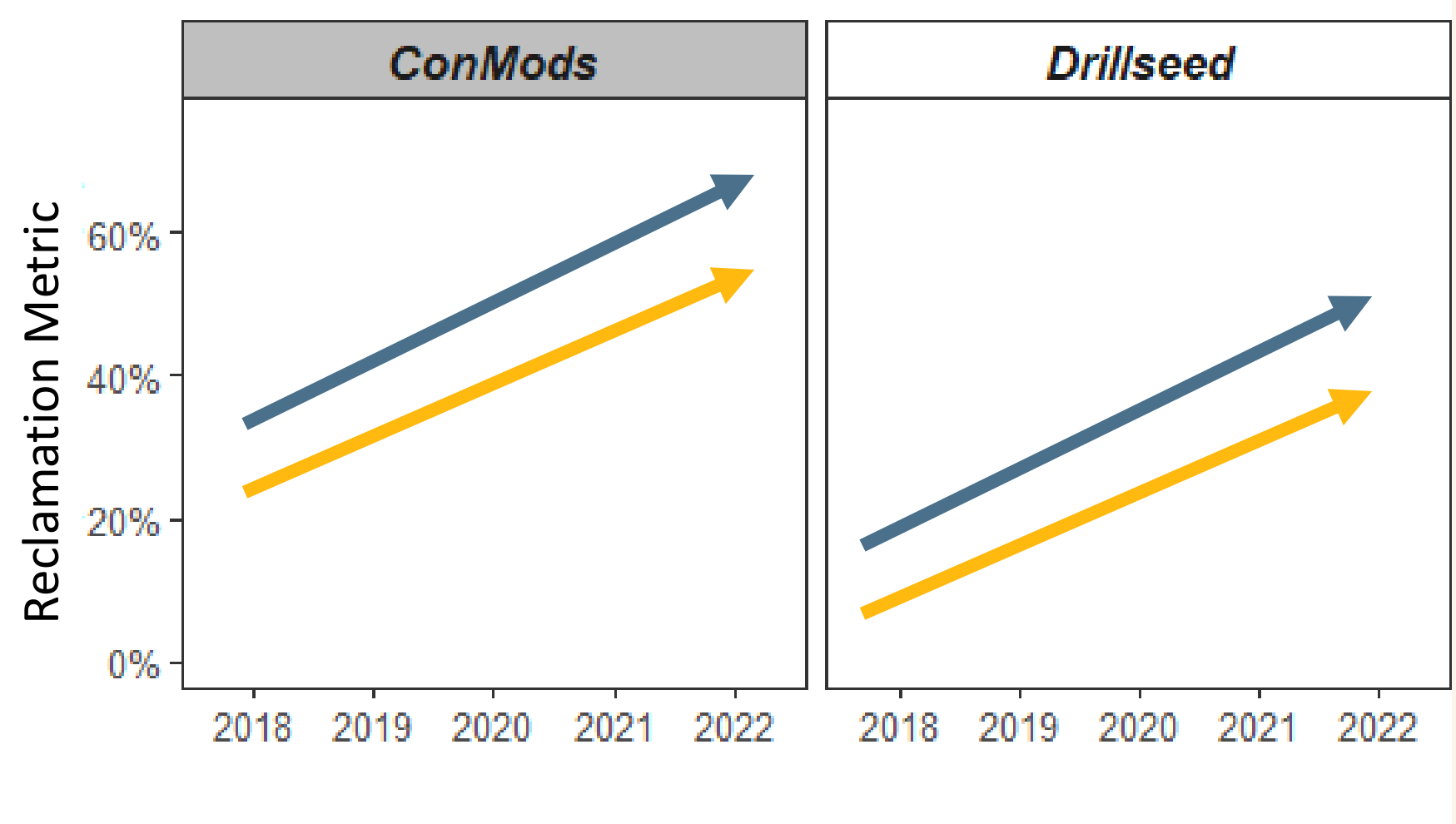


Water Erosion Potential
Soil Aggregate Stability



Biocrust
Level of development

Results: Large-scale figures



Method

Novel ConMod

Traditional Drillseed

Seed Mix

Novel Native-only Mix

Traditional Non-native Mix

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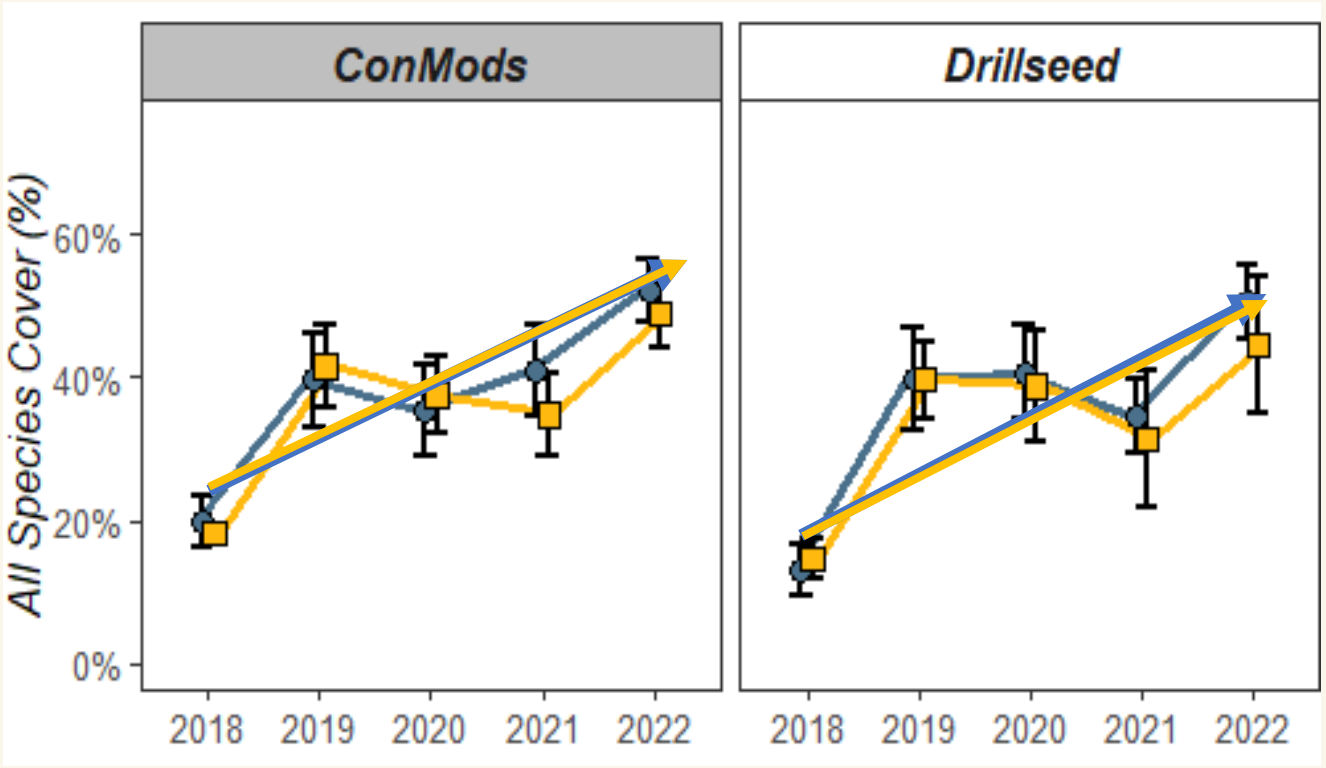
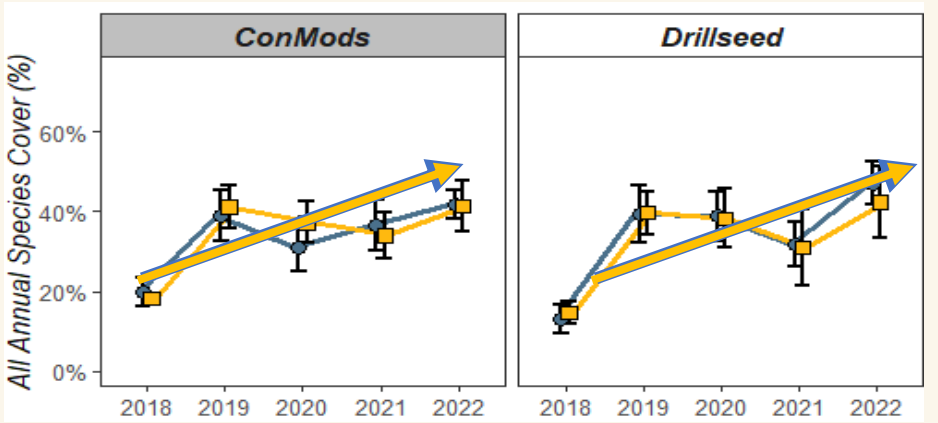
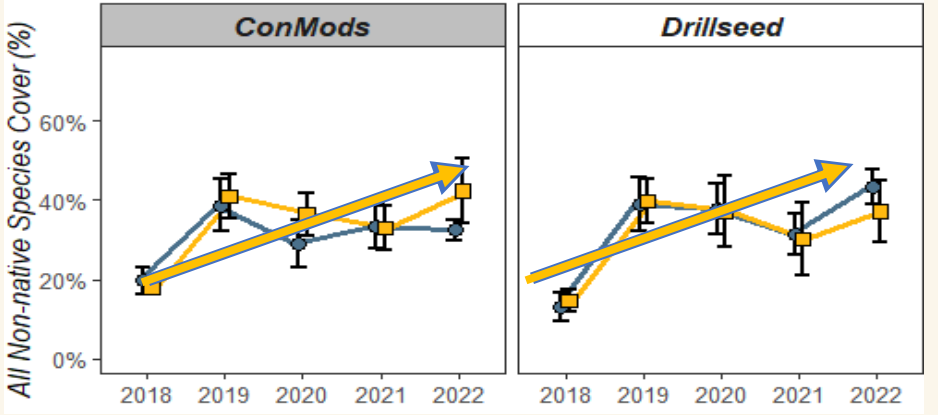
Plant Cover: Large-scale

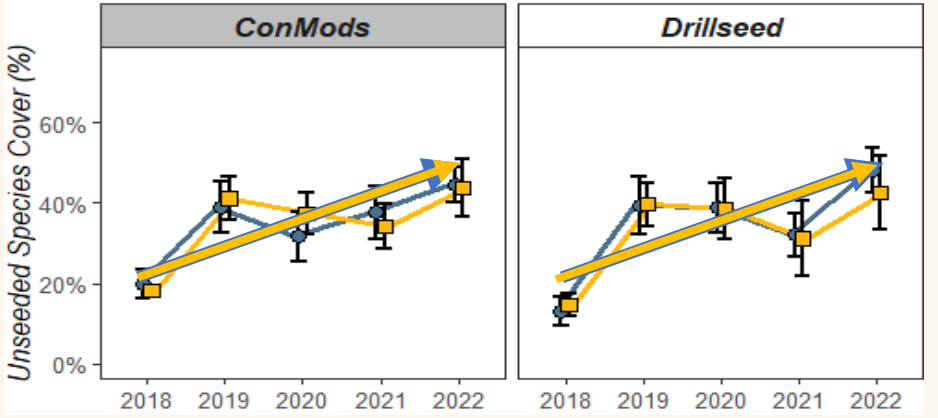


Total Cover

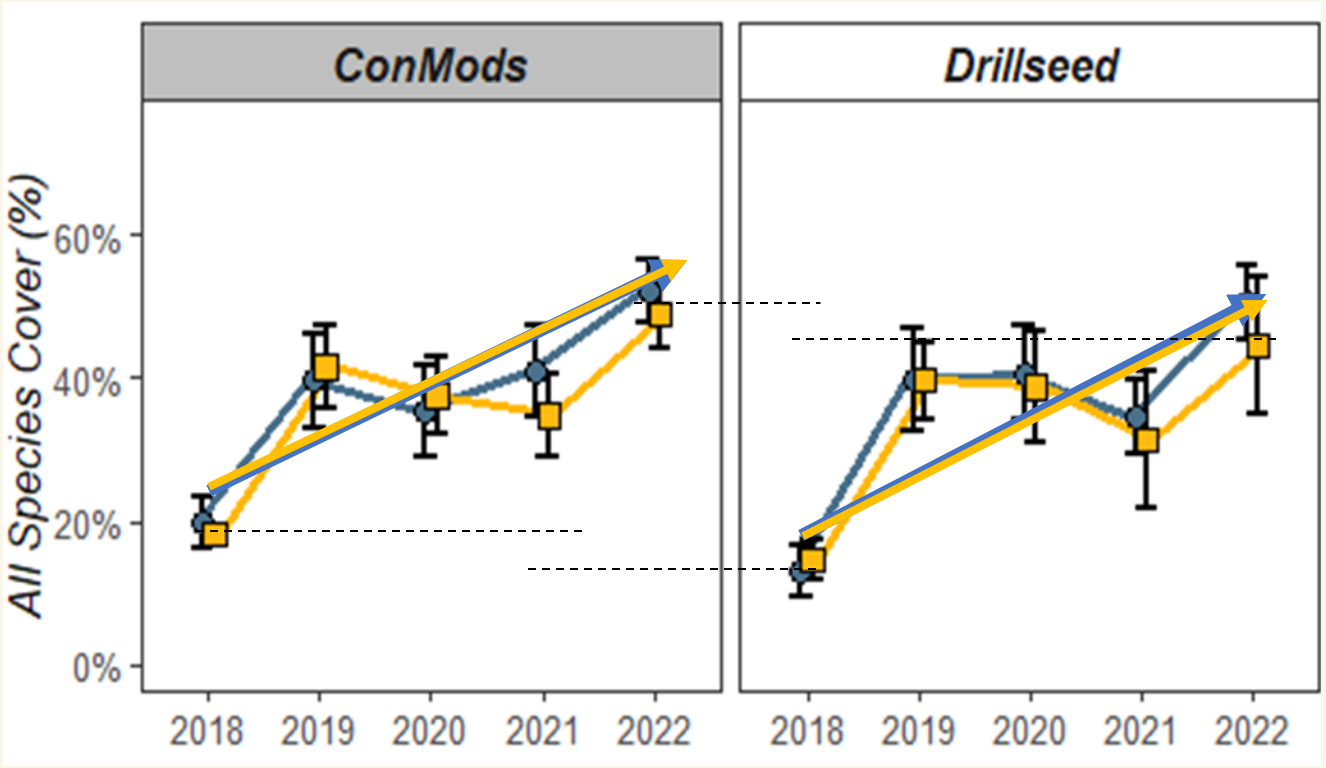
- Increases with time
- Mostly annual, non-native, unseeded species

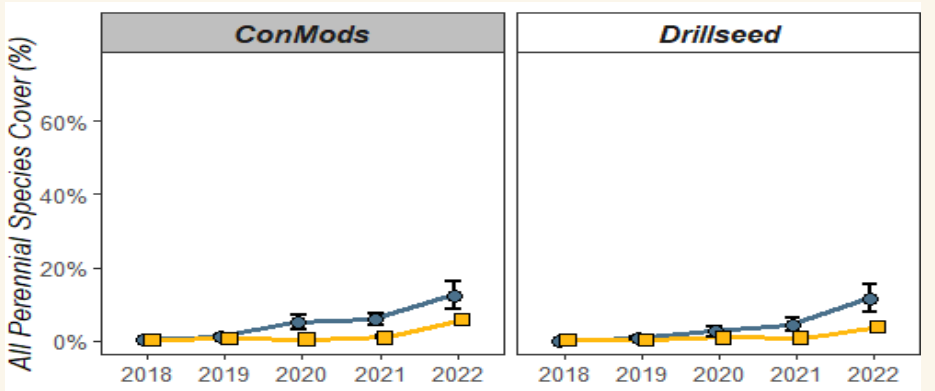


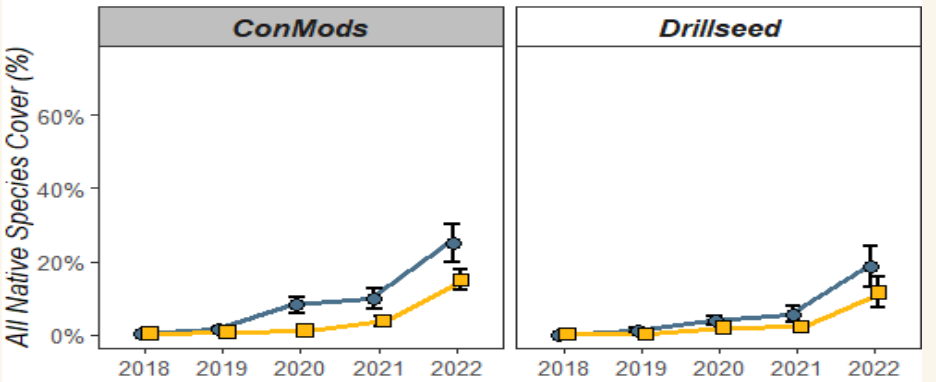


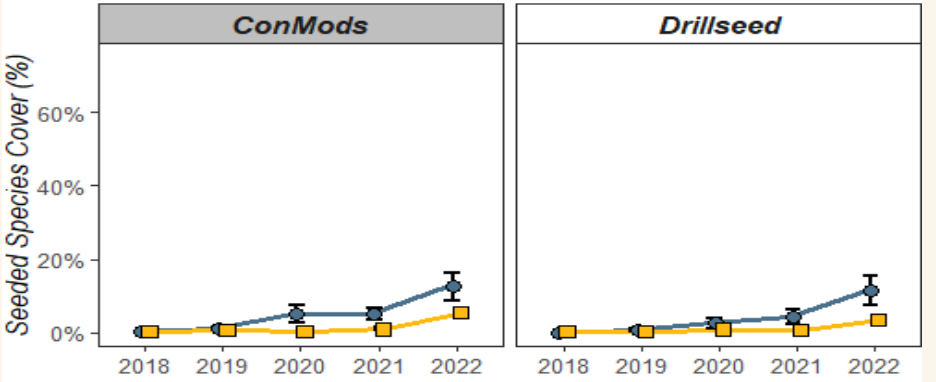


Plant Cover: Large-scale





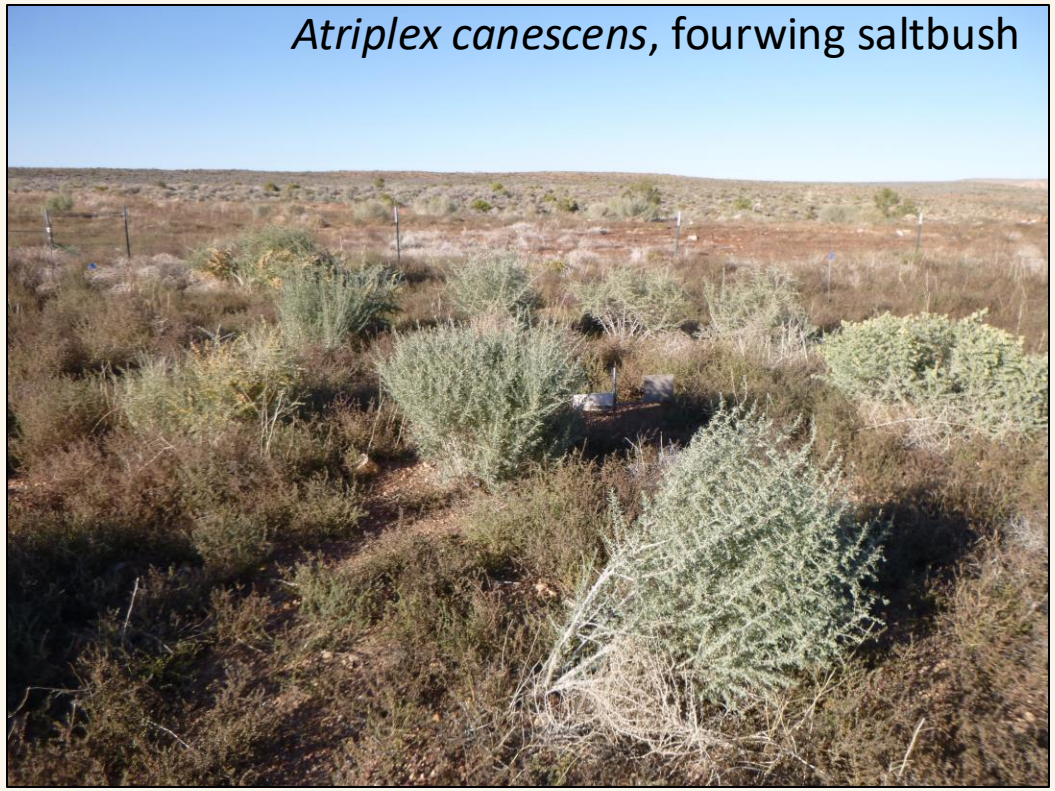


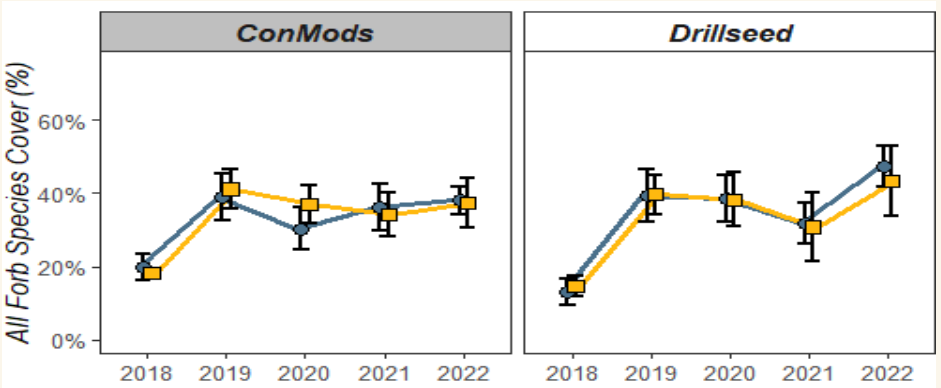


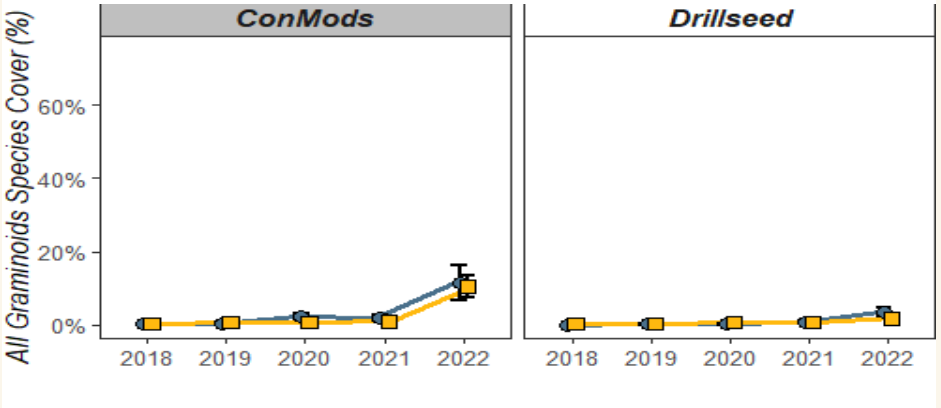
Plant Cover

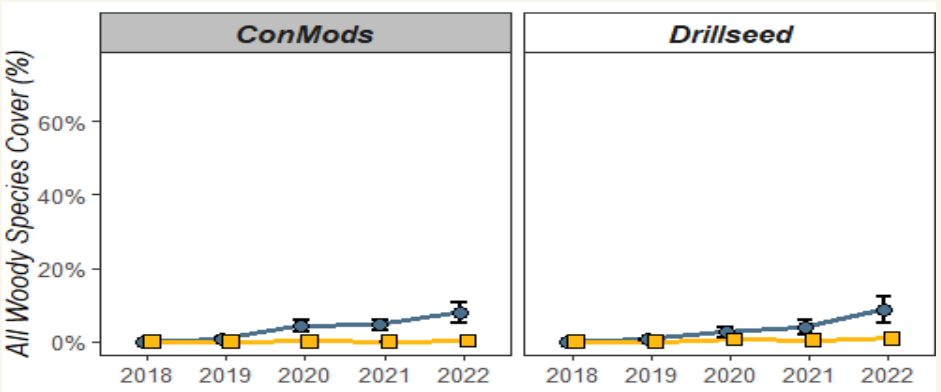
- ConMod higher total coverage than drillseed
  - Driven by perennial, native, seeded species
- Novel native seed mix increased perennial, native, & seeded species

Plant Cover: Large-scale





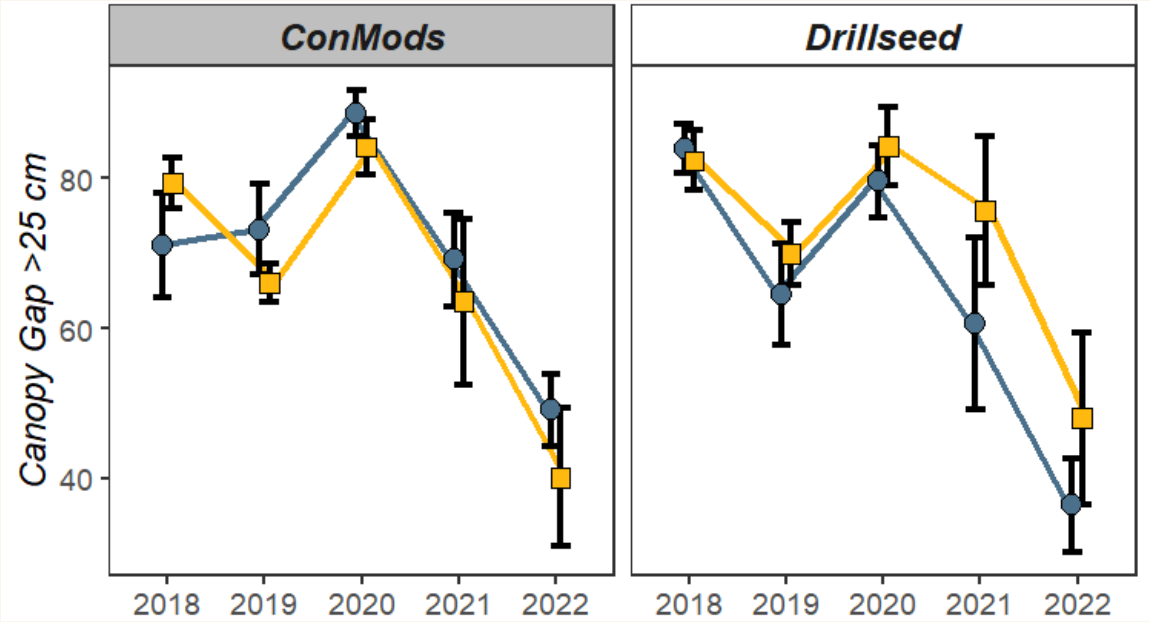


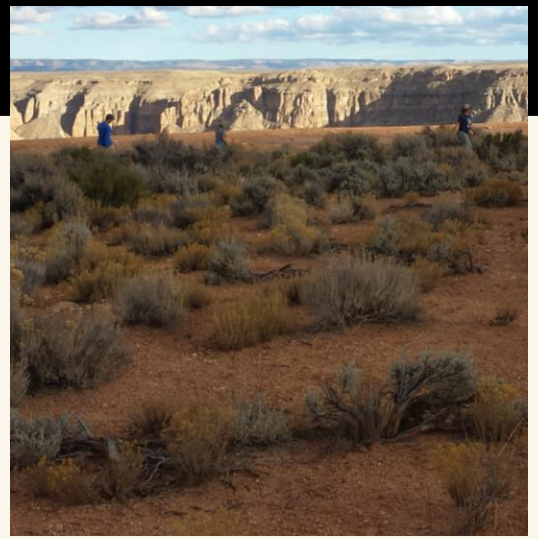


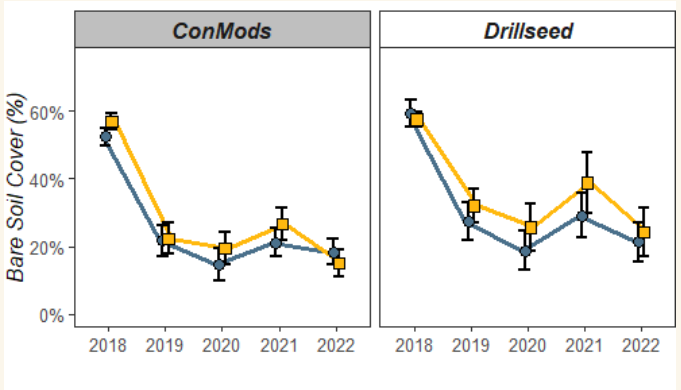
Plant Cover

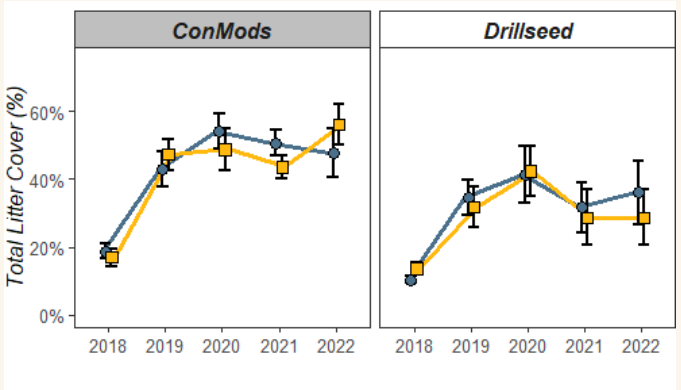
- ConMod increased graminoid species
- Native seed mix increased woody species
  - Driven by fourwing saltbush

Exposed Soil: Large-scale









Canopy gap

- Traditional treatments higher gap
- Decreases with time

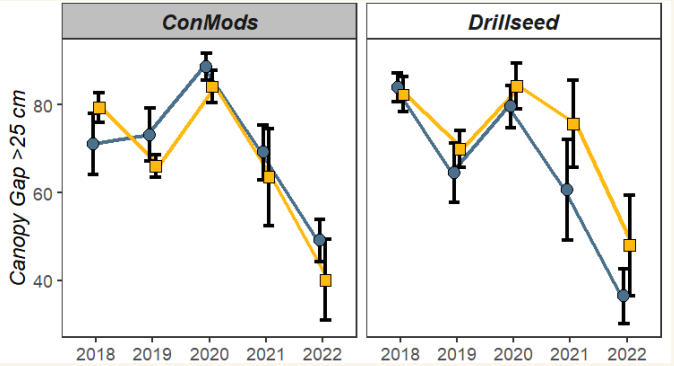
Bare soil

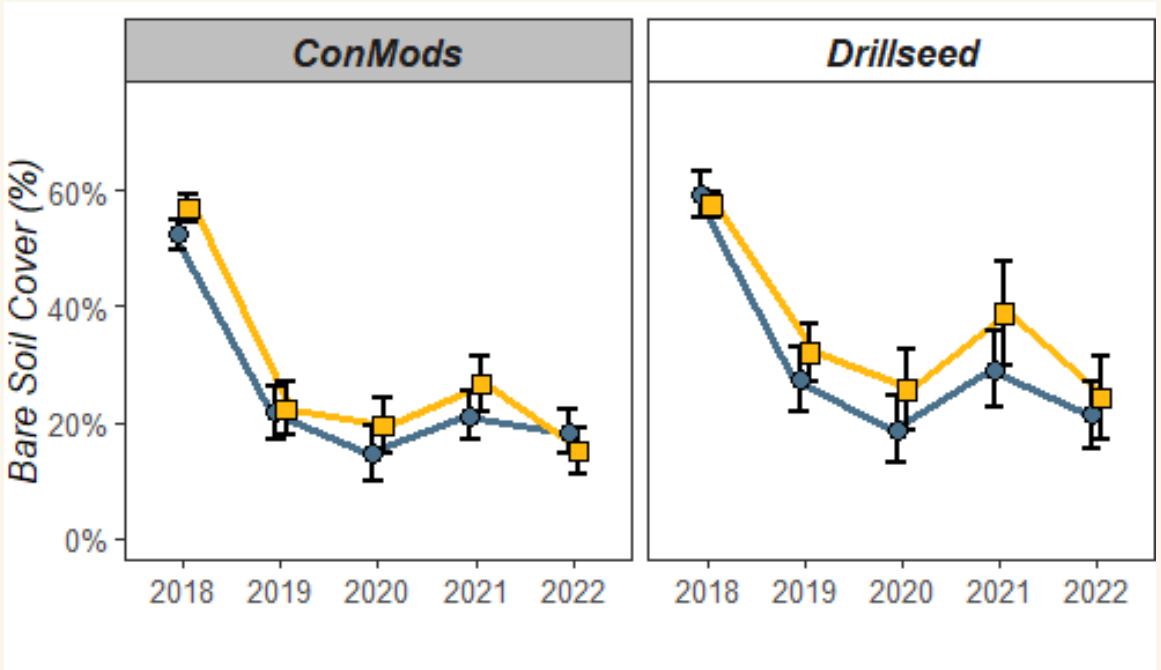
- ConMods have lower % bare soil
- Decreases with time

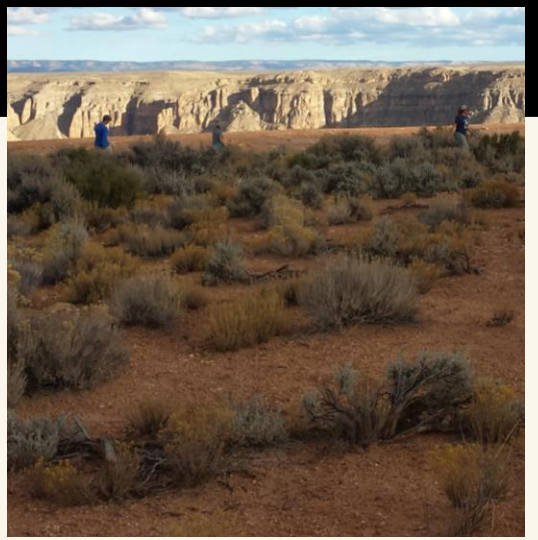
Total Litter

- ConMods have higher % litter cover
- Increases with time

Exposed Soil: Large-scale







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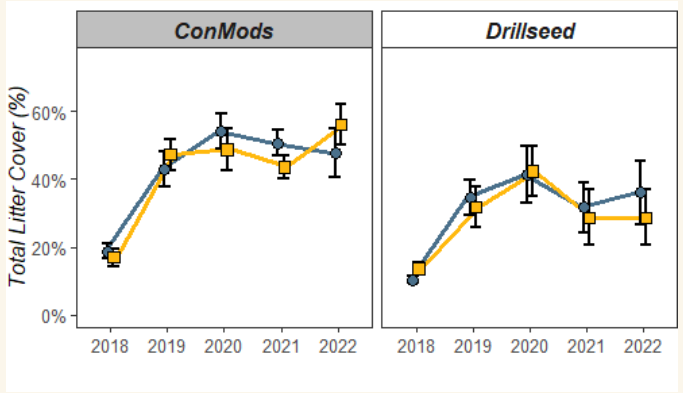

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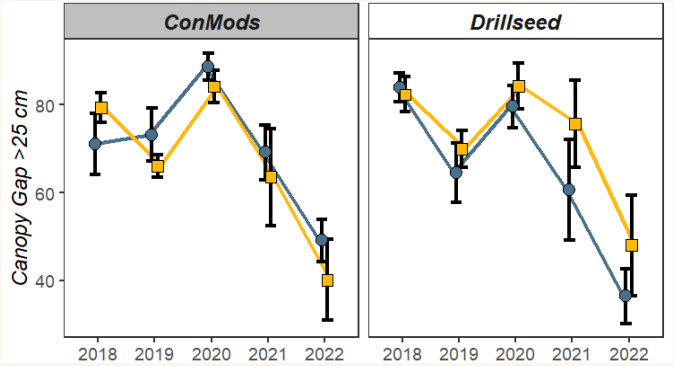

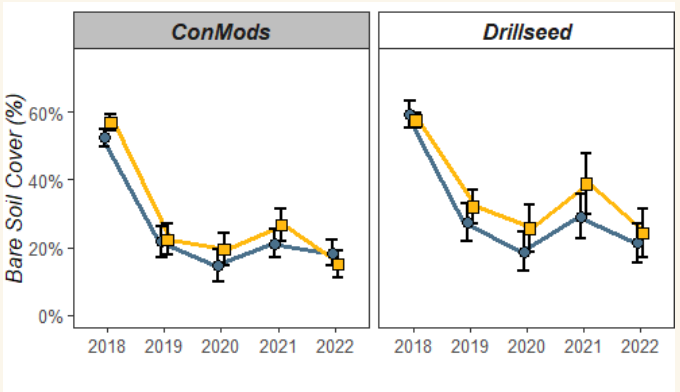

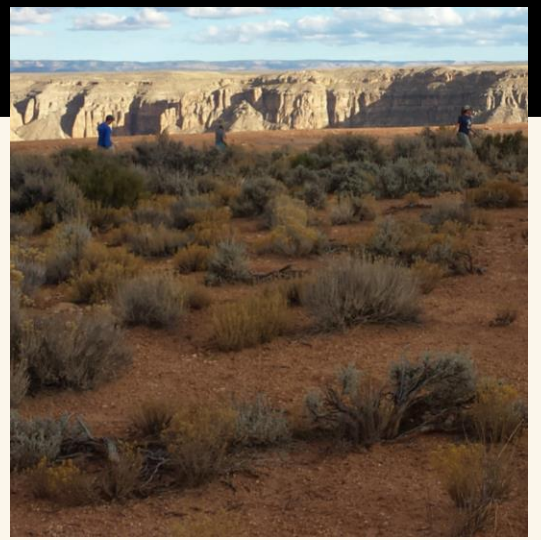

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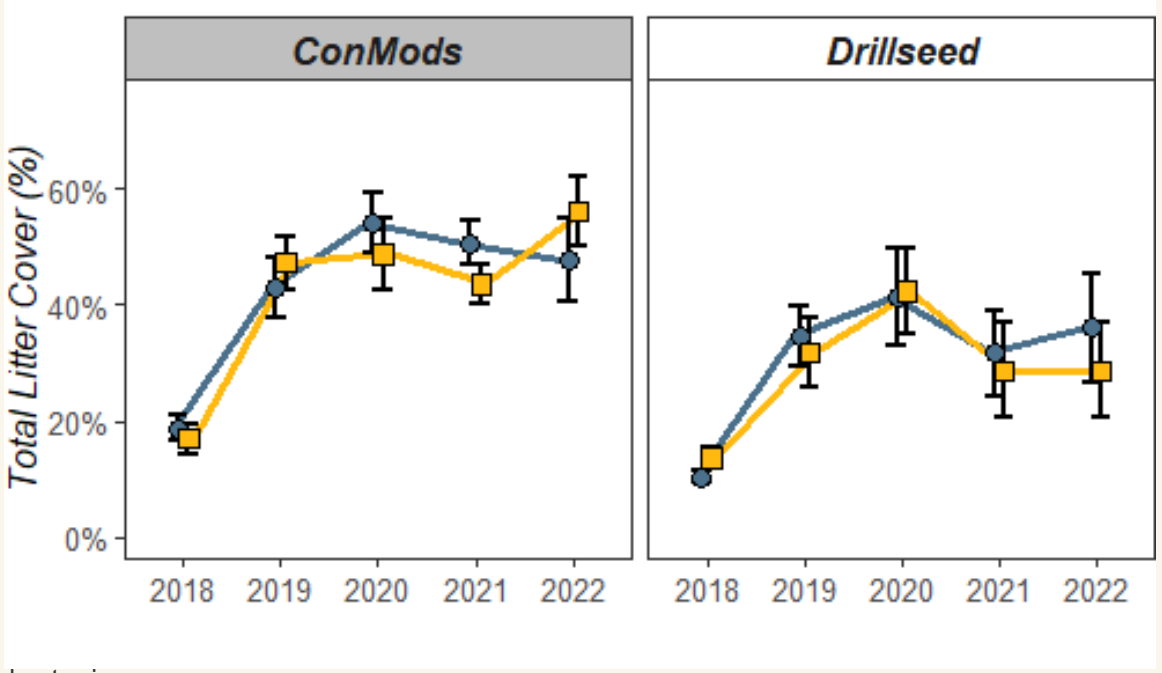
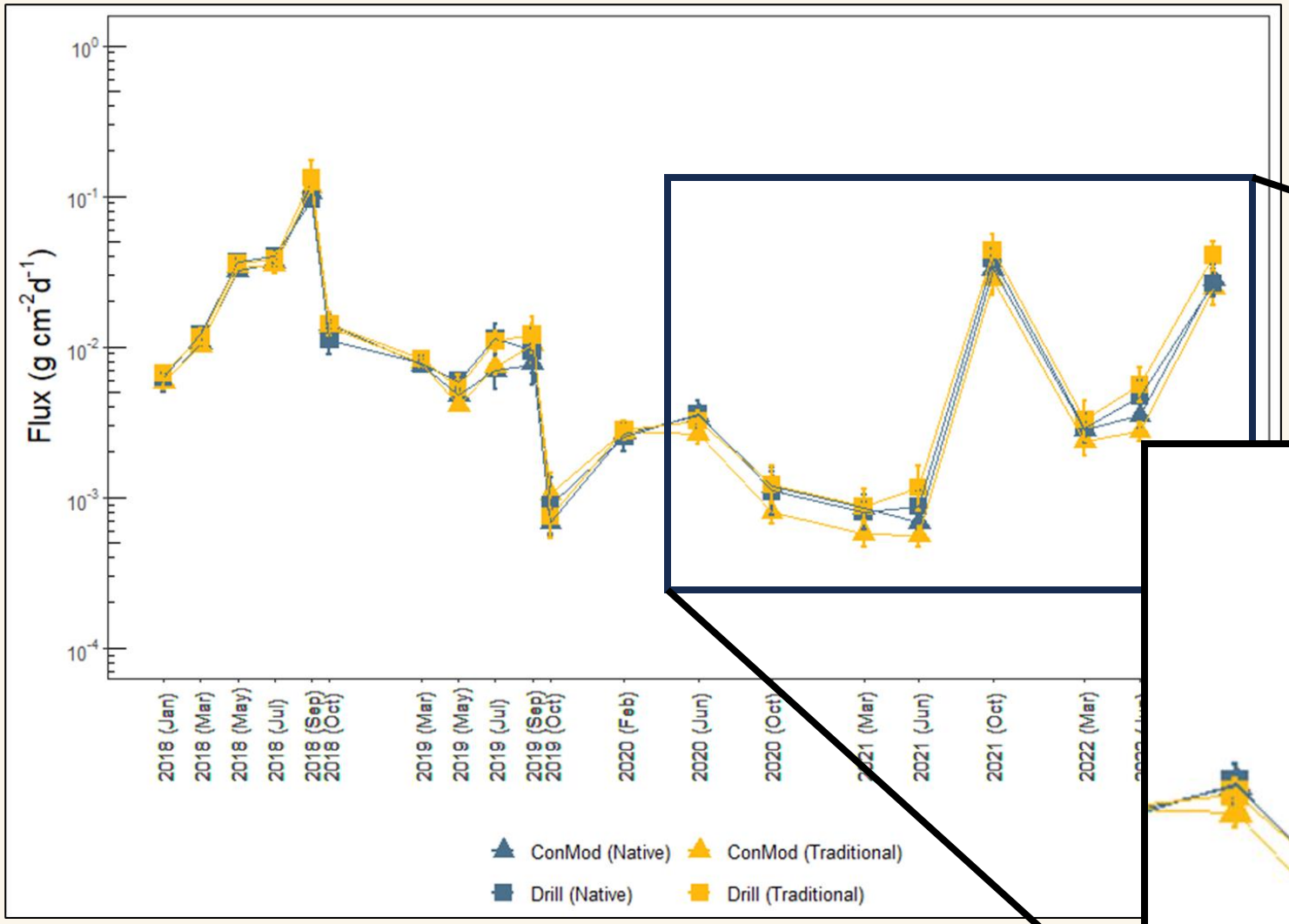
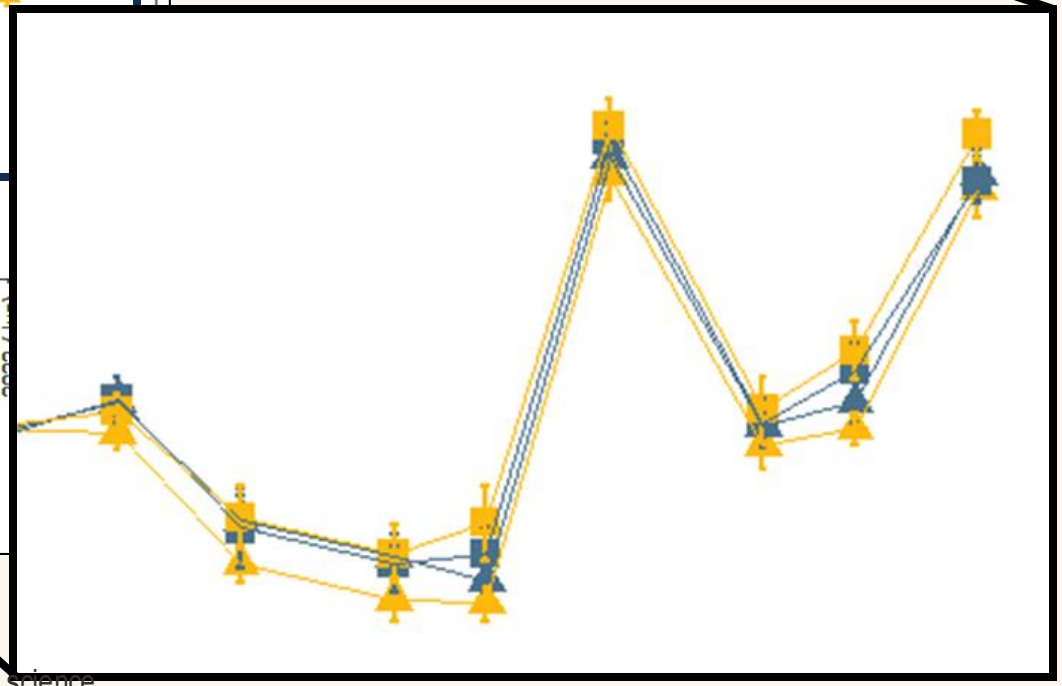


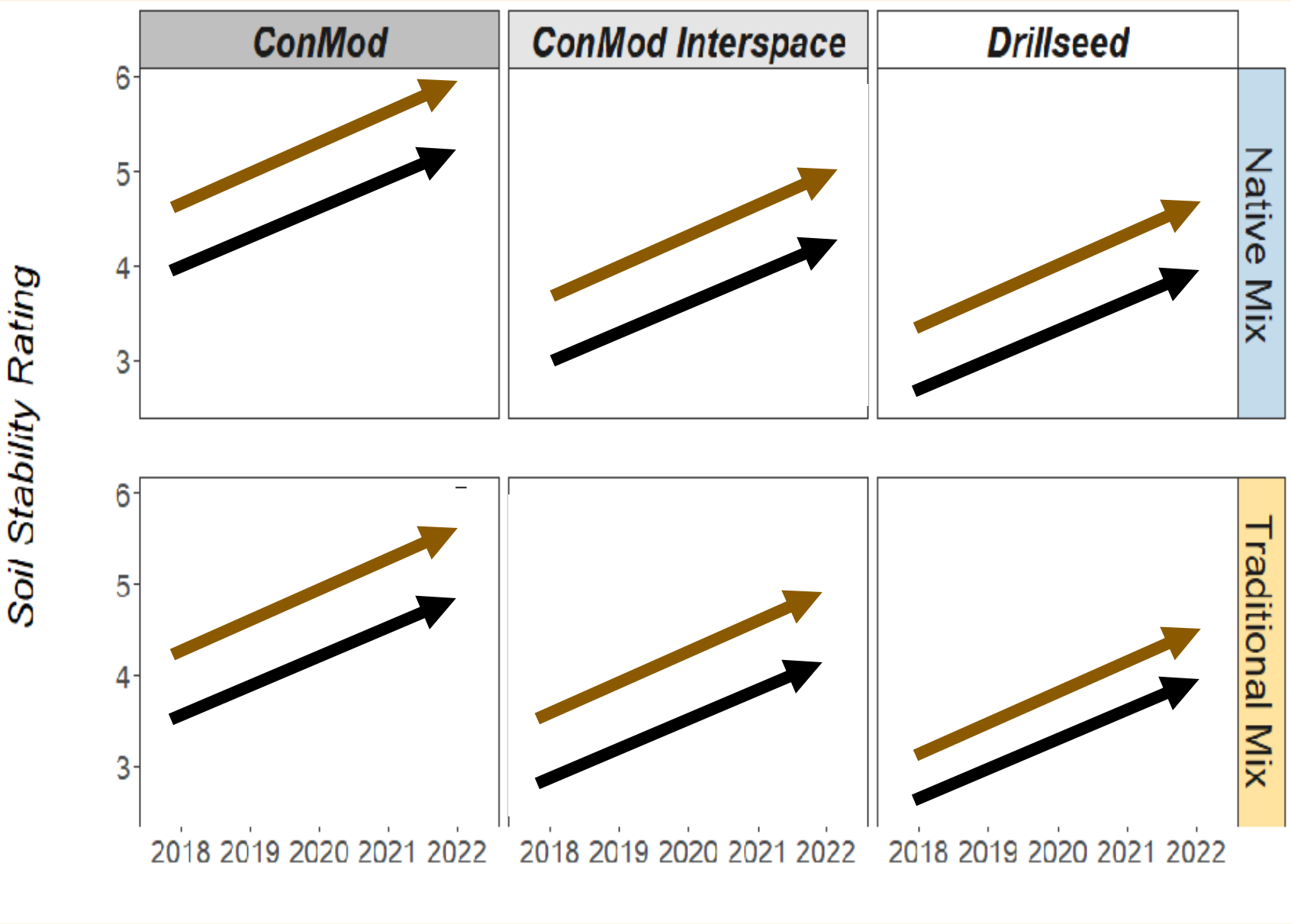
Dust: Large-scale





No effects of treatment

Results: Small-scale figures



Method

Novel ConMod

ConMod Interspace

Traditional Drillseed

Seed Mix

Novel Native-only Mix

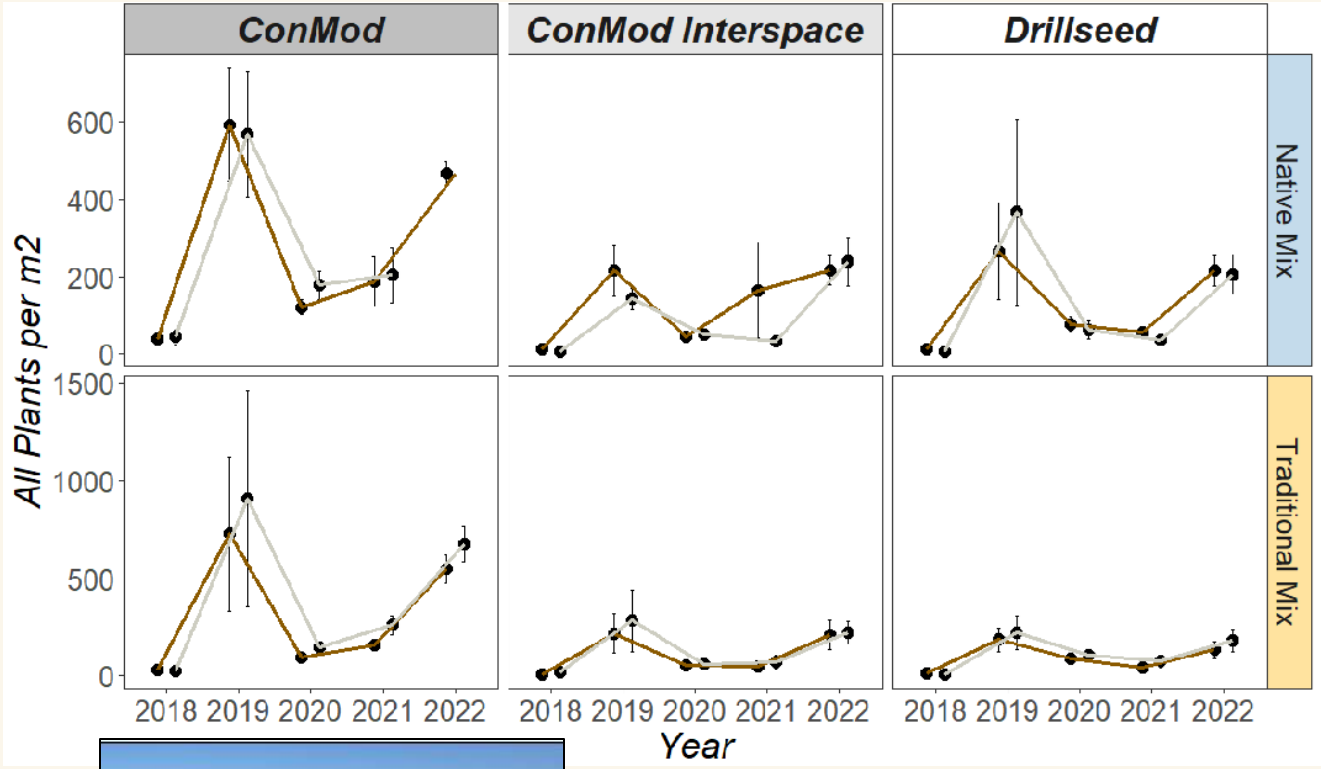
Traditional Non-native Mix

Biocrust Inoculation

Inoculated

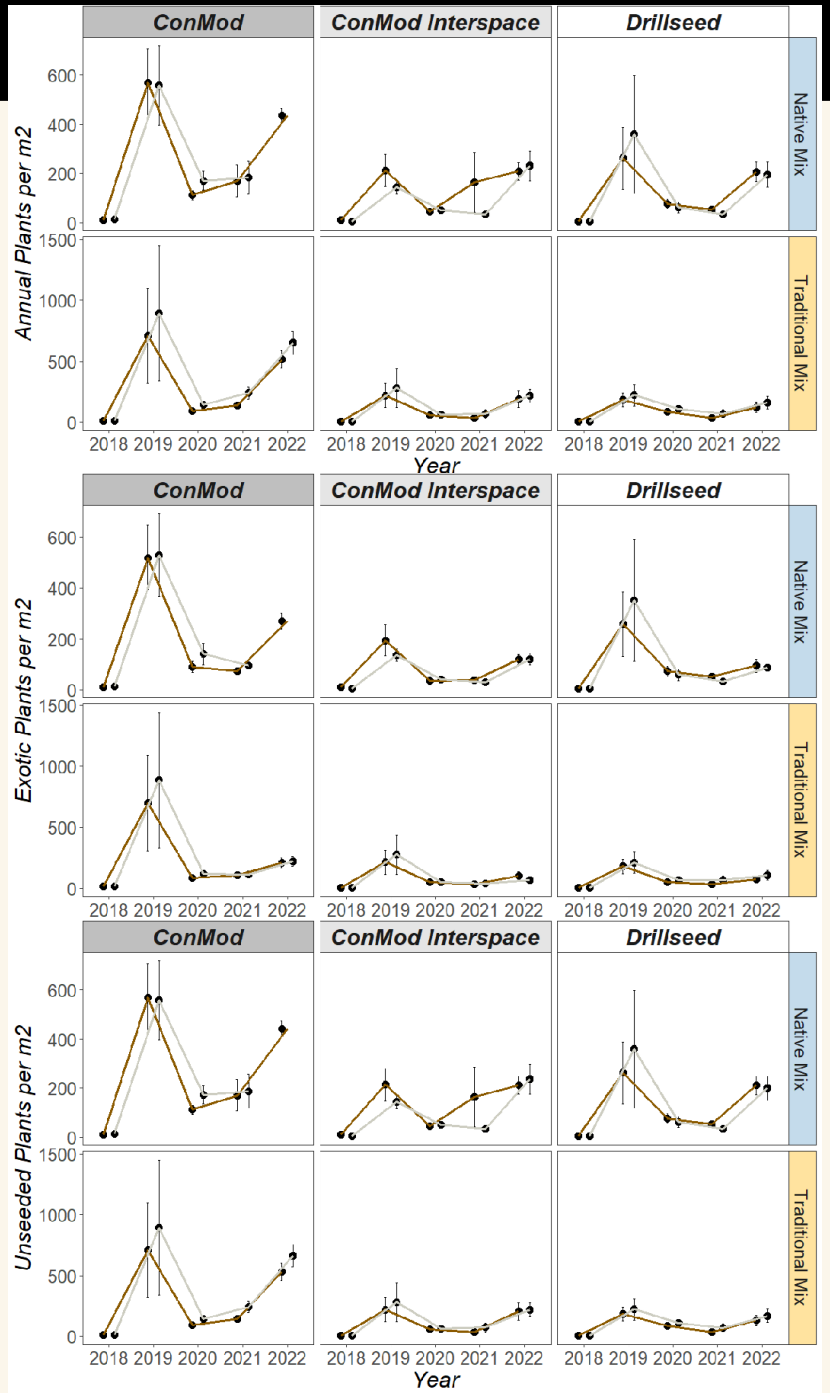
Not Inoculated

Plant Cover: Small-scale

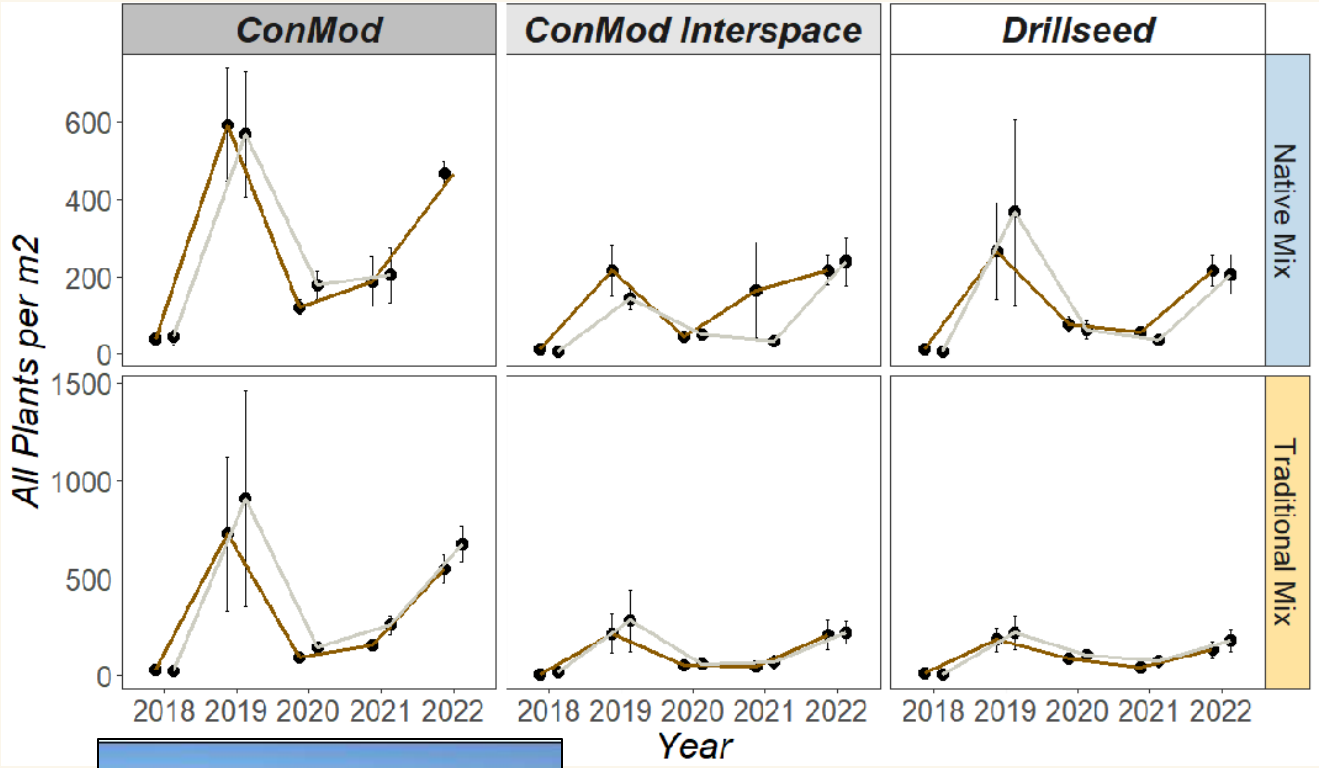


Total Plant Density

- Increases with time
- Mostly annual, non-native, unseeded species

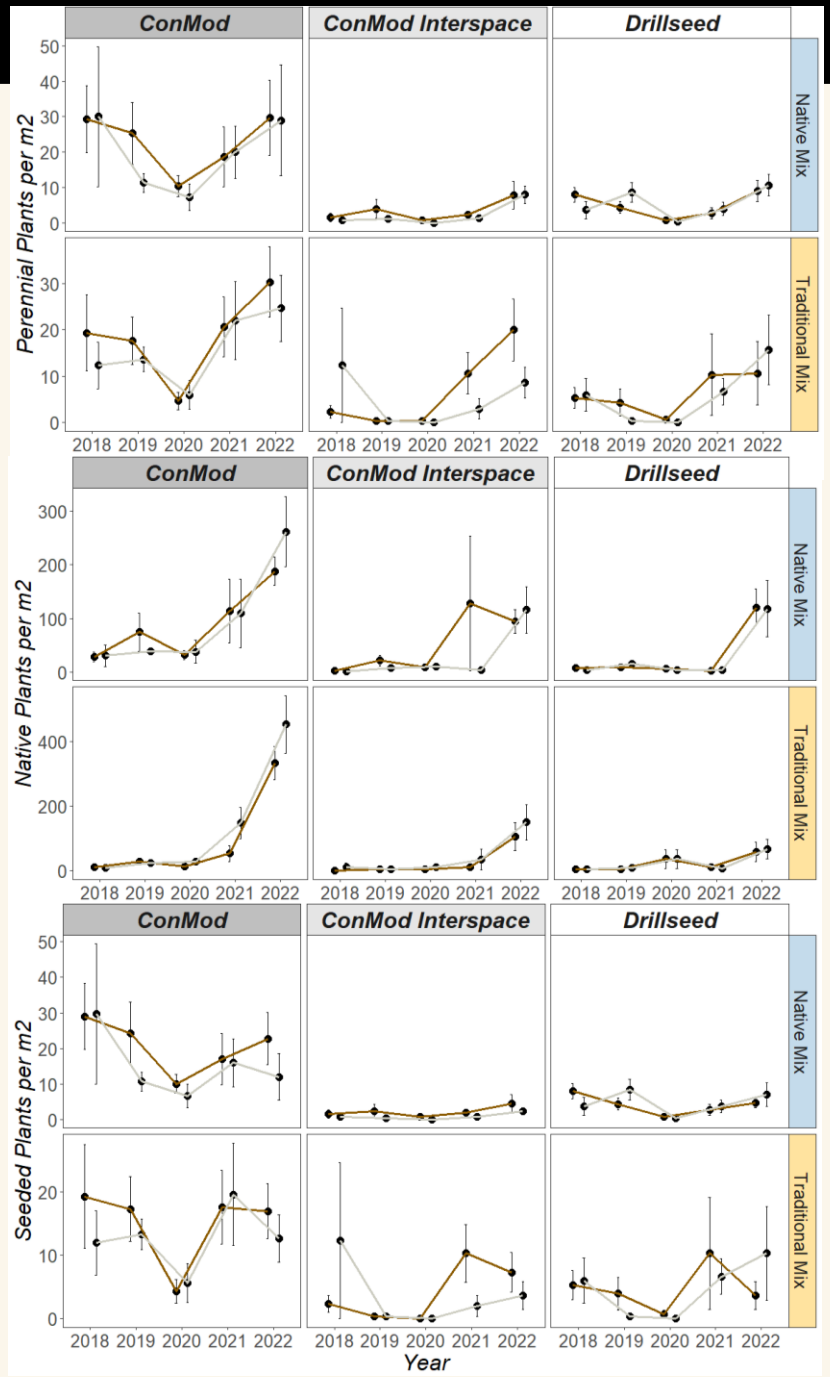


Plant Cover: Small-scale

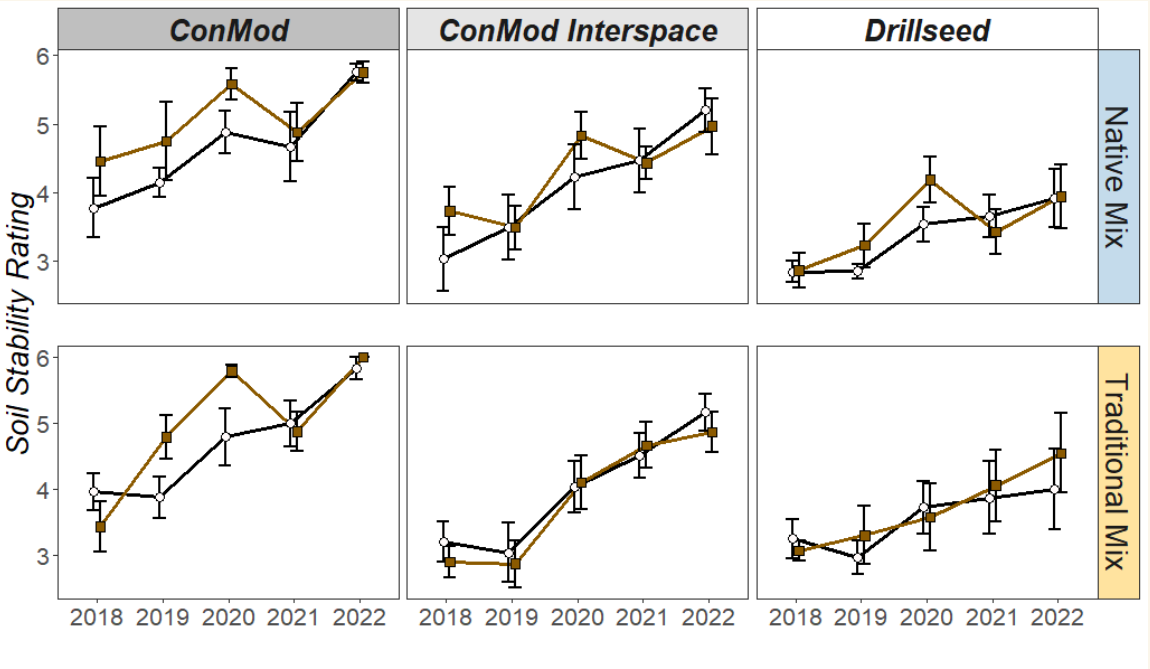


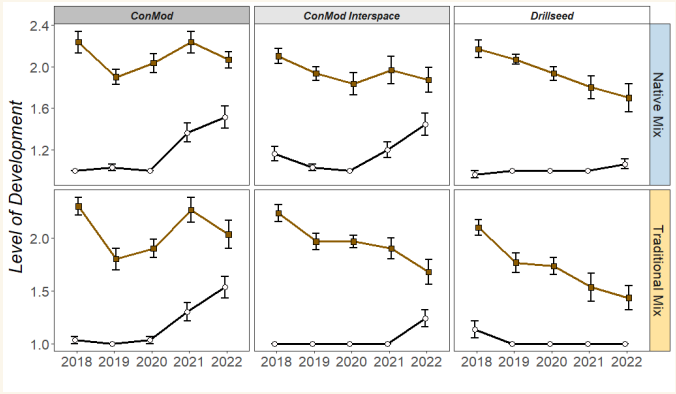
Total Plant Density

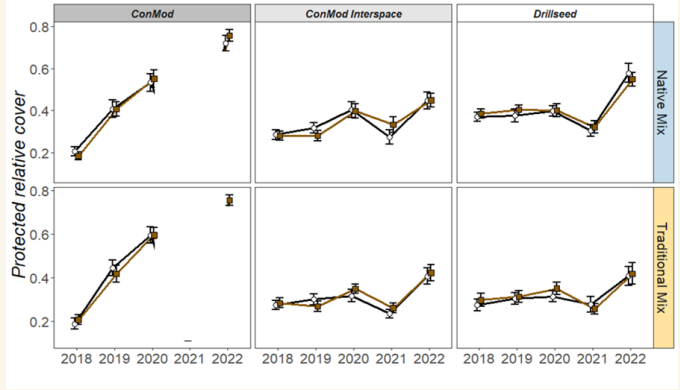
- Increases with time
- Little biocrust effect
- ConMod Interspace low



Soil erodibility: Small-scale







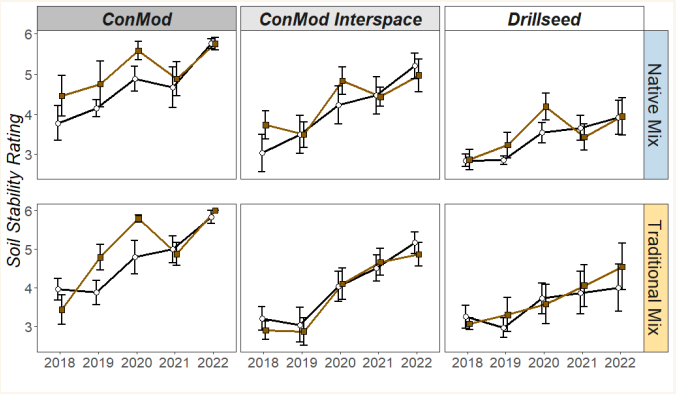
Soil stability

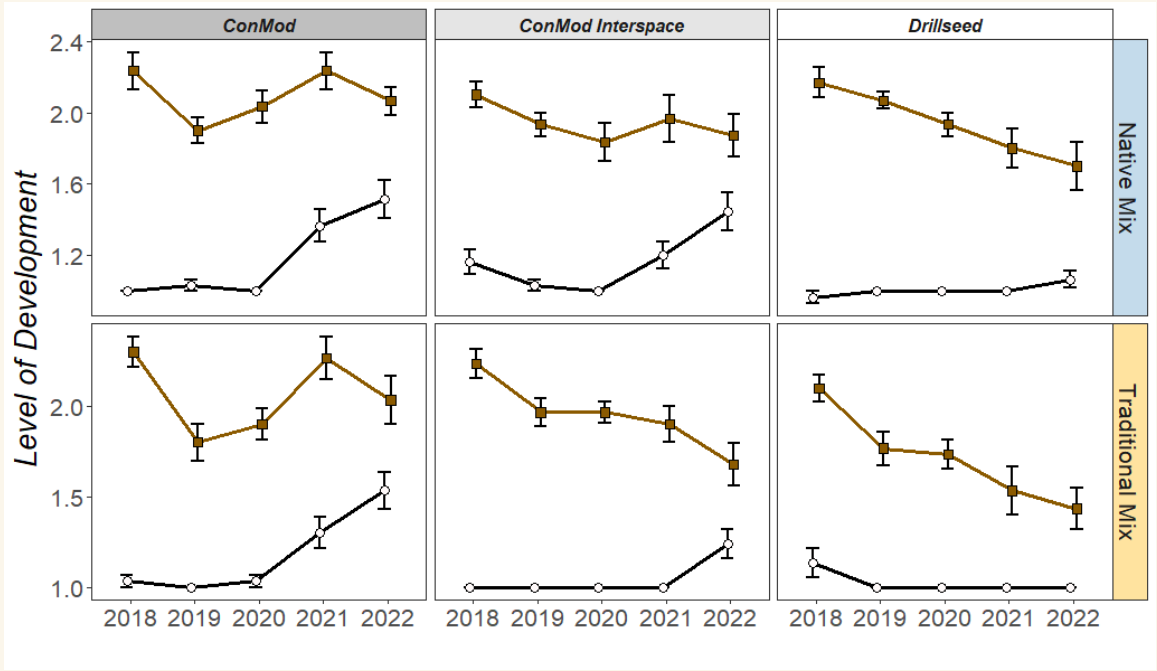
- ConMods higher stability
- Increases with time

  Level of biocrust development
  - ConMods have lower % bare soil
  - Decreases with time in drillseed

  Protected soil cover
  - ConMods have higher % litter cover
  - Increases with time

Soil erodibility: Small-scale





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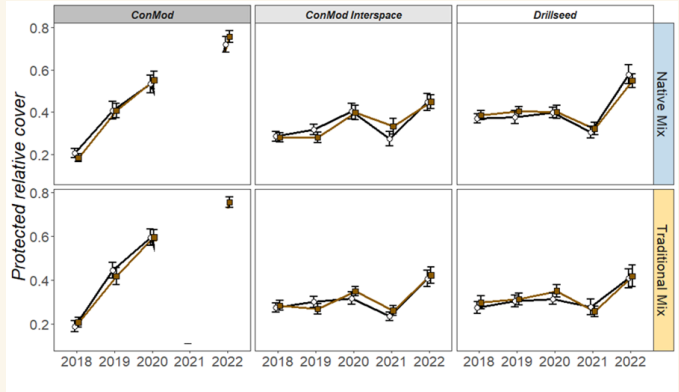
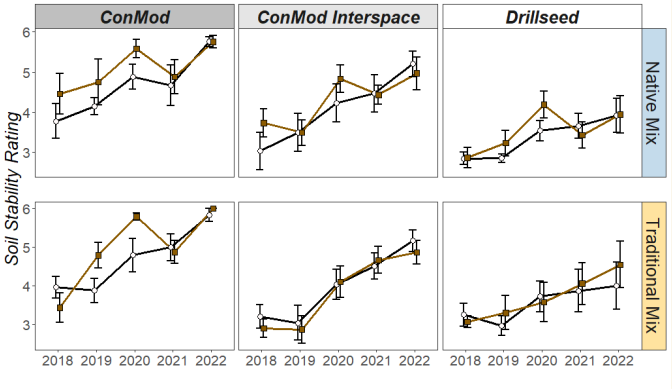
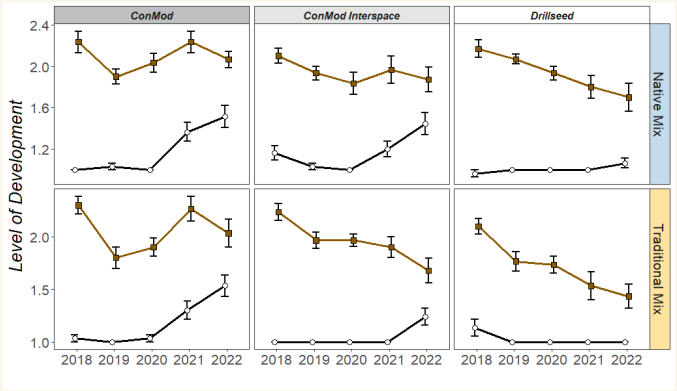


Protected soil cover

- ConMods have higher % litter cover
- Increases with time

Soil erodibility: Small-scale





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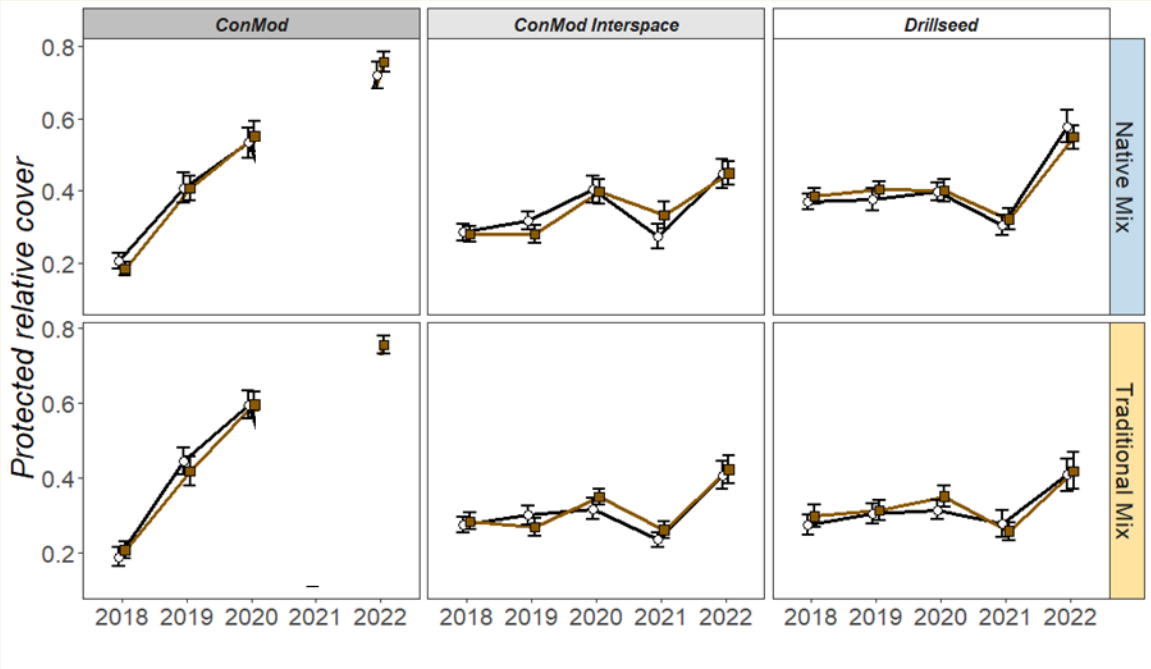


Take homes: Large-scale

- ***All native seed mix***
  - Promote native species, woody, hard to establish
- ***ConMods***
  - Higher total plant cover
  - Decreased exposed soil

Take homes: Small-scale

- ***Interspaces***
  - ConMods may provide some benefit between them
    - Not to plant establishment
    - But to soil stability
- ***Biocrust***
  - Establishes biocrust
  - Increases soil stability
    - particularly effective in combination with ConMods

Take homes: Novel tactics work!

BIL Abandoned Mined Lands

Goals: Improve reclamation on abandoned mines

Planting Tactics: Seed mixes, Planting methods

Small scale plots (2x2 m)

BIL Abandoned Mined Lands

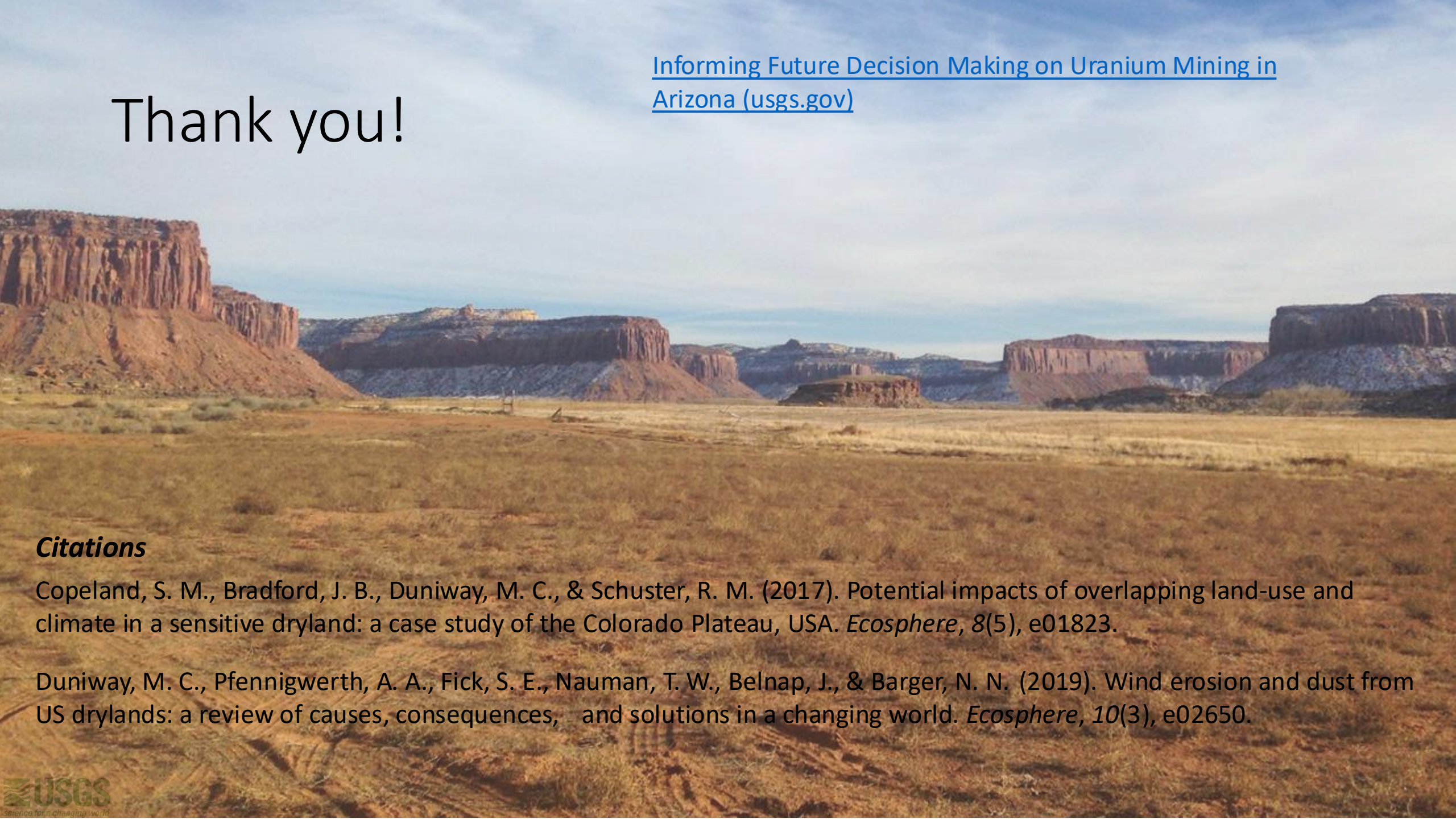
Goals: Improve reclamation on abandoned mines

Planting Tactics: Seed mixes, Planting methods

- Lisbon Mine
  - Copper (UT)
- Questa Mine
  - Molybdenum (NM)
- TBD Mine
  - Uranium (AZ)

Thank you!

[Informing Future Decision Making on Uranium Mining in Arizona (usgs.gov)]



Citations

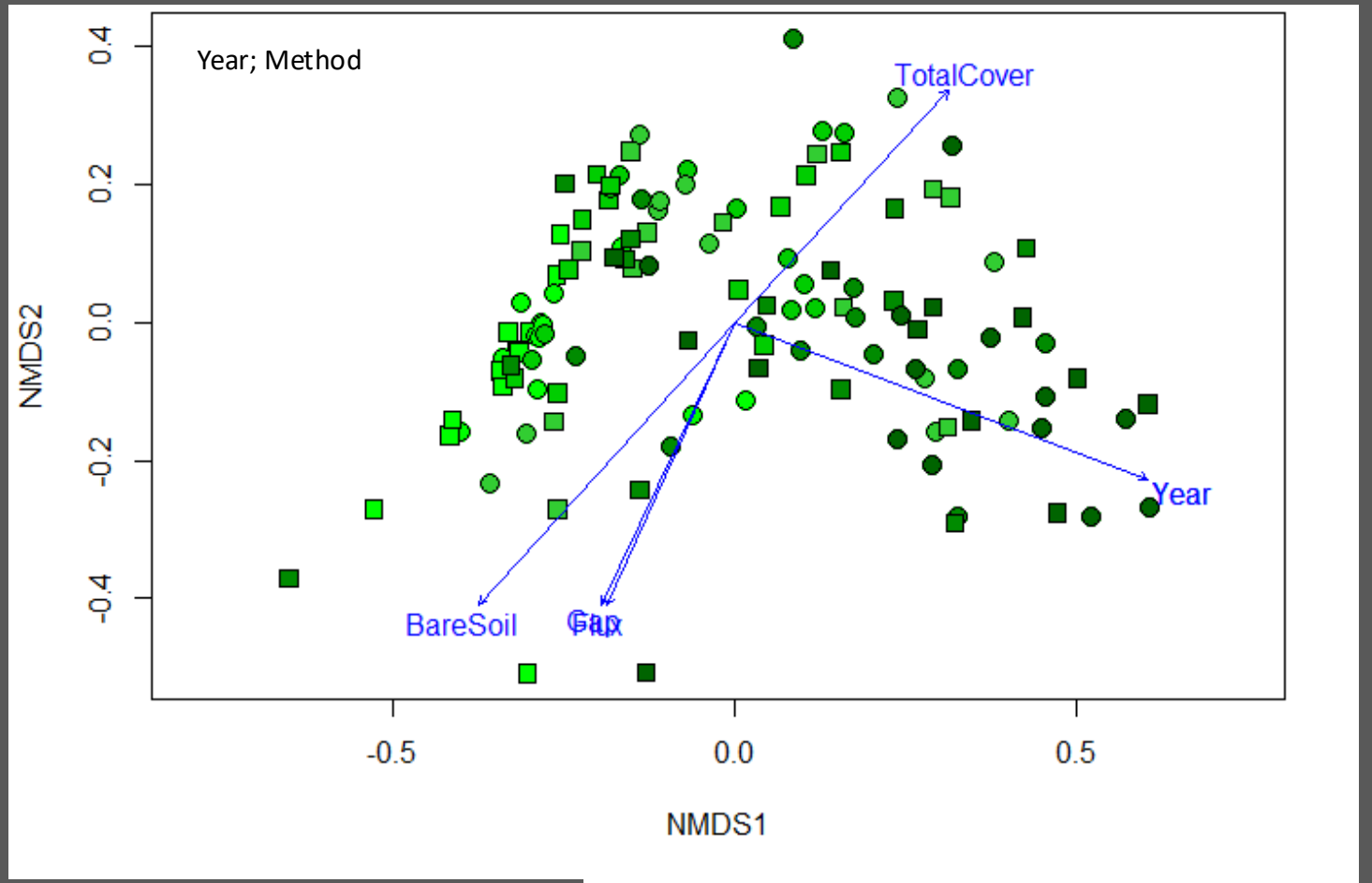
Copeland, S. M., Bradford, J. B., Duniway, M. C., & Schuster, R. M. (2017). Potential impacts of overlapping land-use and climate in a sensitive dryland: a case study of the Colorado Plateau, USA. *Ecosphere*, *8*(5), e01823.

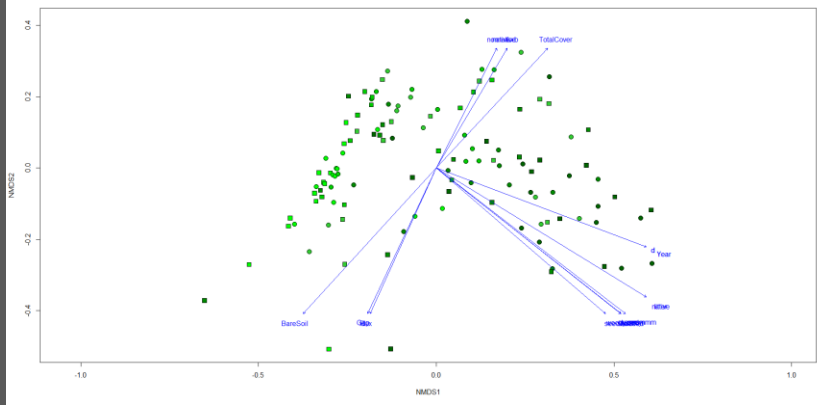
Duniway, M. C., Pfennigwerth, A. A., Fick, S. E., Nauman, T. W., Belnap, J., & Barger, N. N. (2019). Wind erosion and dust from US drylands: a review of causes, consequences, and solutions in a changing world. *Ecosphere*, *10*(3), e02650.

USGS
Science for a changing world

Multivariate

- Bare soil, gap, & flux positive relationship
  - Total cover negative
- Year is perpendicular
- Graminoid, woody, native, seeded, perennial, & litter line up close to year
- Total cover driven by forb nonnative

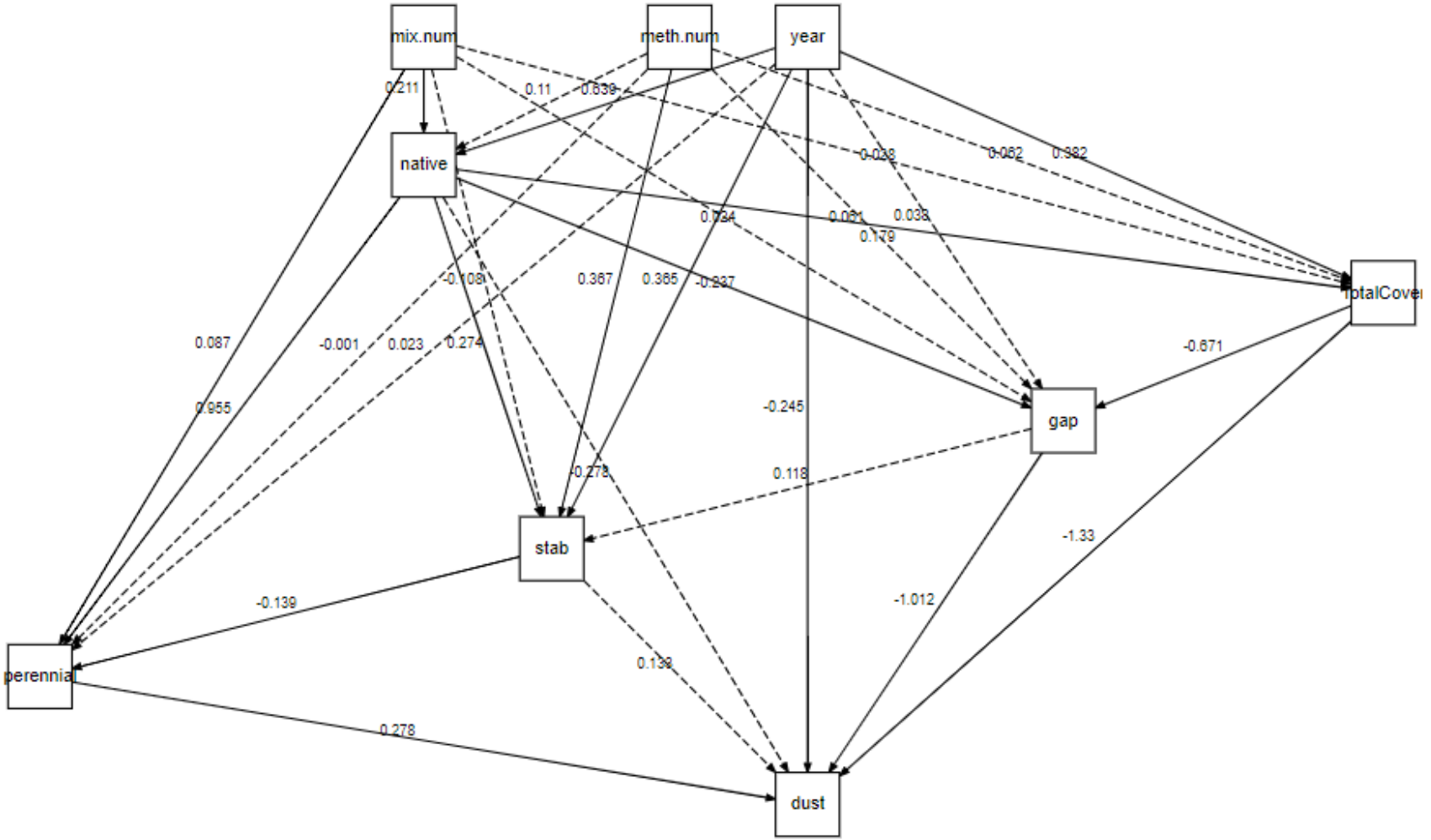




Plot-level

USGS science for a changing world

SEM: piecewise



Plot-level

USGS science for a changing world