Plant-soil feedbacks: The benefit of field-based community level study in uncovering their role in restoration

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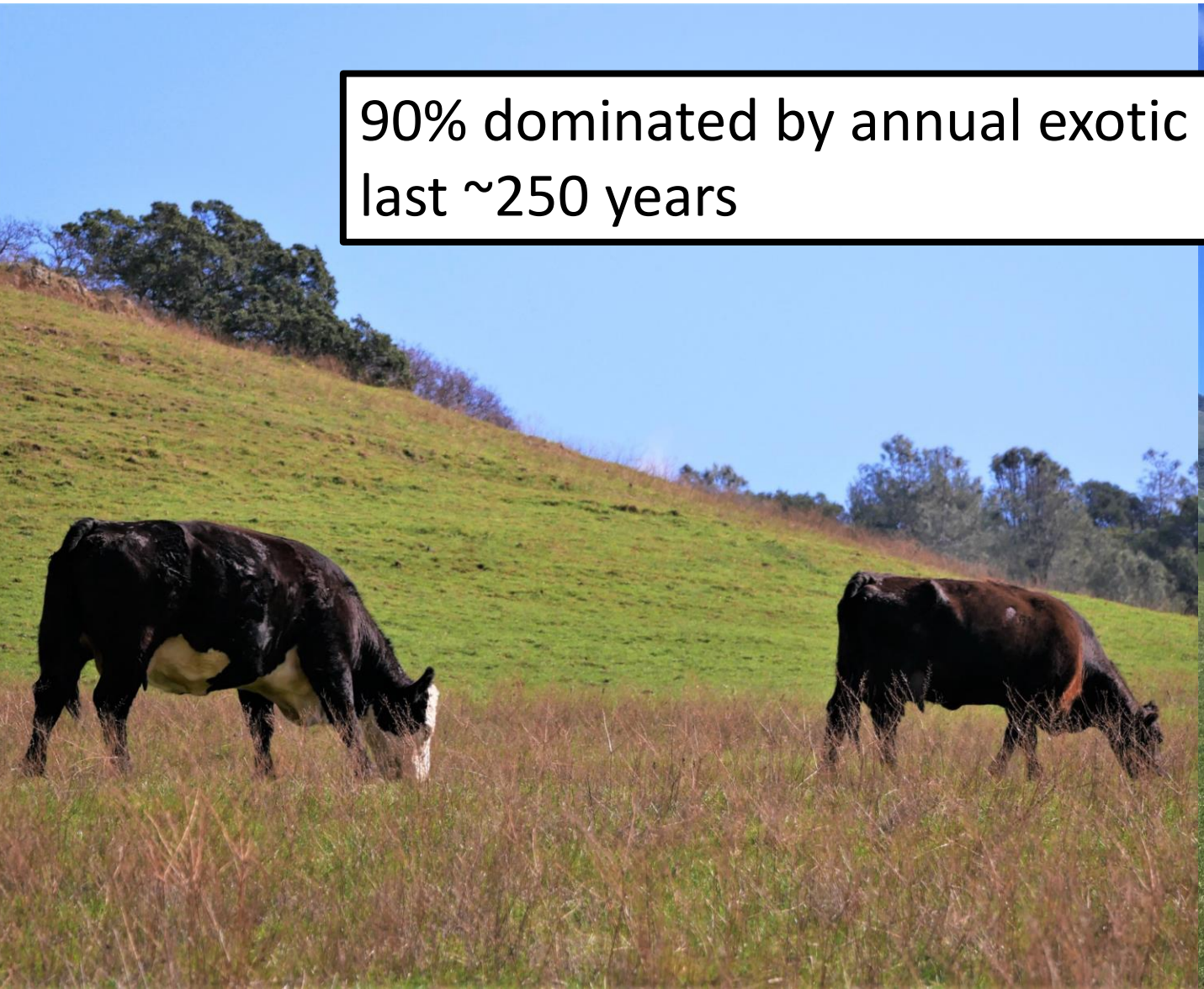
California grasslands

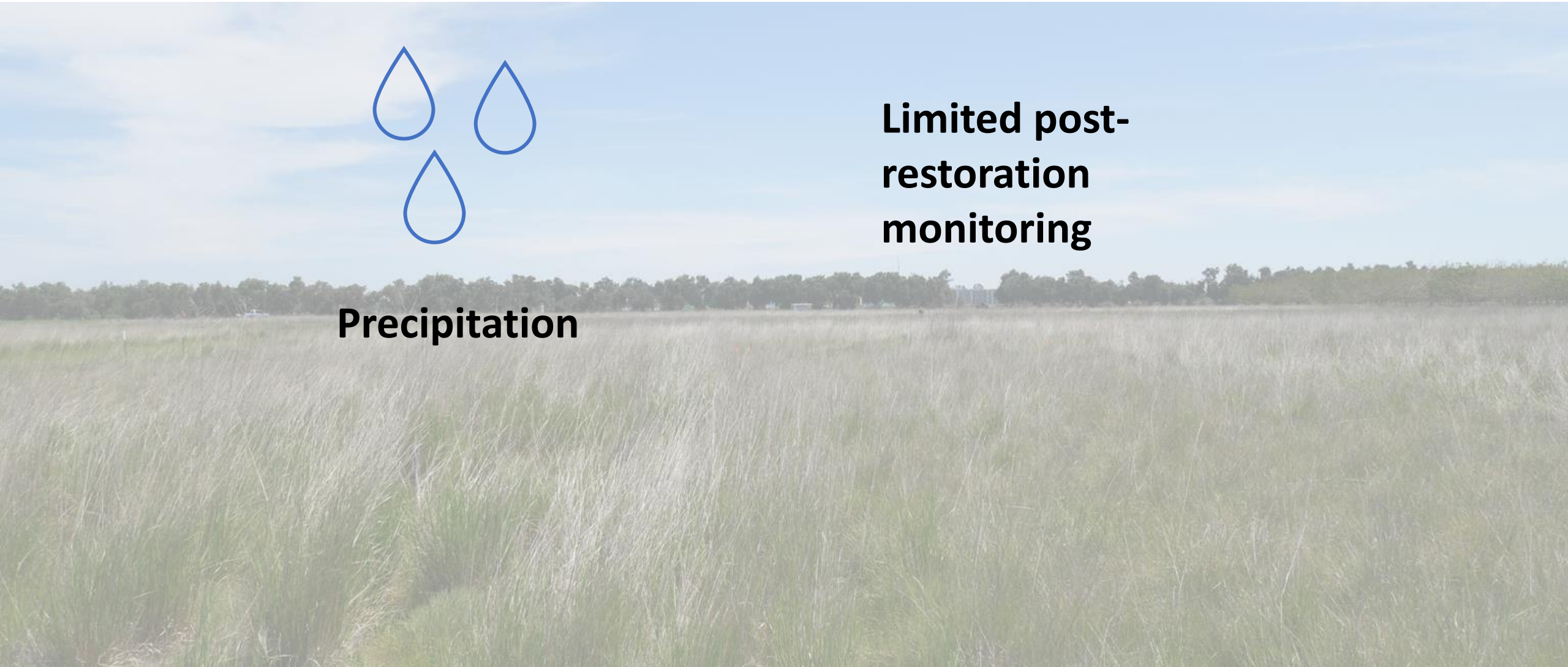
90% dominated by annual exotic species for last ~250 years



Native grassland restoration

- ↑ Biodiversity
- ↑ Native pollinator & wildlife habitat
- ↑ Ecosystem services (e.g. carbon storage)

Unfortunately, many projects fail



Limited post-restoration monitoring

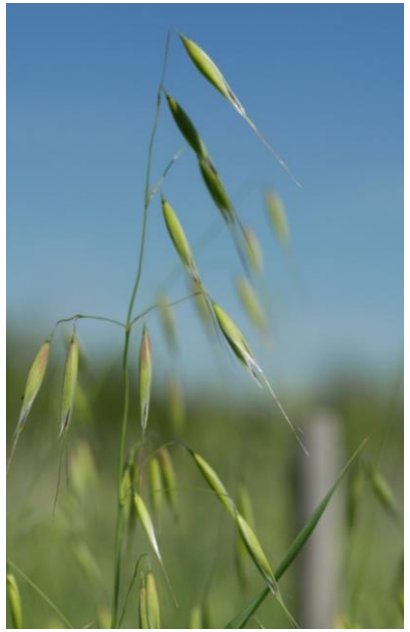
Precipitation

Exotic annual grasses in California

Nitrogen cycling

Microbial community

Deep soil organic matter & C



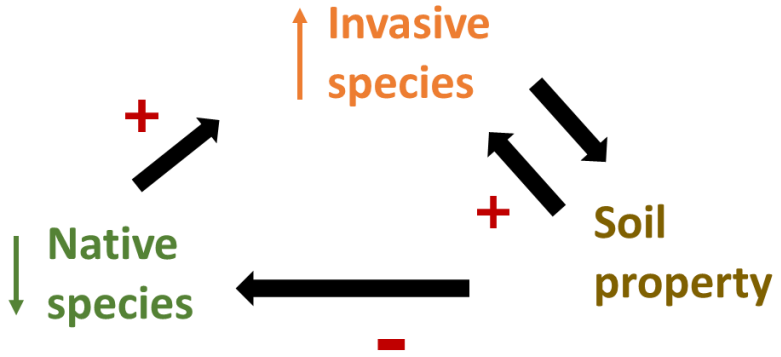
Avena, Bromus, Festuca, etc

Seabloom et al., Eviner, Hawkes, Parker & Schimel, and others

Plant-soil feedbacks

PLANT → SOIL → PLANT

A plant species alters soil biological properties that then influences trajectory of plant community
physical properties
chemical properties



Grmn & Suding, Larios & Suding,
Hausmann & Hawkes, Eviner & Hawkes

Plant-soil feedbacks

Greenhouse studies

- Necessary to determine causality
- *Potentially exaggerate strength of feedback*

Call for more field experiments – are PSFs as strong in settings with competition and weather variability?

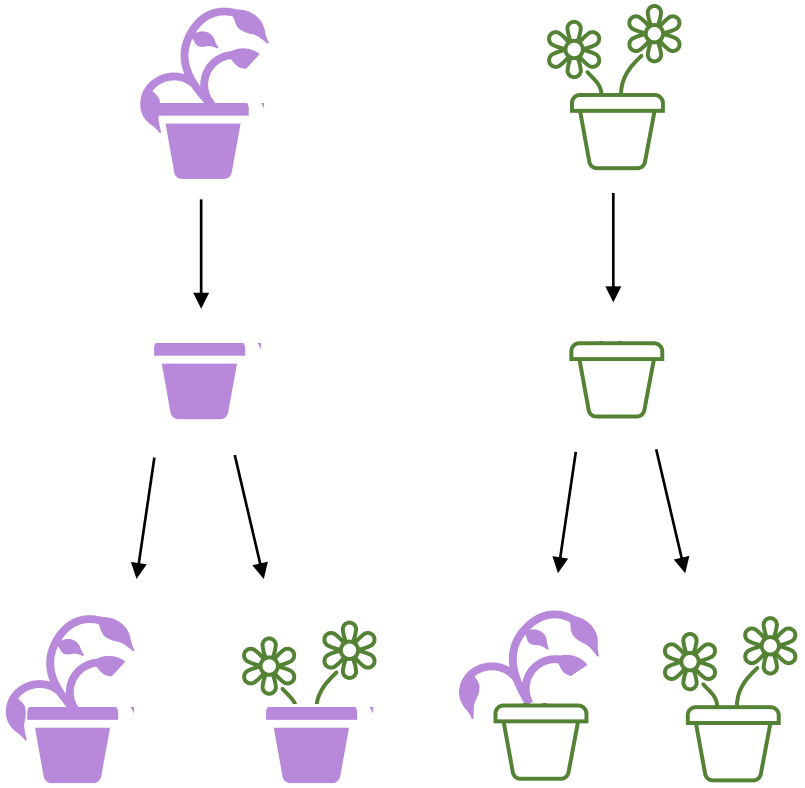
Objectives

1. Are exotic annual grasses altering soil properties in a field setting?
2. Are these changes resulting in plant-soil feedbacks that impact their native grass establishment?
3. If there are feedbacks, how important are they compared to normal seedling competition?
4. Restoration implication: are the exotics changing soil properties that negatively affect native perennial establishment and performance? Do we need to ameliorate the soil in some way?

Traditional experimental design – 2 PHASES

1) Soil Conditioning

2) Feedback/
Performance



If does  better in  home soil
→ positive feedback

If does  better in  away soil → negative feedback

Phase 1: Conditioning

- 1.25 x 1.25 m^2 plots
- Dominated by either NATIVE or EXOTIC grasses for **10 years**

Native perennials

Stipa pulchra, Elymus glaucus and *E. triticoides*

Exotic annuals

E. caput-medusae, Aegilops triuncialis, Avena fatua, Bromus hordeaceous

Native conditioned soil

Exotic conditioned soil

X 8 replicates

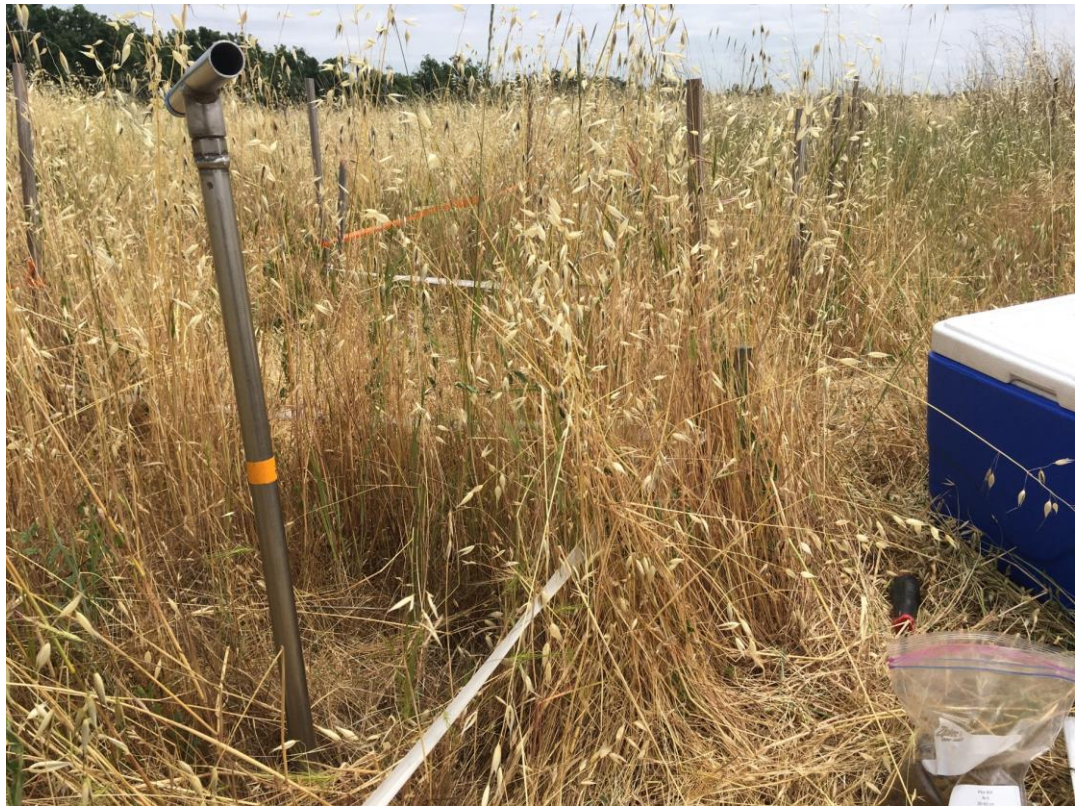
Phase 1: How do the 2 conditioned soils differ?

Native conditioned soil

Exotic conditioned soil

X 8
replicates

Soil cores of 4 depths:
0-15, 15-30, 30-60, 60-90 cm



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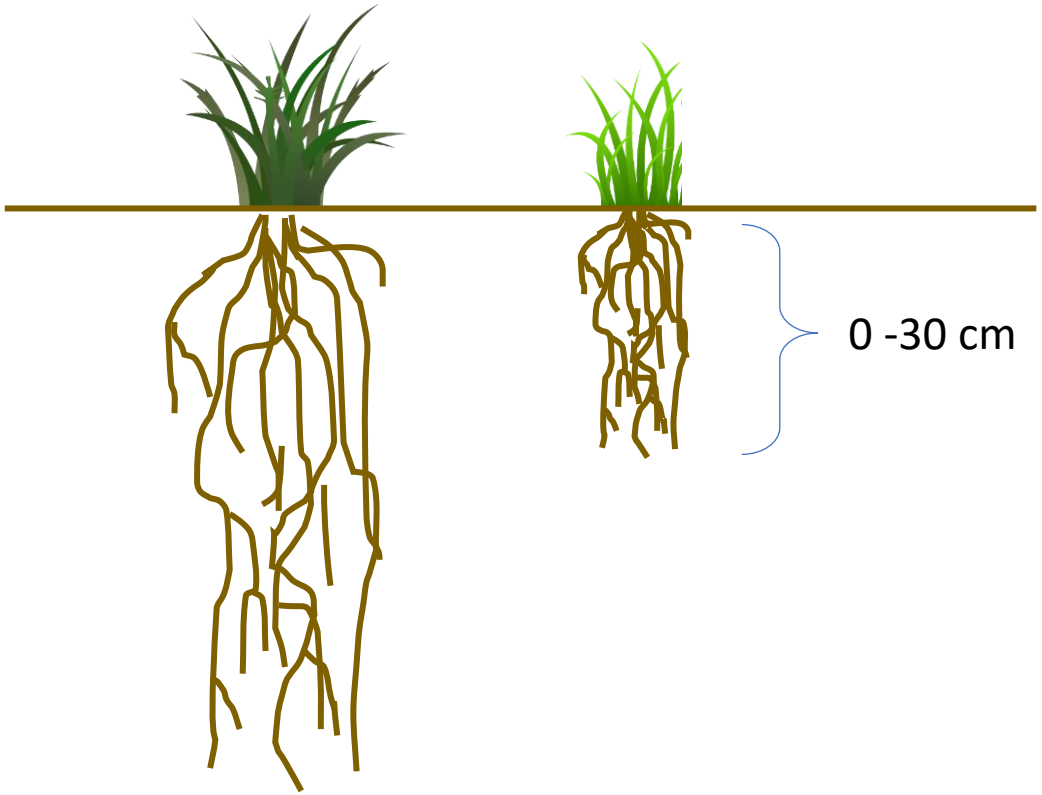
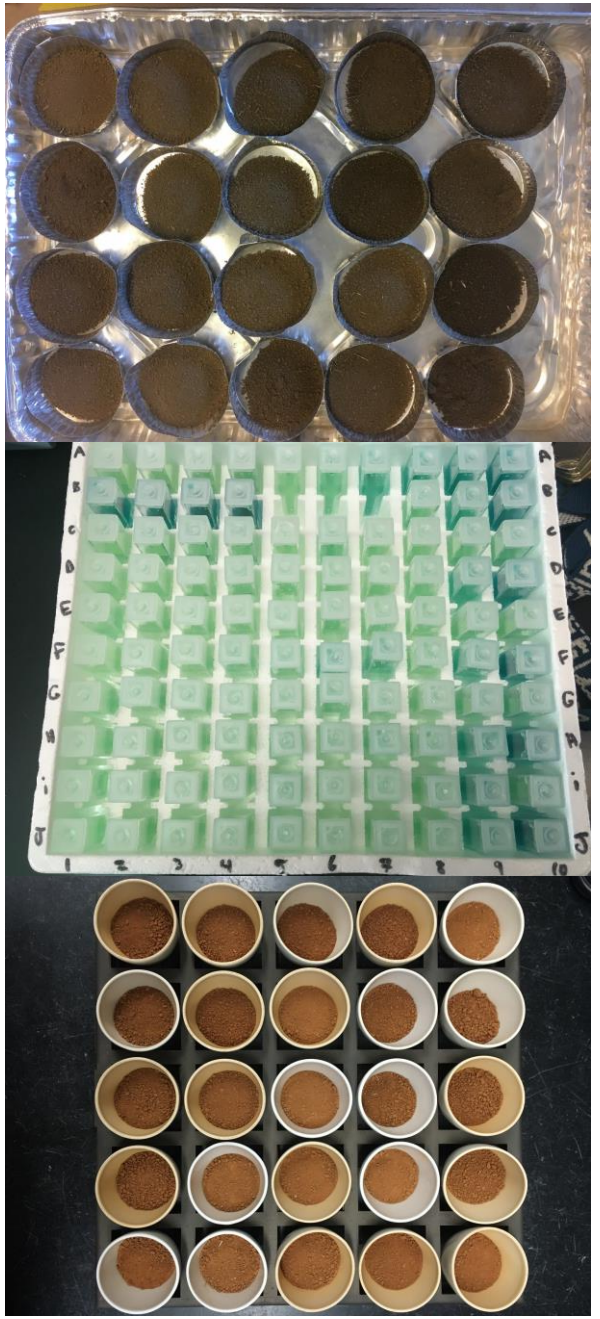


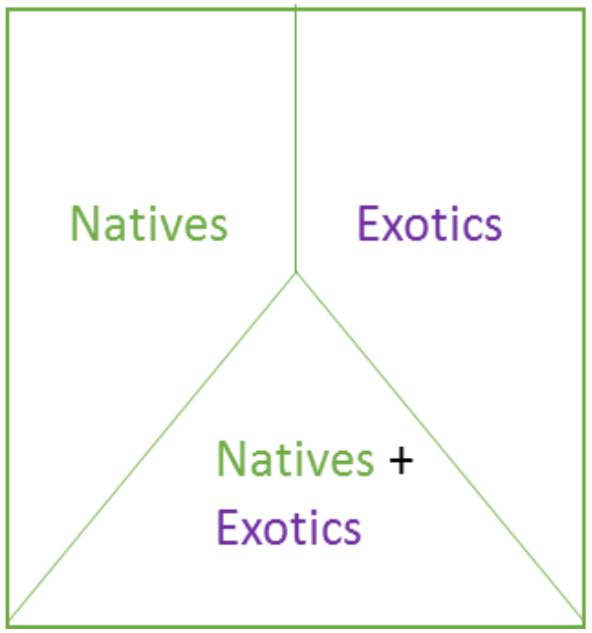
Phase 1: Soil

- **Physical & chemical properties**
  - Gravimetric soil moisture
  - Water holding capacity
  - Soil organic matter
  - % carbon and nitrogen
- **Nitrogen cycling**
  - Net mineralization and nitrification rates (NO_3^- & NH_4^+)
- **Microbial community composition**
  - Bacteria & fungi DNA sequencing

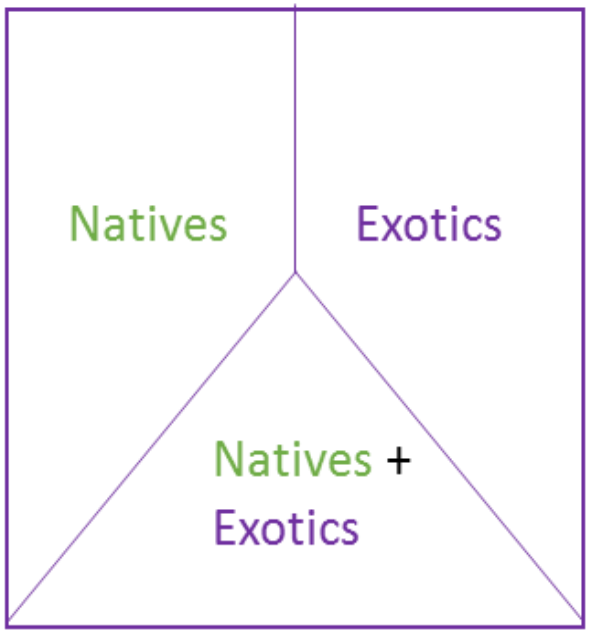


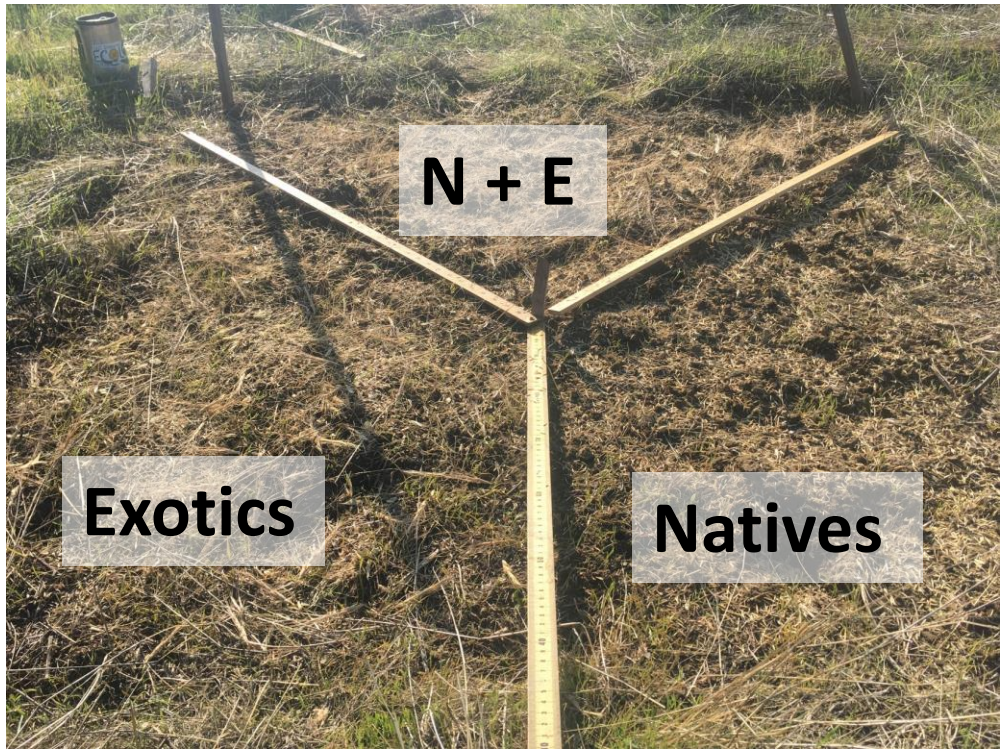
Phase 2: Feedback (Plant Performance)

Native conditioned soil



Exotic conditioned soil





Phase 2: How is plant performance affected?

- **1st growing season**
  - Germination
  - Height @ multiple time points
  - Above and belowground biomass
  - Percent cover
  - Exotic seed production
- **2nd growing season**
  - Height @ multiple time points
  - Above and belowground biomass
  - Percent cover
  - Native seed production

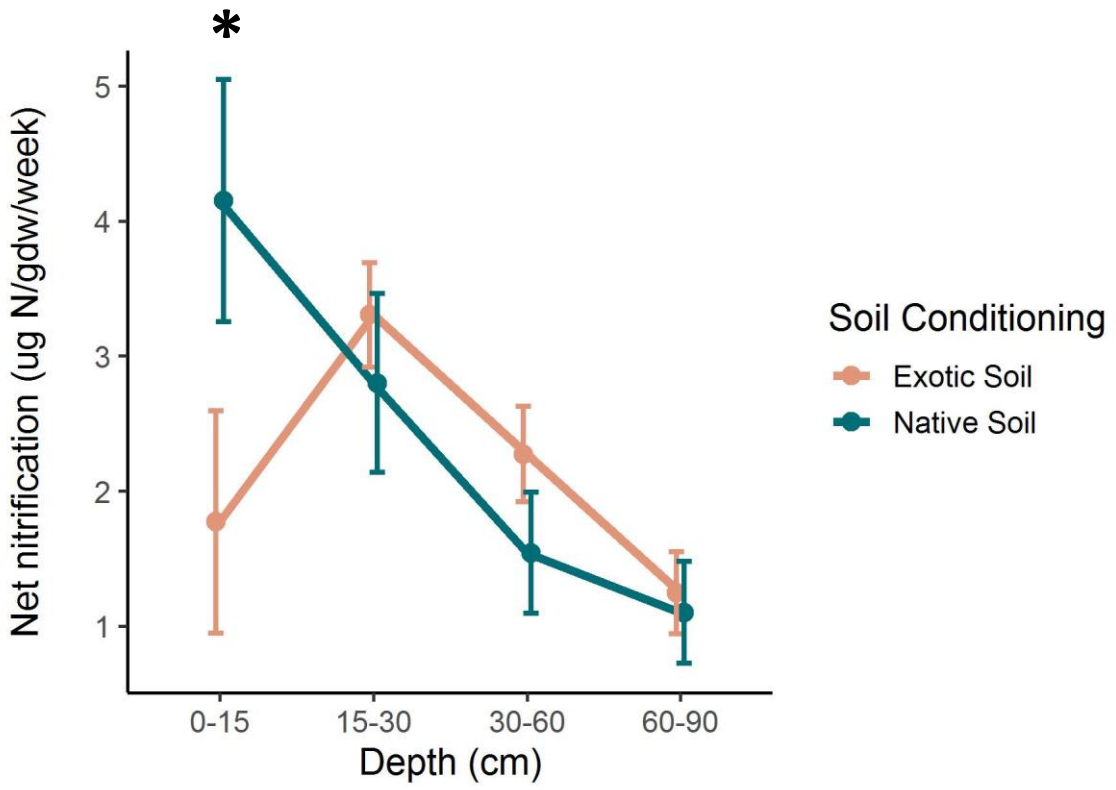


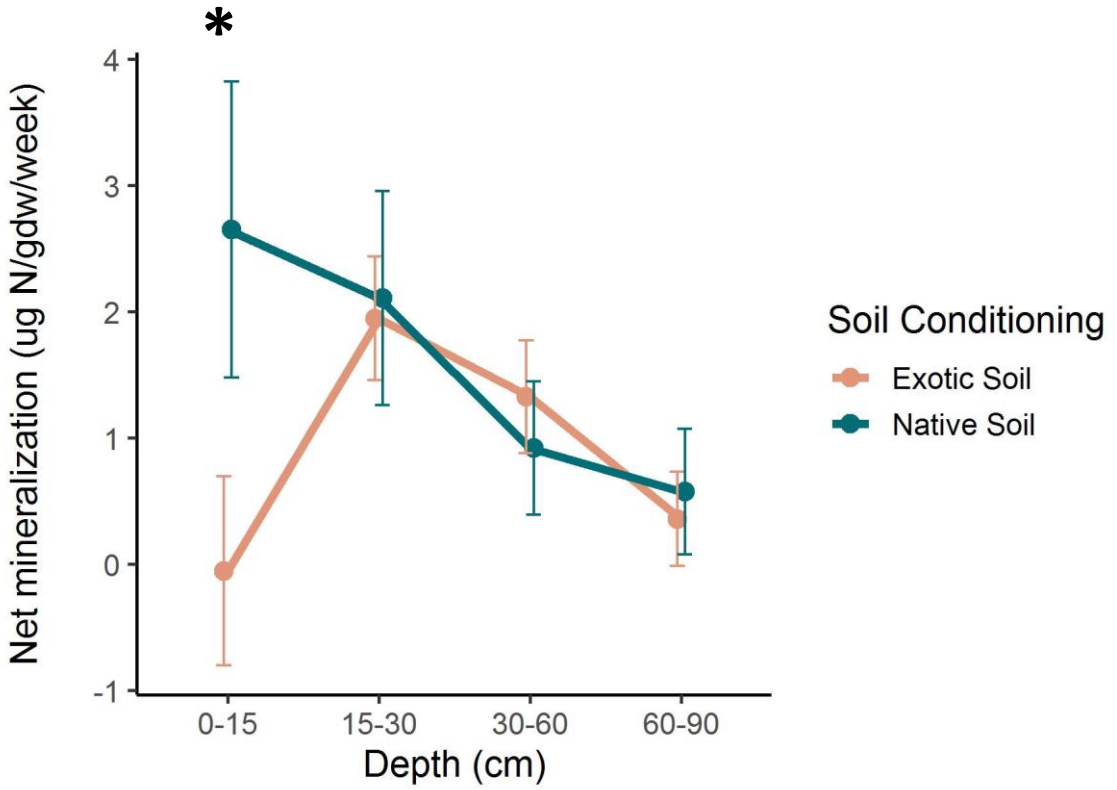
Phase 1: How do the 2 conditioned soils differ?

- Water holding capacity
- Soil organic matter
- % carbon and nitrogen

→ **No Difference**

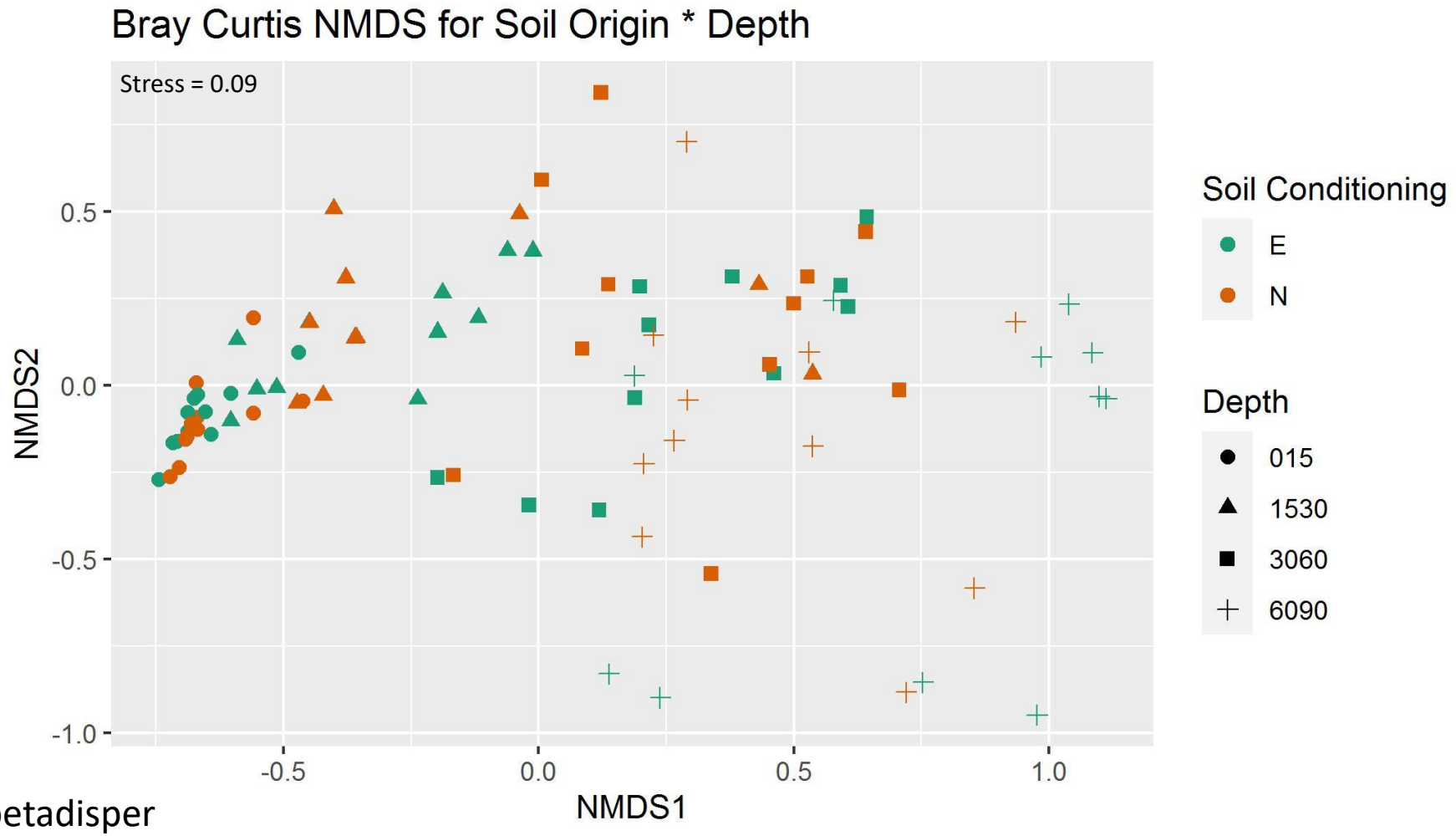
Exotics decrease net mineralization and nitrification rates in top 0-15 cm soil





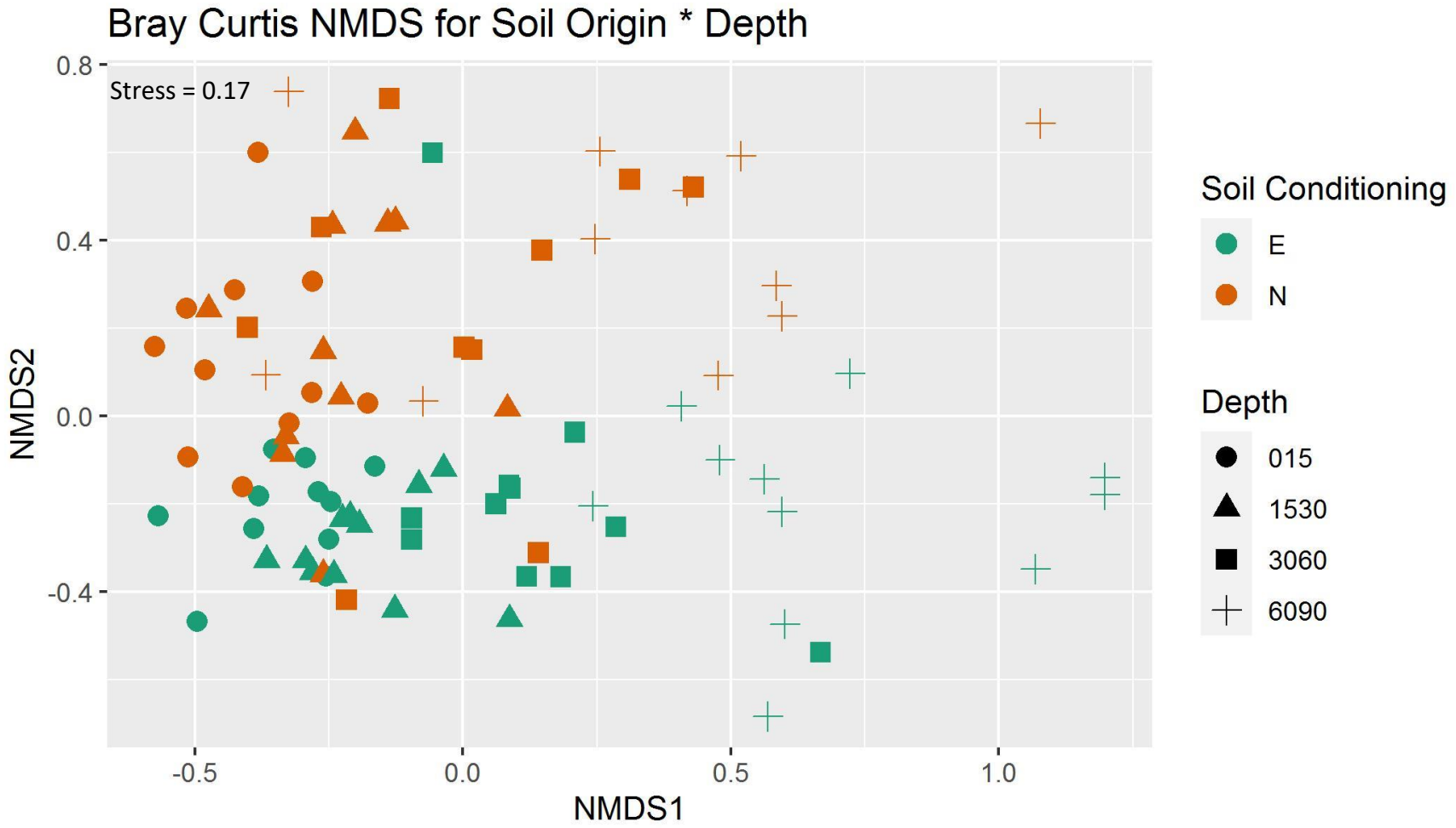
Linear mixed model with random effect/ANOVA/Post-Hoc Tukey

Exotics alter the bacterial community in shallow (0-15 cm) and deep (60-90 cm) soil



PERMANOVA/betadisper

Exotics alter the fungal community across all depths

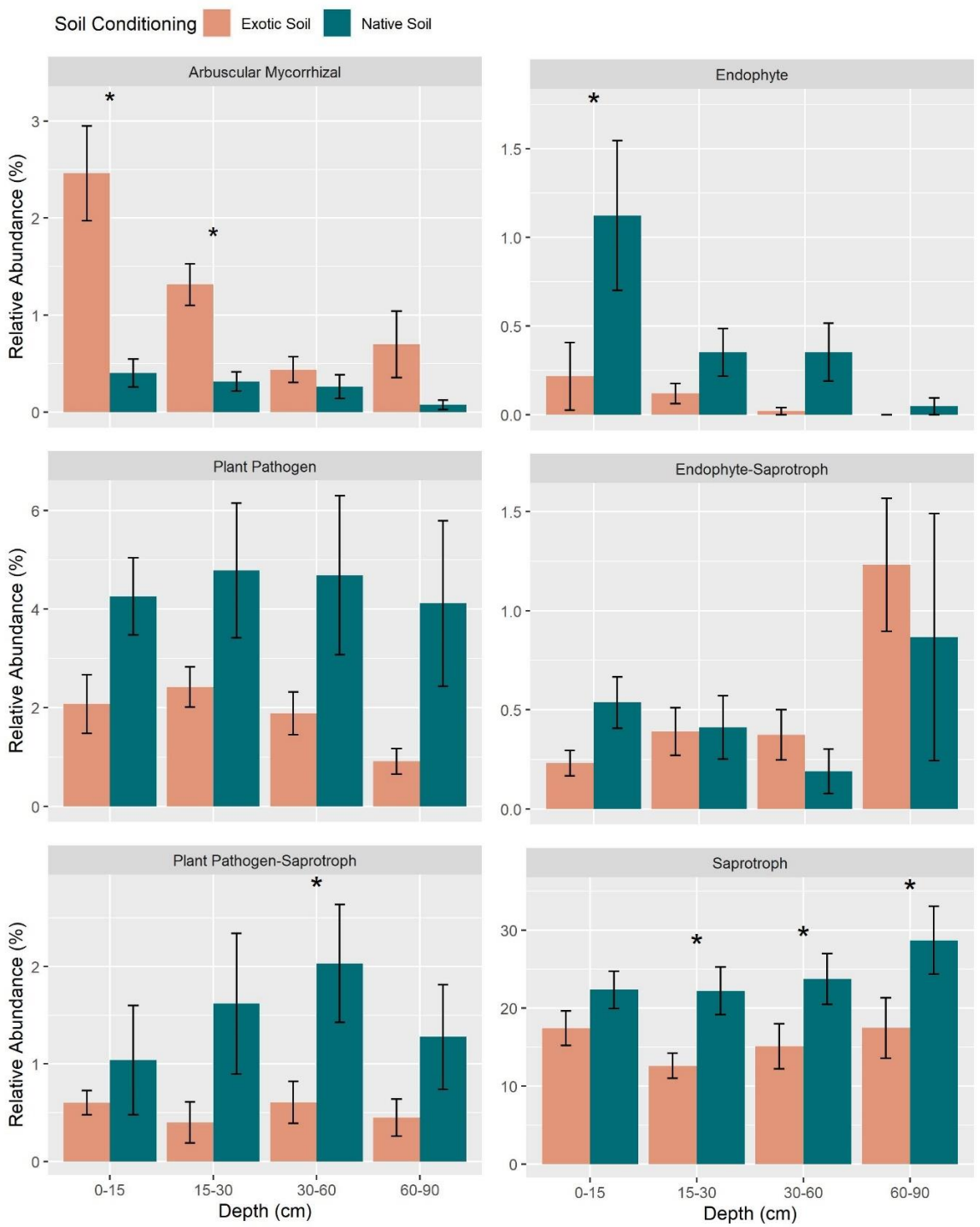


PERMANOVA/betadisper

Exotic soil has more AMF and less pathogens, saprotrophs, endophytes

Functional groups via FUNGuild (Nguyen et al. 2016)

**Only 50% of classified taxa have known guild association



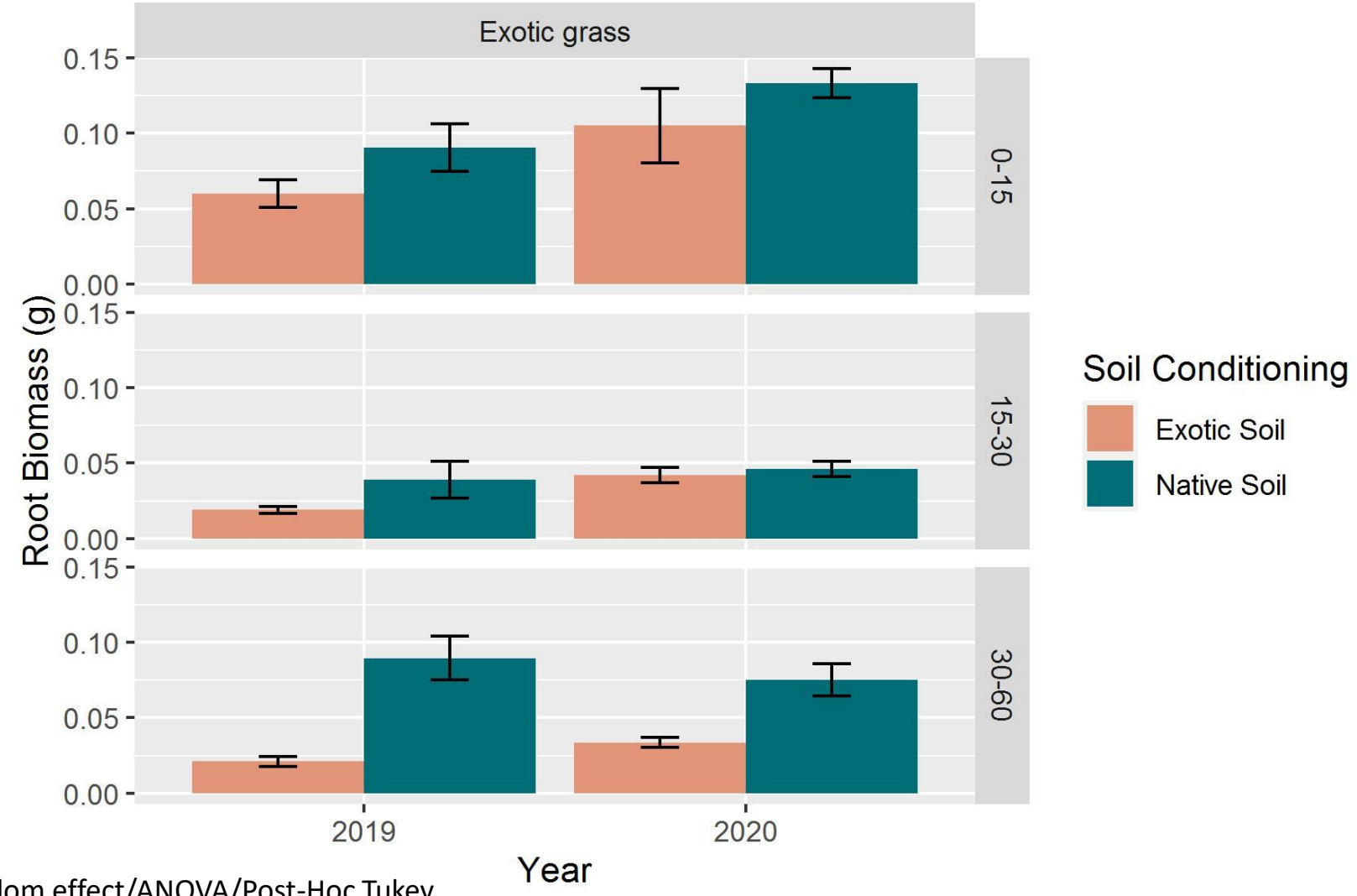
Phase 2: How is **EXOTIC** plant performance affected?

- Aboveground biomass
- Percent cover
- Seed production
- Seed viability

No feedback/
No effect of soil origin

1 of 4 species had weak negative feedback in germination and height

Native soil increases exotic grass belowground biomass



Linear mixed model with random effect/ANOVA/Post-Hoc Tukey

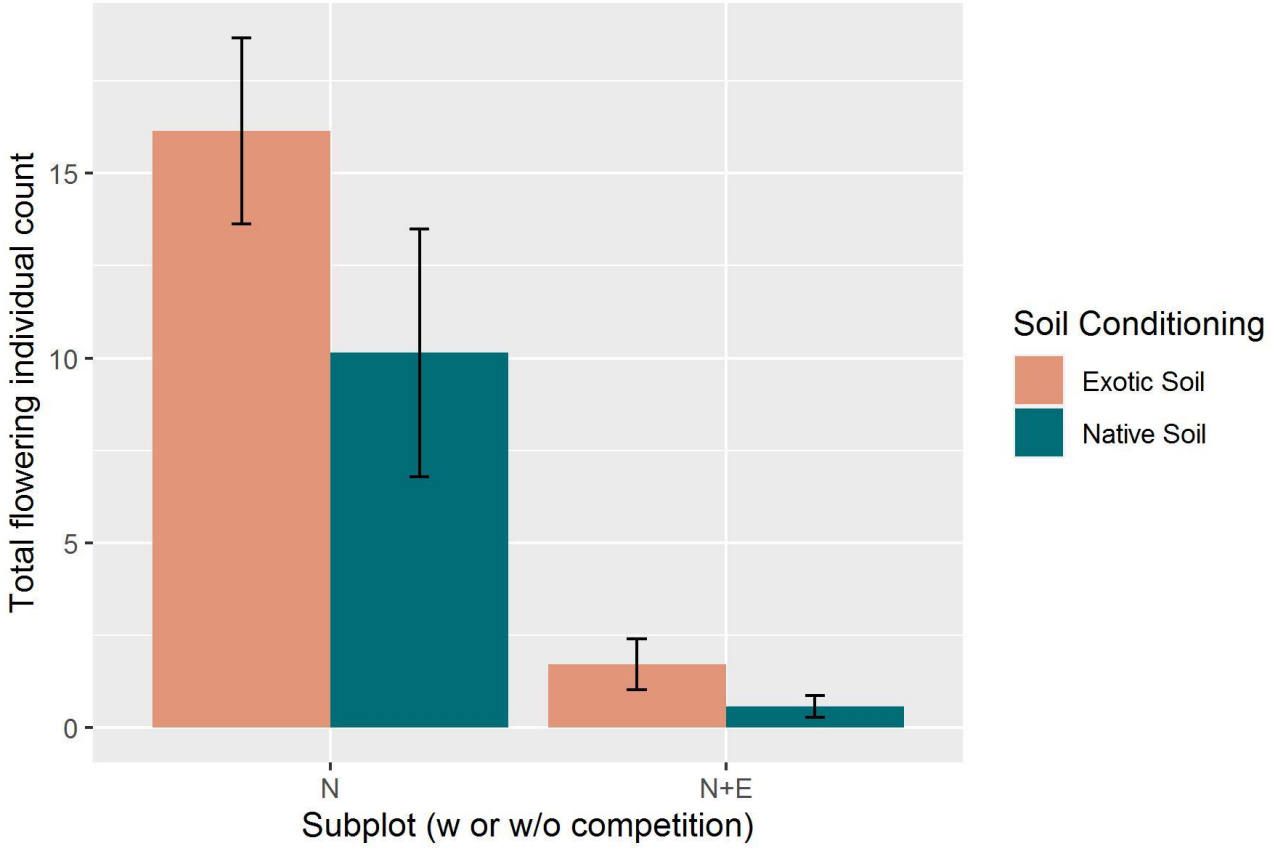
Phase 2: How is **NATIVE** plant performance affected?

- Germination
- Aboveground biomass
- Belowground biomass
- Seed production
- Seed head count/individual

No feedback/

No effect of soil origin

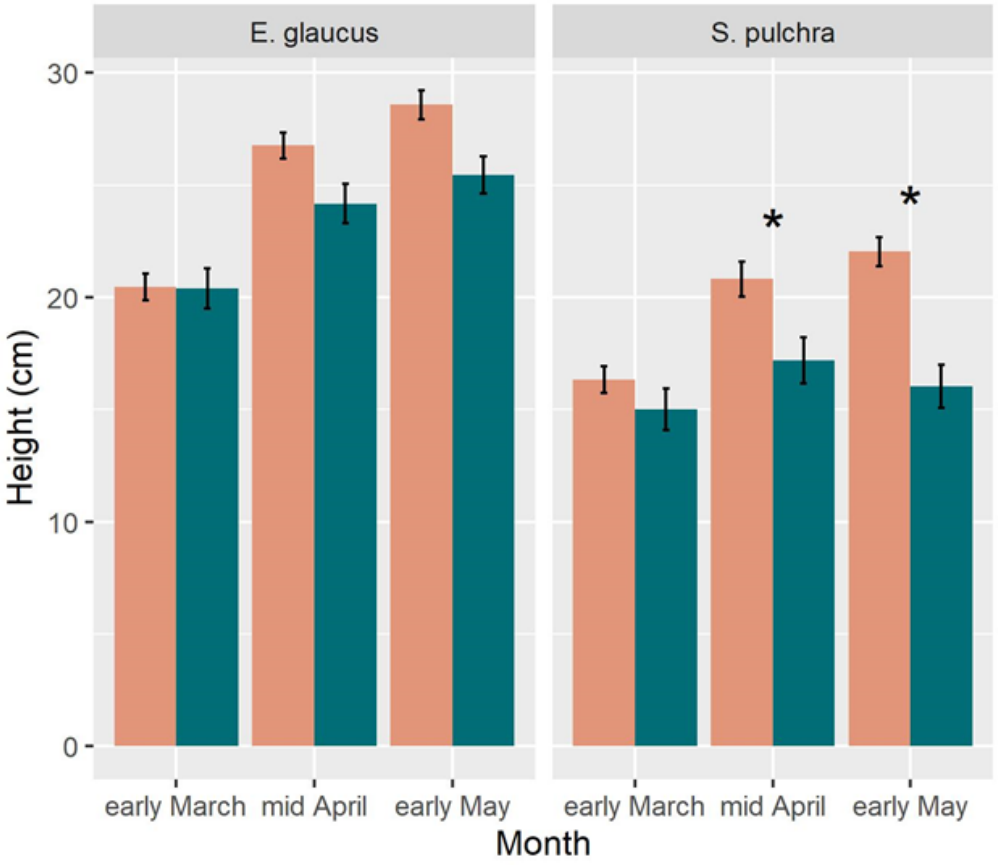
Natives have negative feedbacks - **FLOWERING**



Natives are flowering more in exotic conditioned soils

Generalized linear model with negative binomial distribution

Natives have negative feedbacks - **HEIGHT**



Feedback only in 2nd growing season

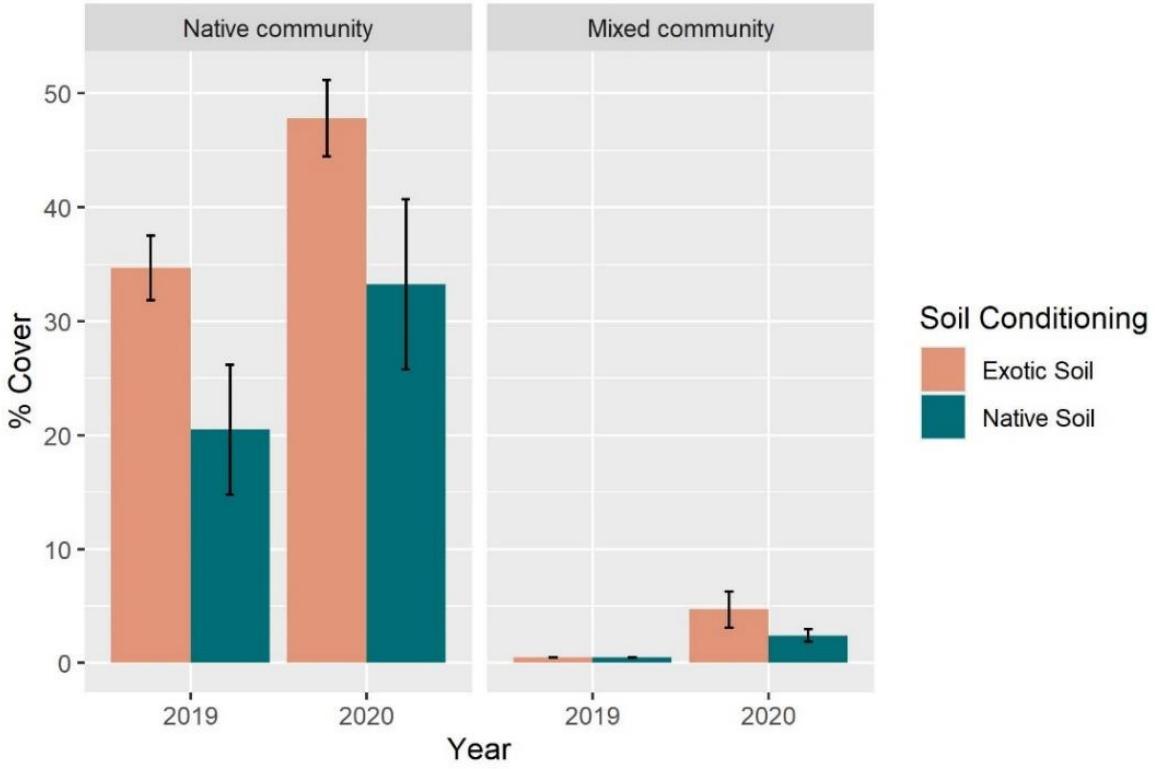
Natives grow taller in exotic conditioned soil

Effects accumulate over time

Native seeded subplot only
Generalized linear model with negative binomial distribution

Natives have negative feedbacks - **COVER**

Feedback only significant if looking at total native cover (not by species)



Natives have 18% higher cover in exotic conditioned soil

A community level feedback

Linear mixed model with random effect/ANOVA/Post-Hoc Tukey

How do exotic and native conditioned soils differ?

Exotic soils compared to Native soils

- Lower shallow soil nitrogen cycling rates
- Different fungal communities (more AMF, less pathogens)
- Different bacterial communities (shallow and deep)

Is there evidence of plant-soil feedback?

For exotic grasses

- Yes, occasionally
  - Height (1 of 4 species)
  - Germination (1 of 4 species)
  - Root biomass (deeper soil)
- Negative feedbacks
  - Grow better in native soil

For native grasses

- Yes
  - Height
  - % Cover
  - # of Flowering Individuals
- Negative feedbacks
  - Grow better in exotic soil

Takeaways

Exotic grasses are changing the soil, but feedback is not as expected

Increased AMF might be beneficial to native seedlings or

Natives are experiencing a ‘release’ from specialized pathogens

Not the bad news for restoration we were expecting!

Takeaways

Still able to be observed in field setting but…

Weed control at beginning of restoration still #1 step!

Researchers need to consider community-level metrics

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THANK YOU