



Community-engaged precision restoration: collaboratively addressing wicked problems in dryland ecosystems

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**FOREST AND RANGELAND
STEWARDSHIP**
COLORADO STATE UNIVERSITY

Thank you | CSU Dryland Ecology and Management Lab & Extension partners



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And a special thanks to other supporting graduate and undergraduate field and research technicians!

...and our research partners on this work!



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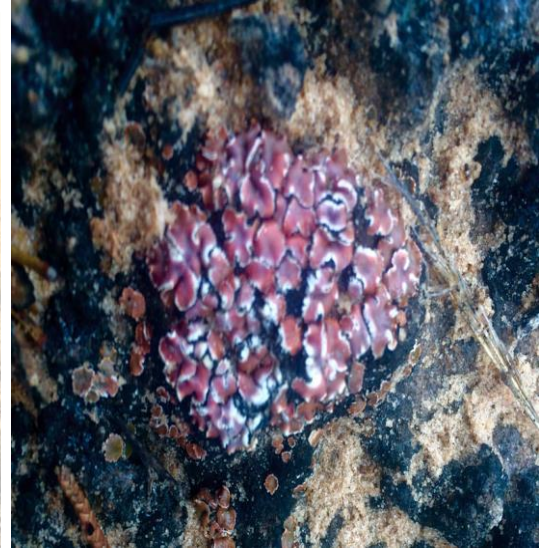
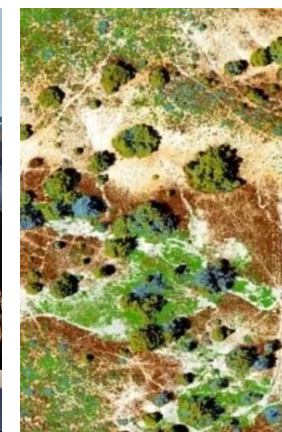
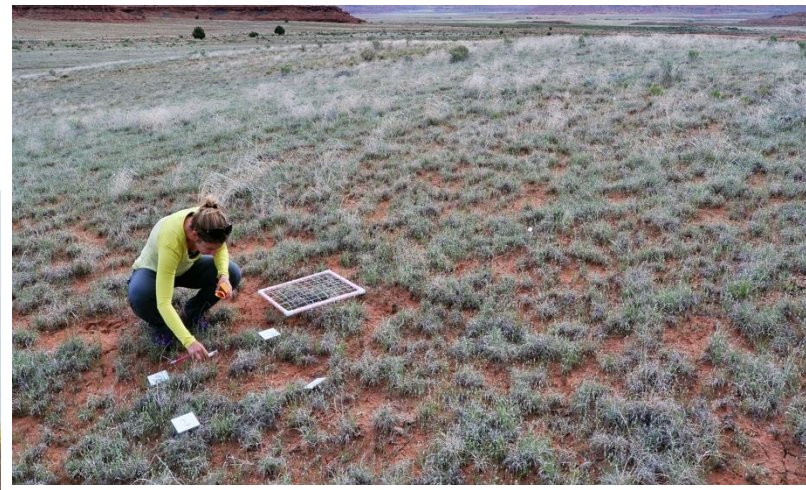


TREES, WATER & PEOPLE
Helping people and the planet



CANYONLANDS
RESEARCH CENTER





Roadmap

Photo | Katy Stites

Introduction

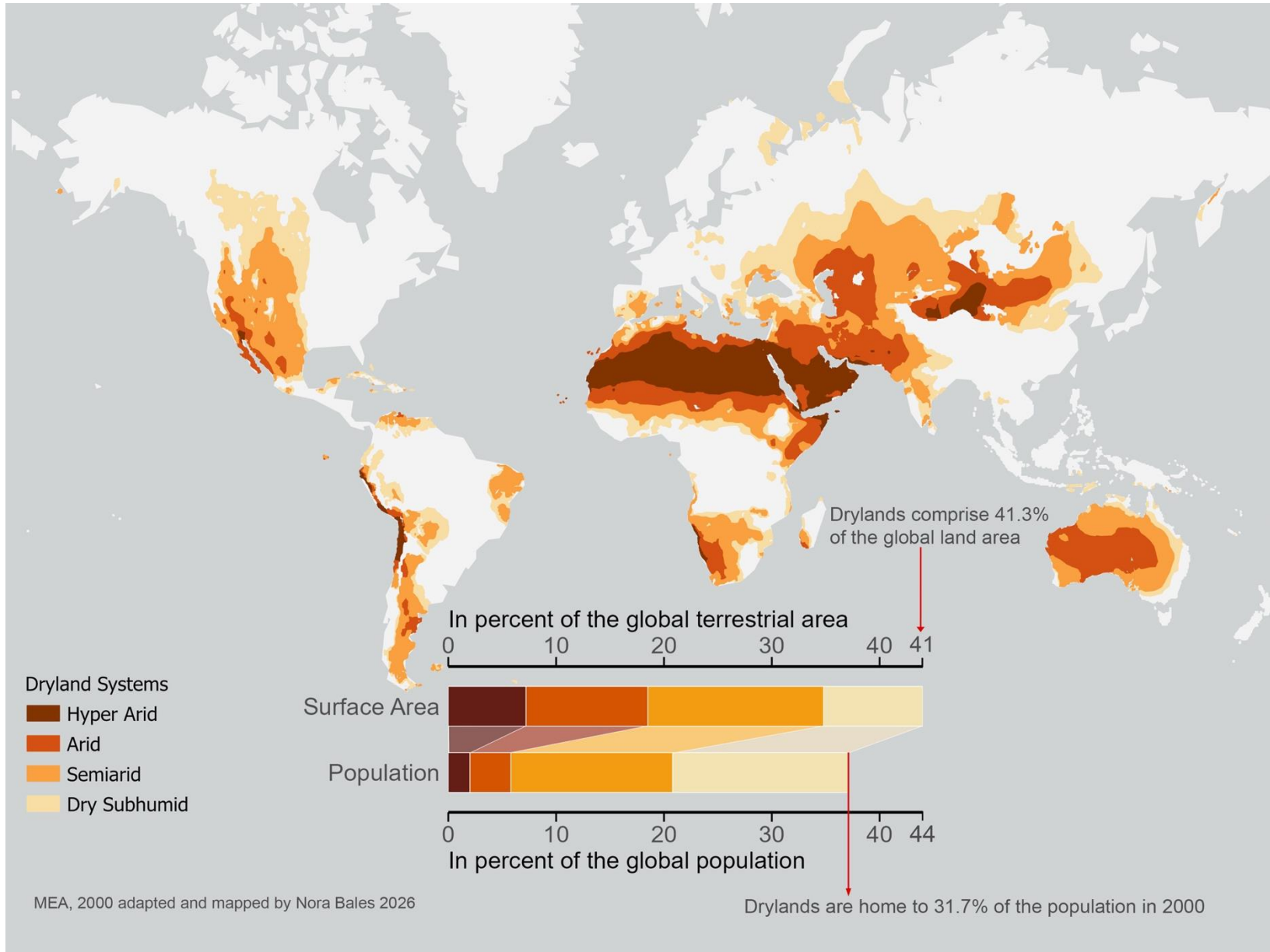
1 | Local, community-engaged
dryland precision restoration

2 | Regional, community-
engaged restoration (RestoreNet)

3 | Harnessing change for
opportunity

Wrap

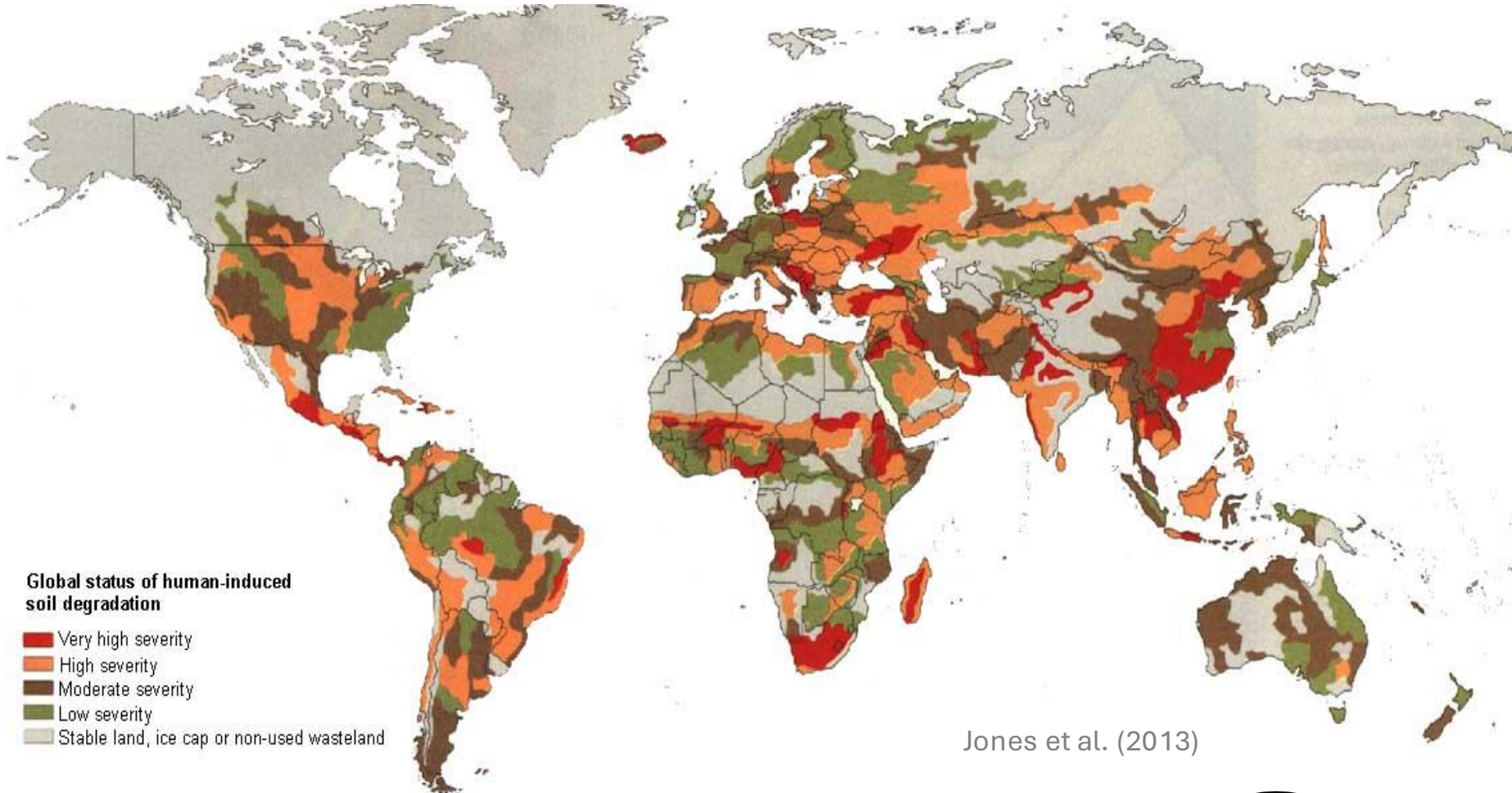
Drylands cover 40.6% of Earth's landmass & support 2.3 billion people



Drylands are highly diverse ecosystems that support immense biodiversity



Drylands experience widespread land degradation and climate change



Jones et al. (2013)

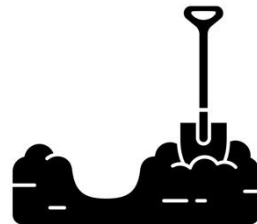


Active restoration interventions are often needed to address dryland degradation

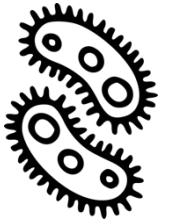
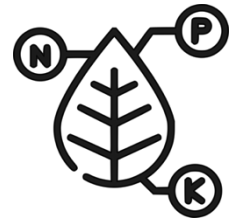
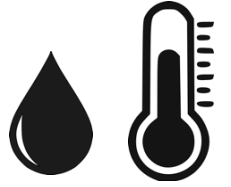
...but, conventional approaches have limited success in meeting large-scale dryland restoration projects...



Seed-based restoration



Additional restoration treatments



Precision restoration

As defined by Copeland et al. (2021)

A framework to increase the success of ecological restoration by targeting specific **biotic and abiotic barriers**

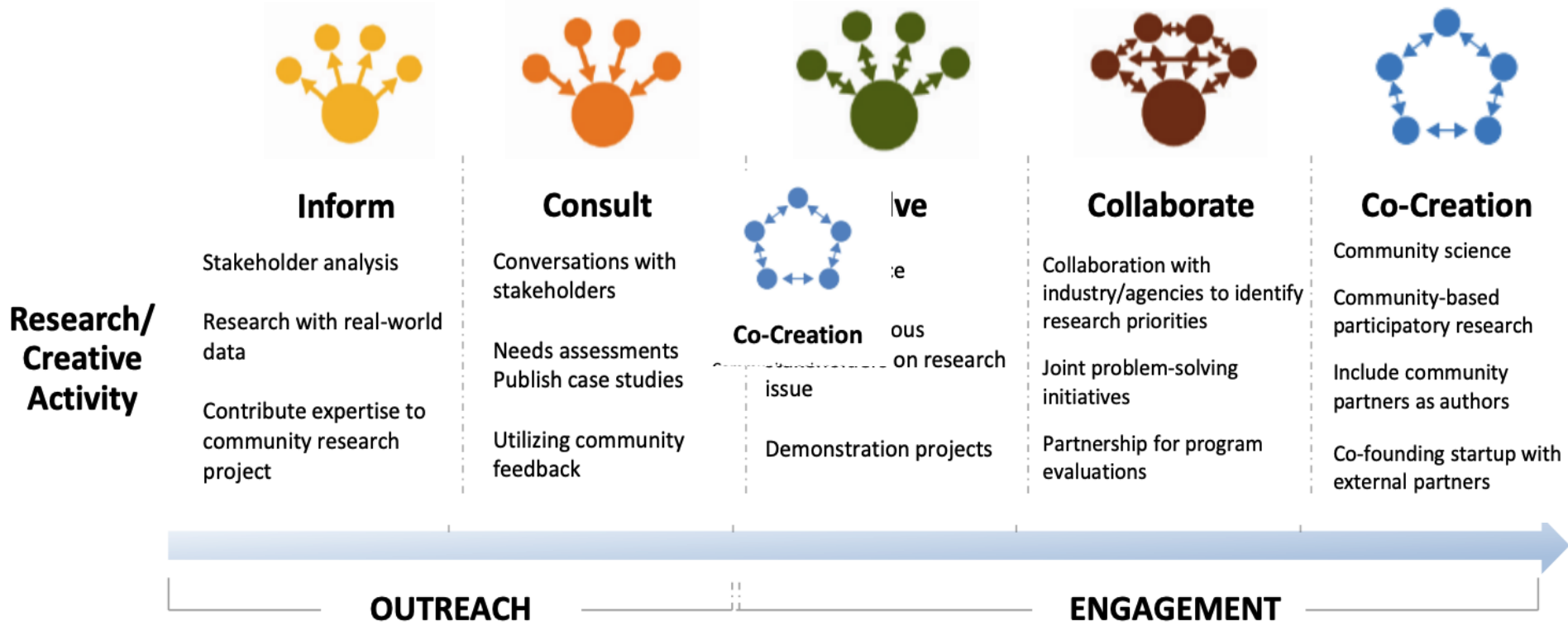
involving local communities and knowledge systems is key





Continuum of Engaged Scholarship

Engagement can be a means for accomplishing, informing and enriching research, teaching and service outcomes. This continuum outlines a variety of engaged activities with progressively increasing levels of involvement with external partners and the community.

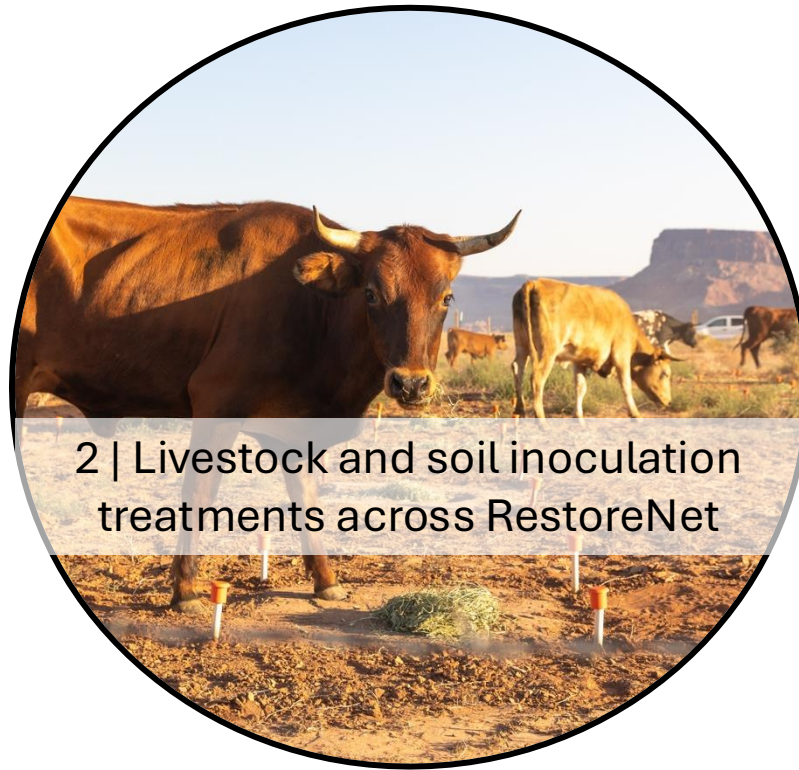
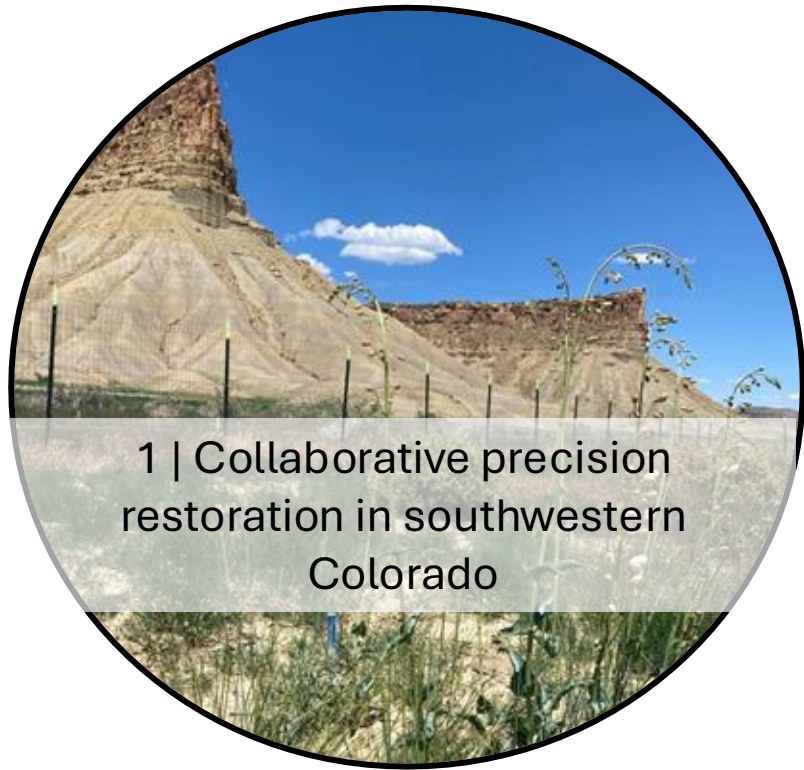


Adaptation of Colorado State University's Continuum of Engaged Scholarship (2019)



How can we use community-engaged precision restoration to restore degraded drylands?

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Introduction

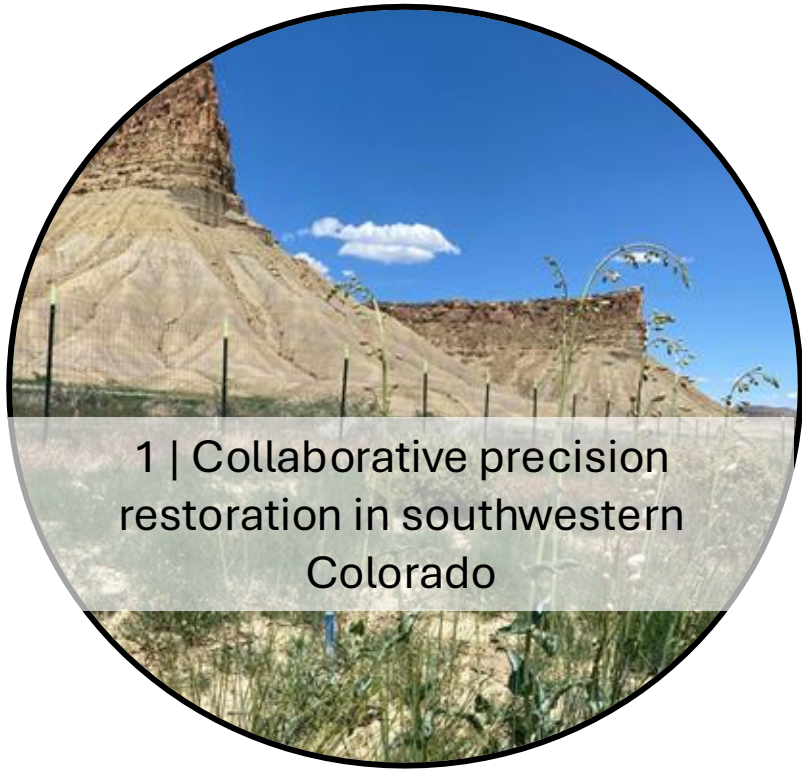
1 | Local, community-engaged dryland precision restoration

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How can we use community-engaged precision restoration to restore degraded drylands?



Introduction

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Wrap



Photo | Carrie Havrilla



“We need ‘groceries’ for the cattle.” ~ Former Chairman Manuel Heart

Photo | Carrie Havrilla

Using collaborative restoration science, how can we find solutions to promote success of seed-based restoration in degraded drylands?



Photo | Carrie Havrilla



Collaborate

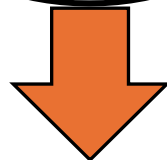
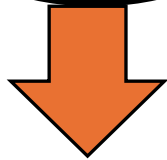


Co-Creation

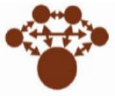
Relationship-building and collaboration



Collaborative dryland restoration research



Support the Tribe's dryland restoration decision-making



Collaborate



Co-Creation

Relationship-building and collaboration



Collaborative dryland restoration research



Support the Tribe's dryland restoration decision-making



Collaborate



Co-Creation

UMUT relationship building & research co-development

Respect and support Tribal goals and sovereignty. CSU was invited by UMUT leadership to support the Tribe's restoration and climate adaptation goals. Follow the lead of Tribal members and Environmental Programs leadership.

Acknowledge Indigenous and Traditional Ecological Knowledge. Tribal members and elders have great knowledge of these lands, plants, and ecosystems that extends back generations.

Show up. Sustain community engagement and listen. Invited participation at listening sessions to identify community needs.



Relationship-building and collaboration



Collaborative dryland restoration research



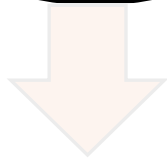
Climate-adaptive
place-based
restoration



Seed pellet
technology

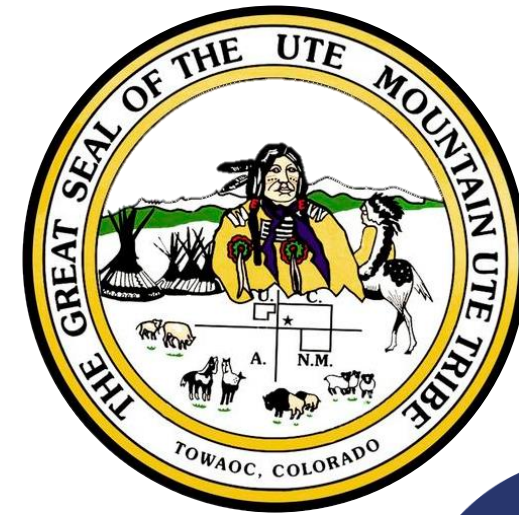


RestoreNet + local
restoration treatments



Support the Tribe's rangeland restoration decision-making

Place-based restoration of a culturally important site



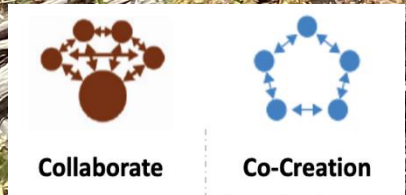
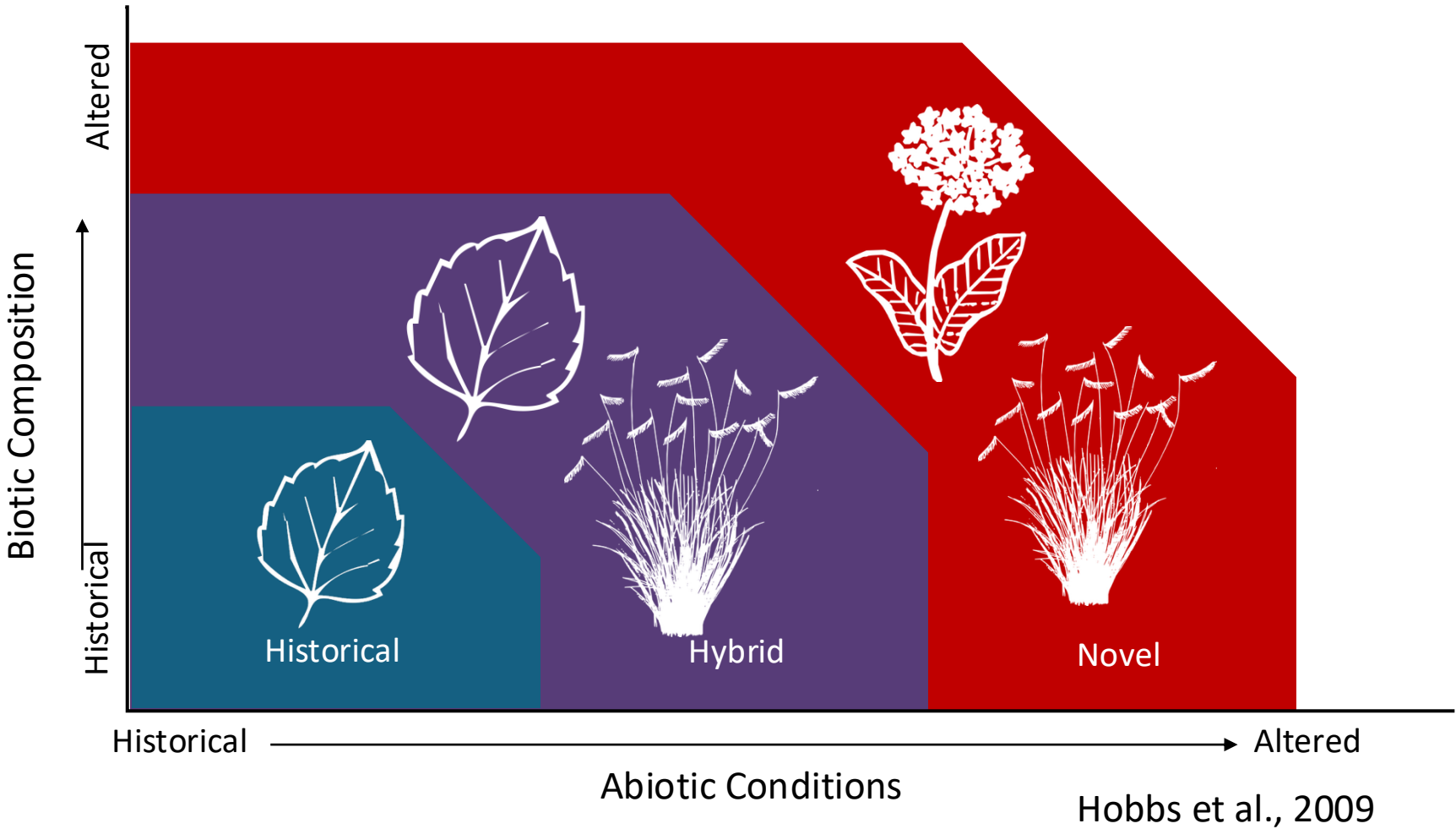
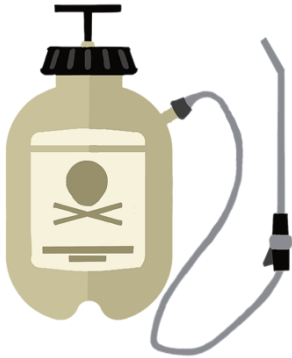
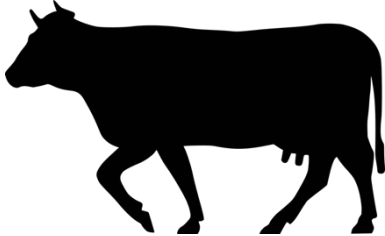


Photo | Carrie Havrilla

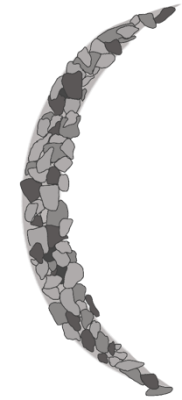
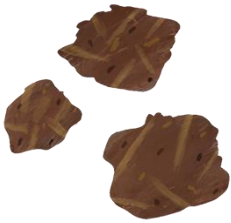
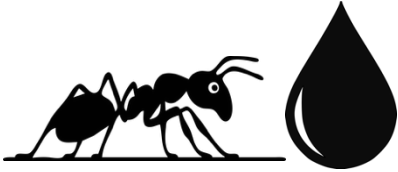
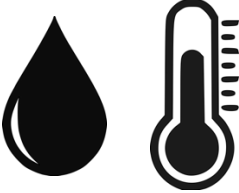
Climate-adapted restoration strategies need to reflect novel conditions



Biotic barriers



Precision restoration treatments



Precision reperiment treatments



Control



Broadcast Seeding



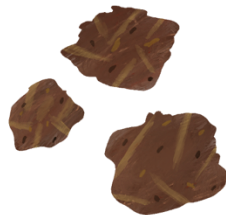
Coarse Woody Debris

+ seed 




Media Luna Rock Structures

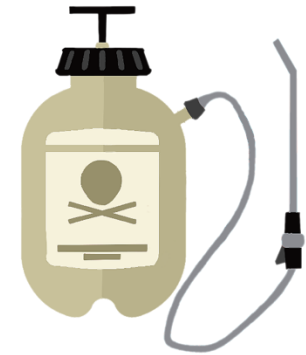
+ seed 



Seed Pellets

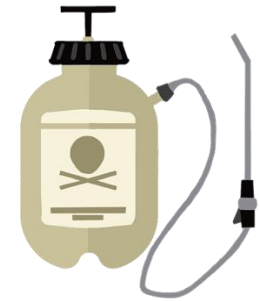
+ seed 

X

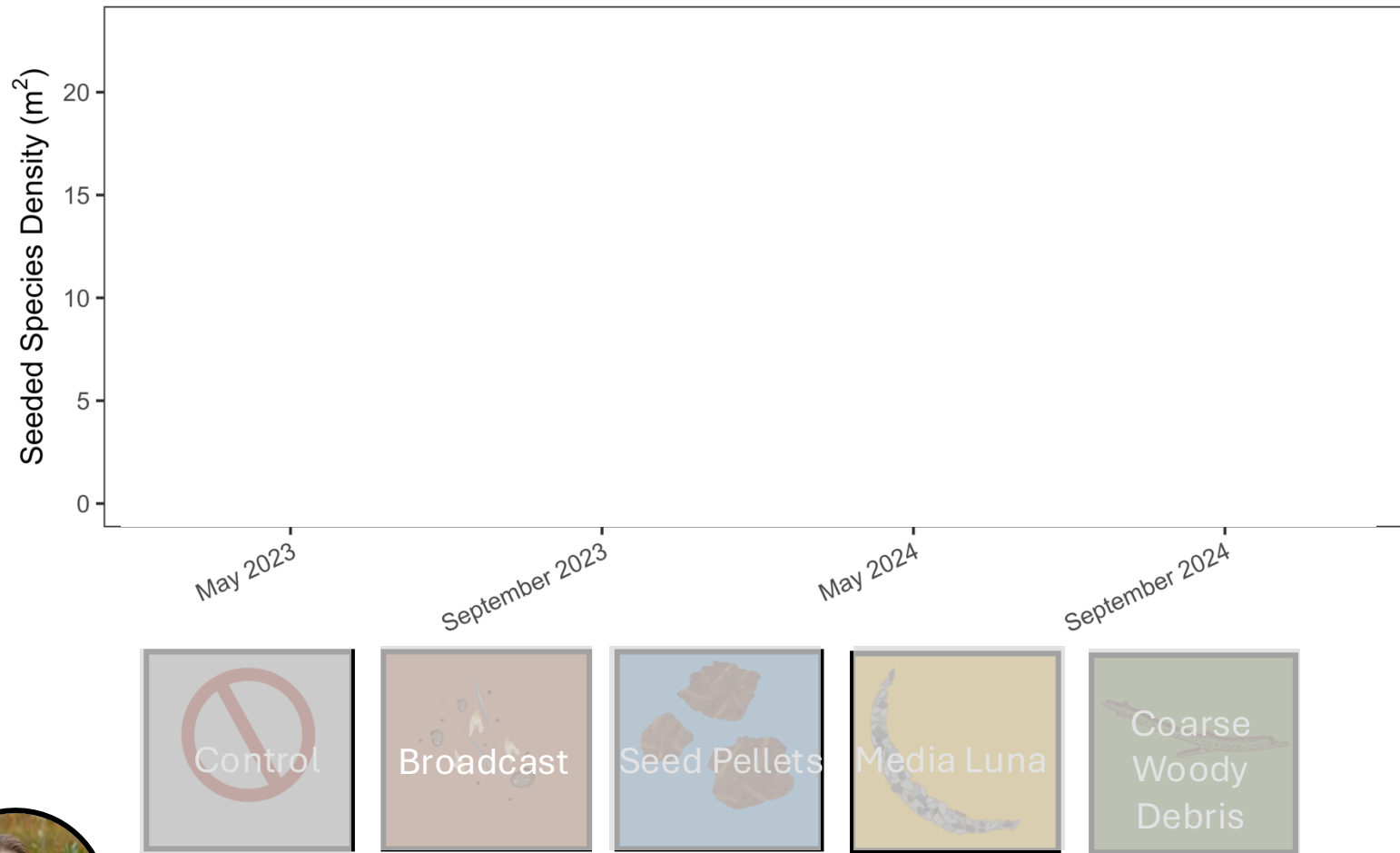


Milestone™
(aminopyralid)

Herbicide controlled knapweed, but triggered a strong secondary invasion



Treatment effects were limited, but moisture retention strategies showed promise for increasing SBR success



Relationship-building and collaboration



Collaborative dryland restoration research



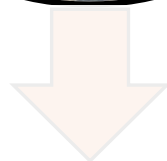
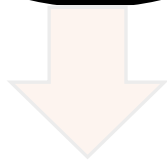
Climate-adaptive
place-based
restoration



Seed pellet
technology



RestoreNet + local
restoration treatments



Support the Tribe's rangeland restoration decision-making

Seed pellets (or “seed balls”)

Seed + Clay + Other optional Amendments



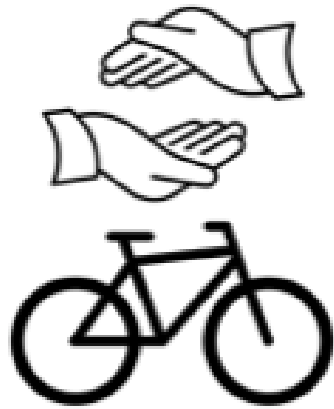
Seed pellets may be useful because:

- Protect seeds from potential predators
- Protect seeds until germination conditions are ideal (e.g., large precipitation event)
- Improve seed distribution and seeding efficiency
- Easy way to add amendments
- May improve germination and establishment success

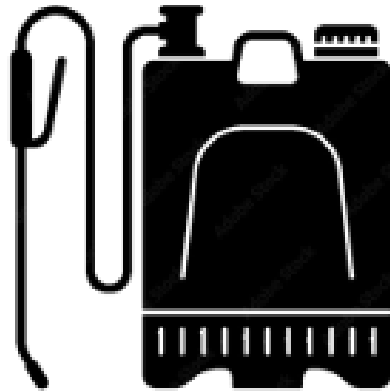
...but our understanding of best practices for seed pellet synthesis in precision restoration is limited...



Seed pellet experiments (*in the greenhouse*)



METHOD

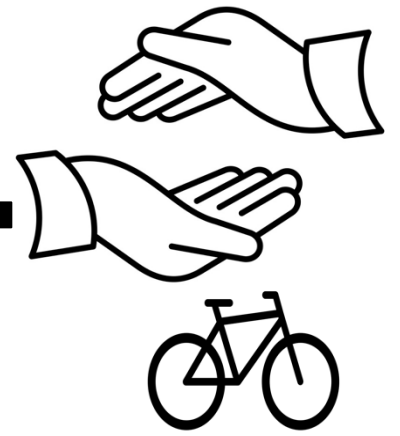


HERBICIDE
PROTECTION



SOIL
MICROBIAL
ADDITIONS

METHOD



Which method of making seed pellets best supports seedling establishment?



Hand-made



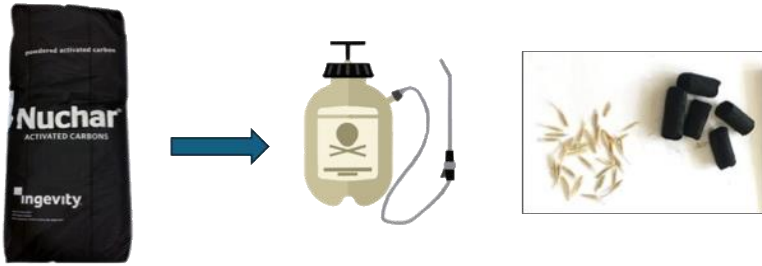
Mechanically-made



Mechanically-made seed pellets increased seeded species establishment relative to broadcast seeding



Does adding activated carbon to seed pellets protect seedlings from herbicide?



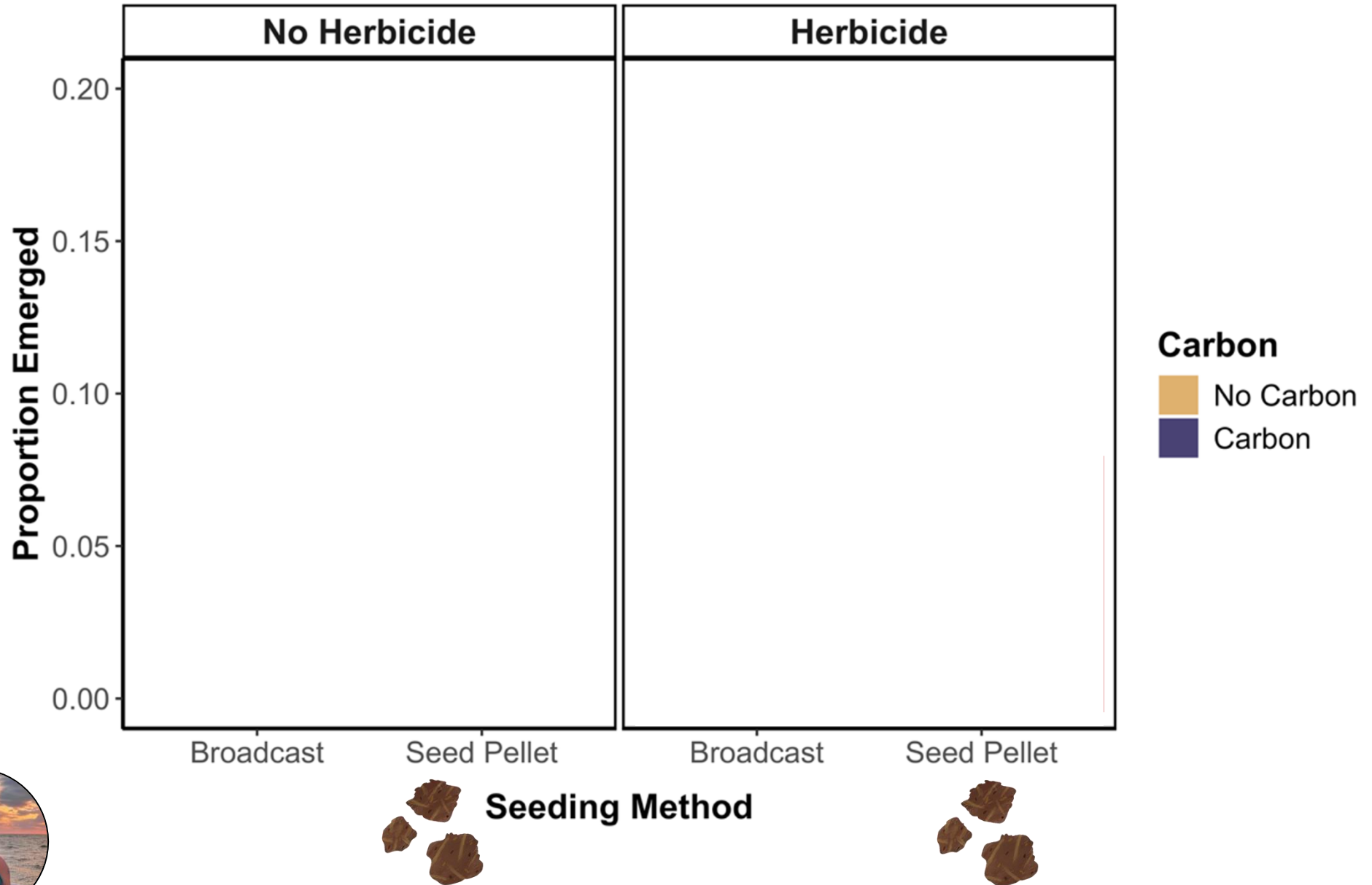
	Seed Pellet or Broadcast	Clay	Carbon	Herbicide
Experiment 1: Activated Carbon and Herbicide			or	or
			+ or	or

Swartz, Caldwell, and Havrilla (2026)





HERBICIDE
PROTECTION





SOIL MICROBIAL ADDITIONS

Biocrust: soil surface dwelling communities of: cyanobacteria, lichen, and moss.

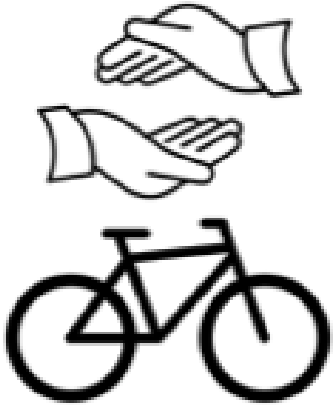
Benefits: soil stability, water retention, improved fertility (N)

Does adding biocrust inoculum to seed pellets promote seed germination and growth?

Finding: Yes! Soil microbial additions (biocrust) improved emergence in and out of seedballs



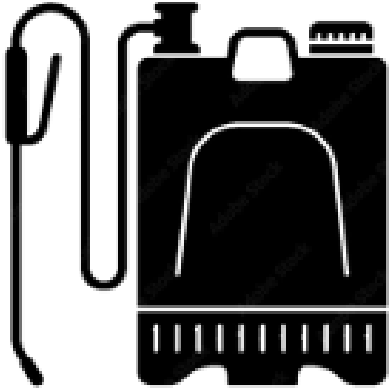
Summary: promising seed pellet strategies and amendments



METHOD



MECHANICALLY-MADE



HERBICIDE PROTECTION



ACTIVATED CARBON



SOIL MICROBIAL ADDITIONS

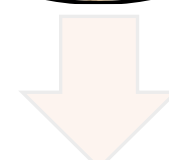
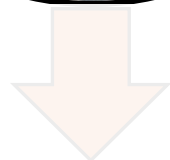
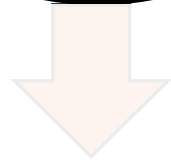


BIOCRUST INOCULUM

Relationship-building and collaboration



Collaborative dryland restoration research



Support the Tribe's rangeland restoration decision-making

RestoreNet: Distributed Field Trial Network for Dryland Restoration

ACTIVE

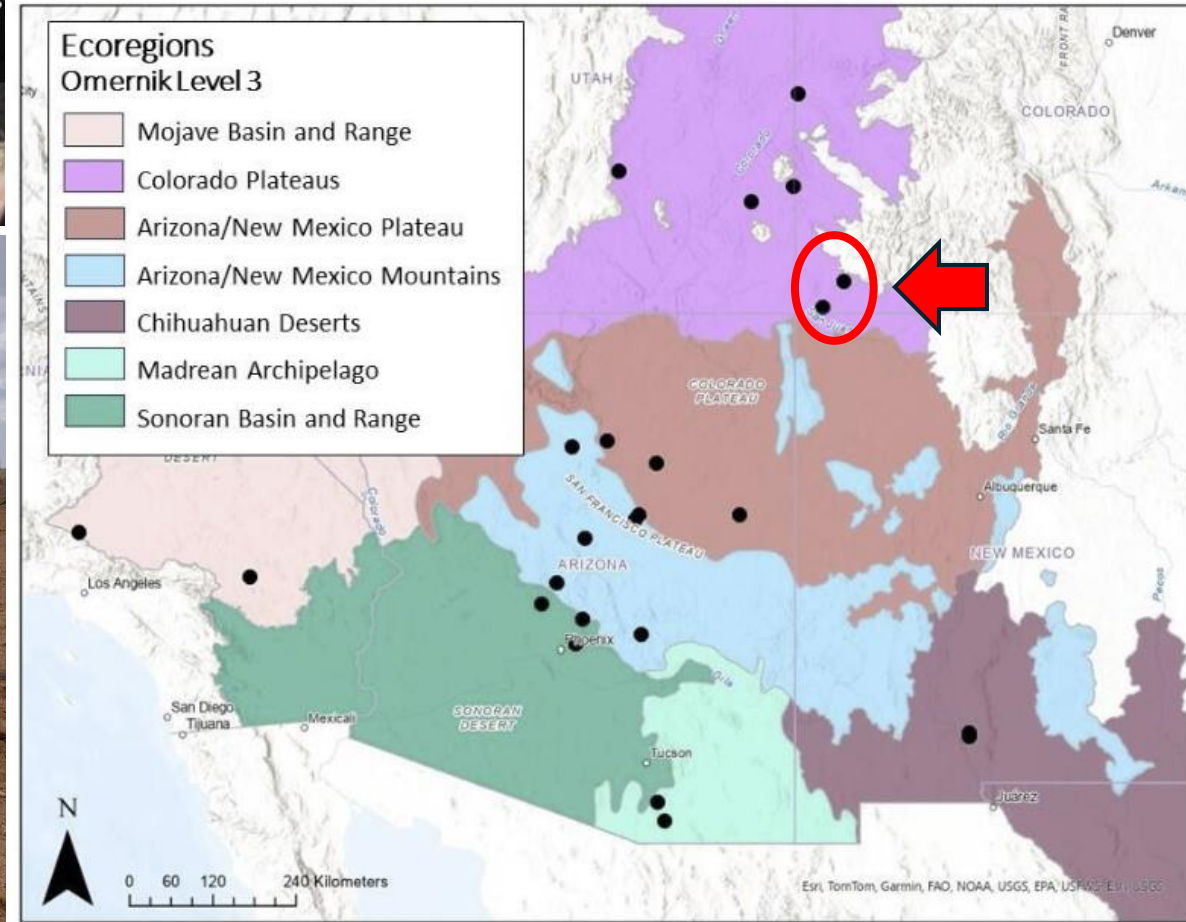
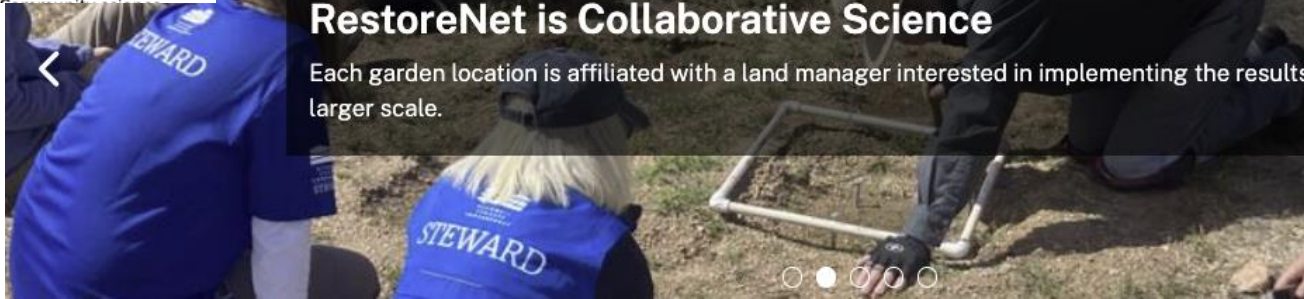
By [Southwest Biological Science Center](#) August 5, 2017



Co-Creation

RestoreNet is Collaborative Science

Each garden location is affiliated with a land manager interested in implementing the results larger scale.







Outplanting success

Once plants establish, they can survive and thrive

- “Restoration islands” may be a restoration tool

Most successful species:

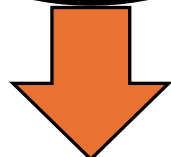
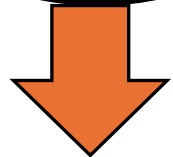
- *Pascopyrum smithii* (Western wheatgrass)
- *Krascheninnikovia lanata* (Winterfat)
- *Oryzopsis hymenoides* (Indian Ricegrass)
- *Linum lewisii* (Blue flax)
- *Penstemon palmeri* (Palmer’s penstemon)



Relationship-building and collaboration



Collaborative dryland restoration research



Support the Tribe's dryland restoration decision-making

Broadcast seeding alone is ineffective

Low-cost water retention treatments (e.g., pits, woody debris) may improve seeding success

Seed pellets can aid establishment, but it matters how you make them and what's in them

Outplanting success suggests "restoration" islands may be an important future tool



USDA awards CSU, Ute Mountain Ute Tribe \$1 million for rangeland climate resilience

08 Jan, 2025
By [Jayme DeLoss](#)

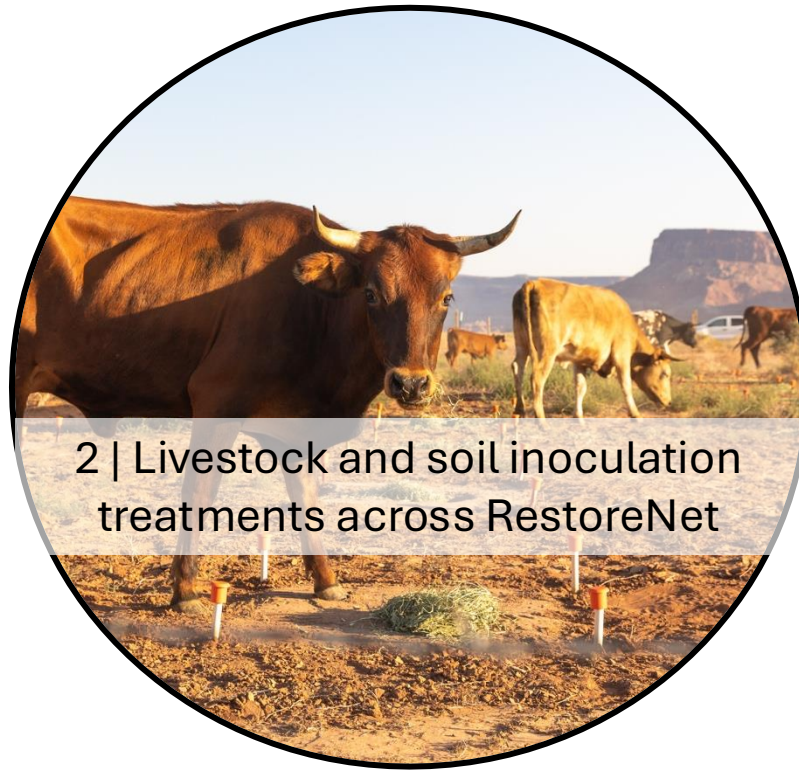


Cattle graze on rangeland in western Colorado, a region impacted by drought. Drought and climate change threaten rangeland livelihoods in the western U.S., but a new CSU effort aims to promote climate-smart agricultural practices and increase the long-term resilience and sustainability of rangelands. Photo by Retta Bruegger

“The Tribe is excited and proud to be an integral part of the STEERS project. We believe this effort will help guide the Tribe forward in its efforts to improve climate resilience.”

~ Manuel Heart, chairman of the Ute Mountain Ute Tribe

How can we use community-engaged precision restoration to restore degraded drylands?



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RestoreNet: Distributed Field Trial Network for Dryland Restoration

ACTIVE

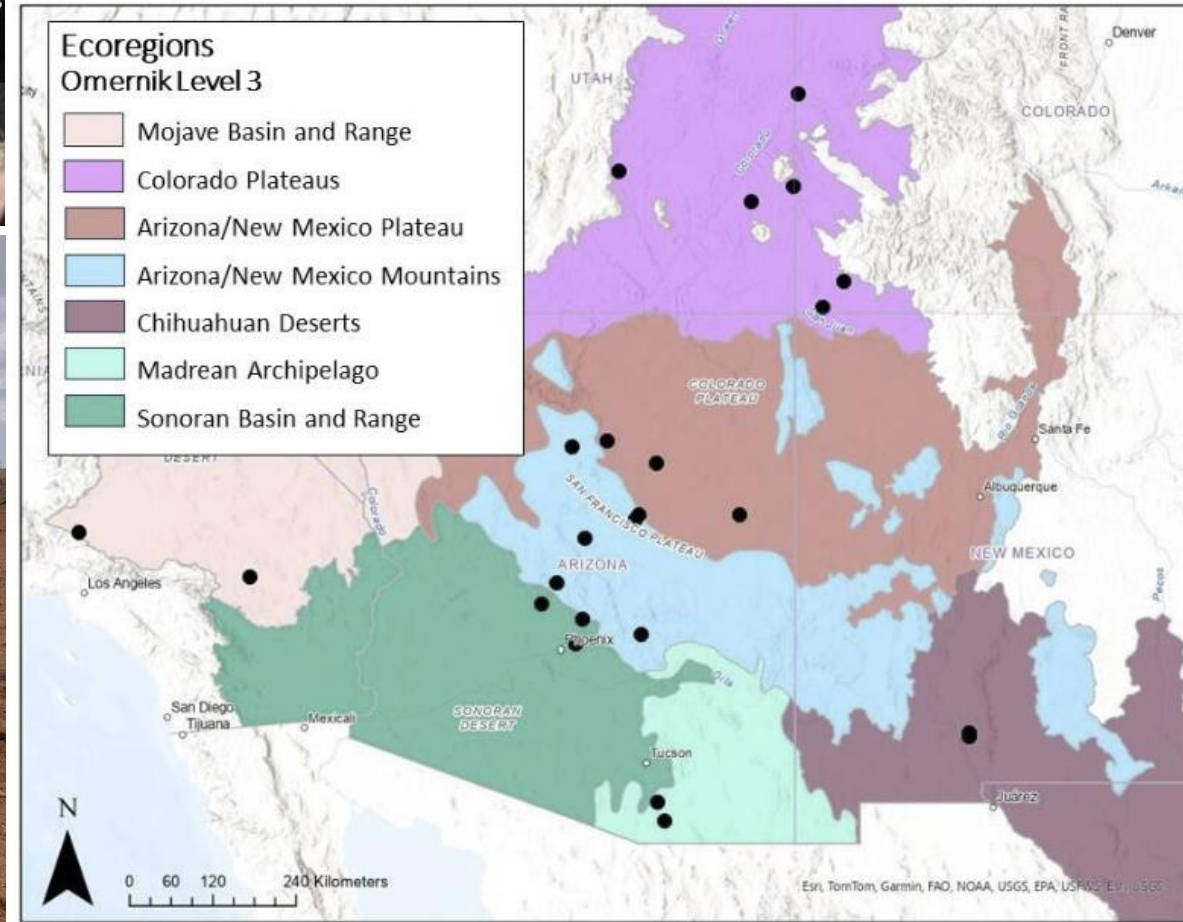
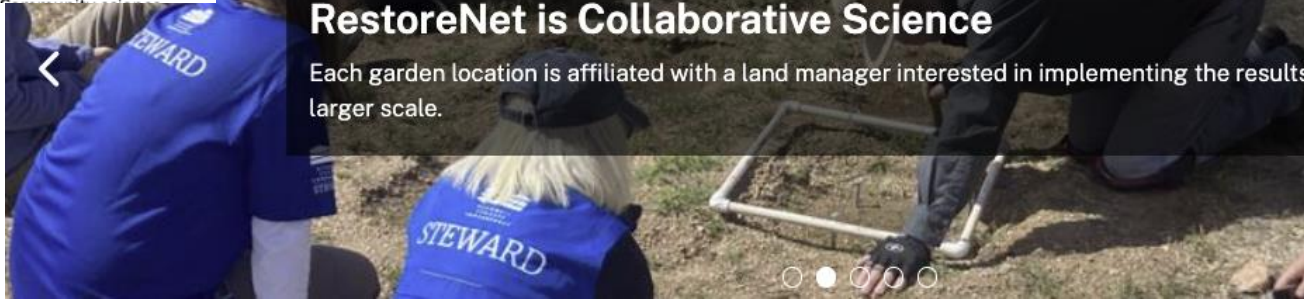
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RestoreNet “1.0” restoration treatments



Journal of Applied Ecology

RESEARCH ARTICLE | [Free Access](#)

RestoreNet: An emerging restoration network reveals controls on seeding success across dryland ecosystems

[Caroline A. Havrilla](#) ✉, [Seth M. Munson](#), [Molly L. McCormick](#), [Katherine M. Laushman](#), [Kathleen R. Balazs](#), [Bradley J. Butterfield](#)

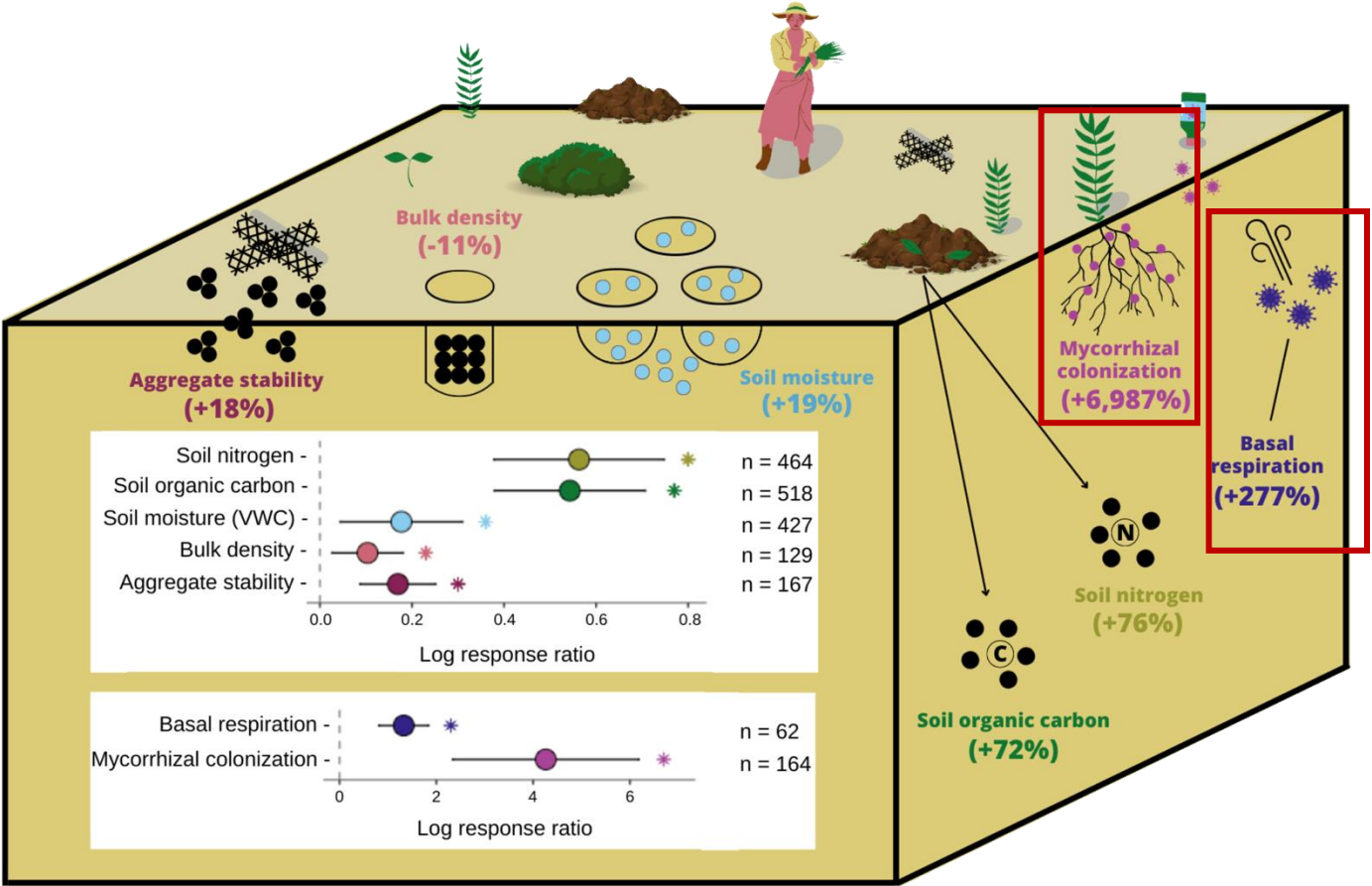
ECOLOGICAL APPLICATIONS
ECOLOGICAL SOCIETY OF AMERICA

ARTICLE | [Full Access](#)

Soil surface treatments and precipitation timing determine seedling development across southwestern US restoration sites

[Hannah L. Farrell](#), [Seth M. Munson](#) ✉, [Bradley J. Butterfield](#), [Michael C. Duniway](#), [Akasha M. Faist](#), [Elise S. Gornish](#), [Caroline A. Havrilla](#), [Loralee Larios](#), [Sasha C. Reed](#), [Helen I. Rowe](#) ... [See all authors](#) ▾

Soil restoration improves soil health across global drylands



Kimmell, Fagan, & Havrilla (2023)



Precision restoration treatments



X

X

Abiotic

Biotic

Pits



Seed Pellets



Soil inoculation





Photo | Katy Stites






















Photo | Katy Stites



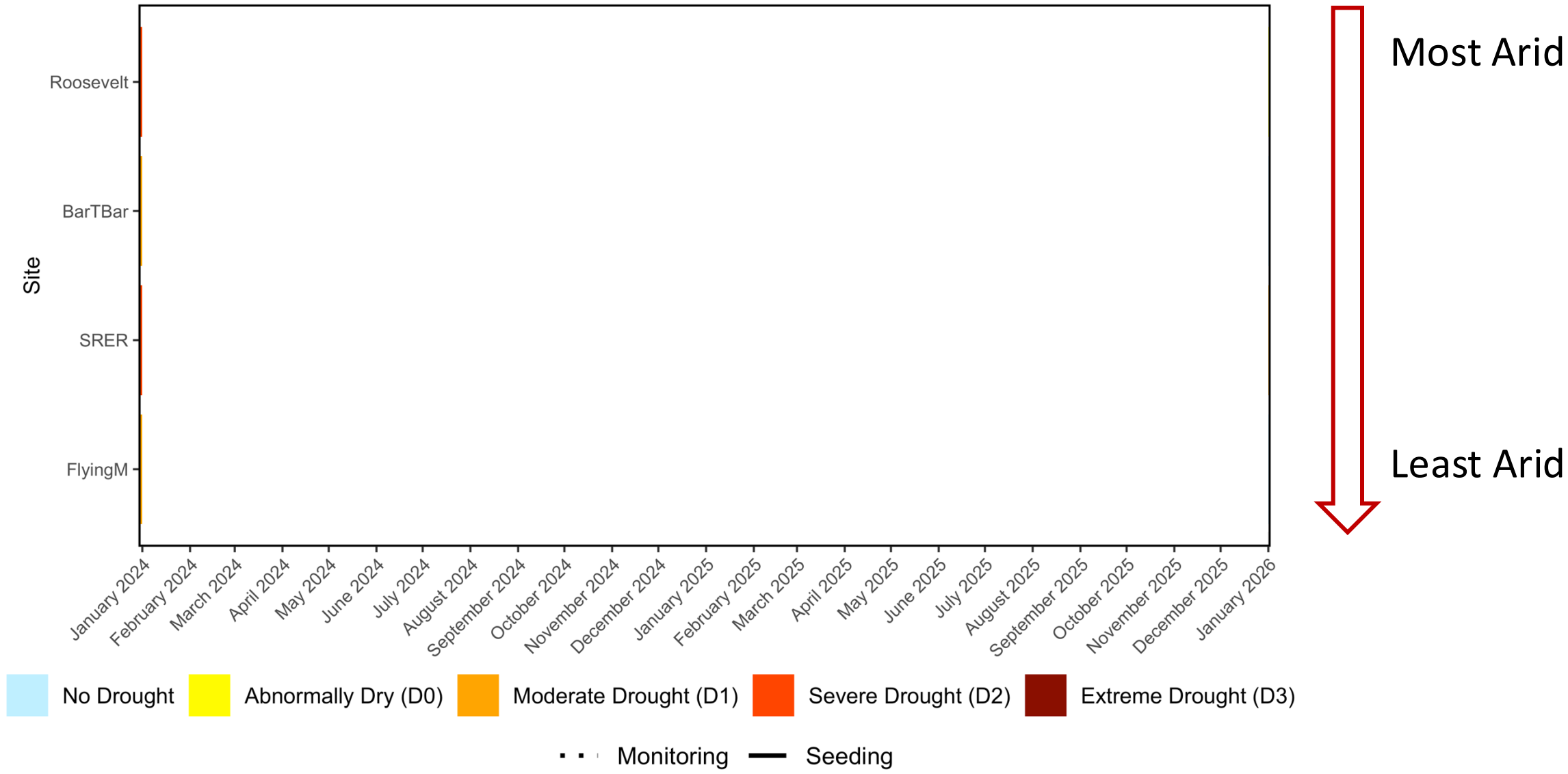
Restoration treatments (increasing intensity)



 Control	 +  Control + Soil Inoculum (High Volume)
 Broadcast Seed	 +  Broadcast Seed + Soil Inoculum (High Volume)
 +  Pits + Broadcast Seed	 +  +  Pits + Broadcast Seed + Soil Inoculum (High Volume)
 Seed Pellets	 +  Seed Pellets + Soil Inoculum (Low Volume)
 +  Pits + Seed Pellets	 +  +  Pits + Seed Pellets + Soil Inoculum (Low Volume)



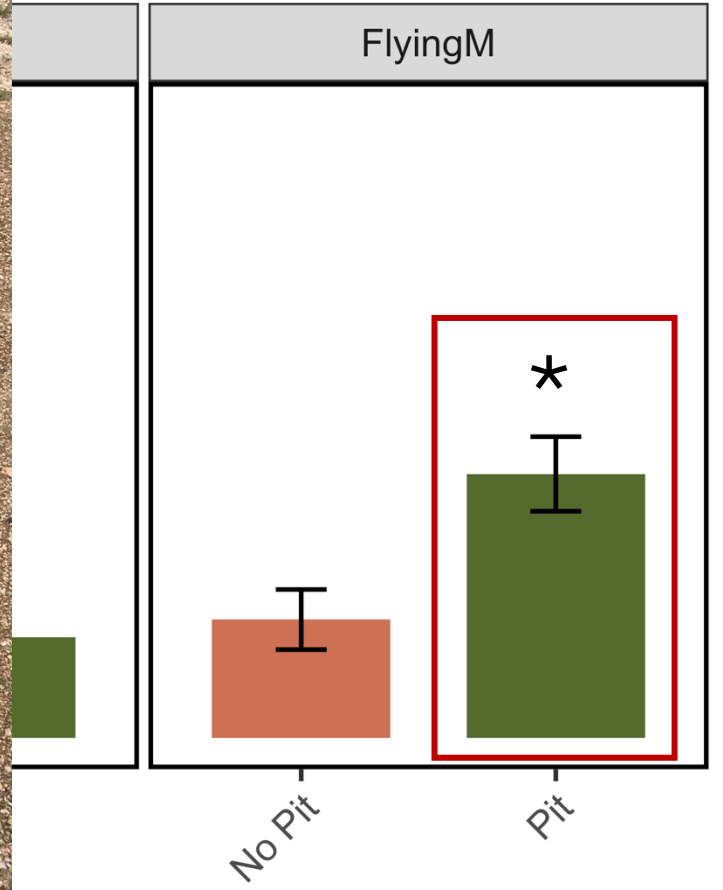
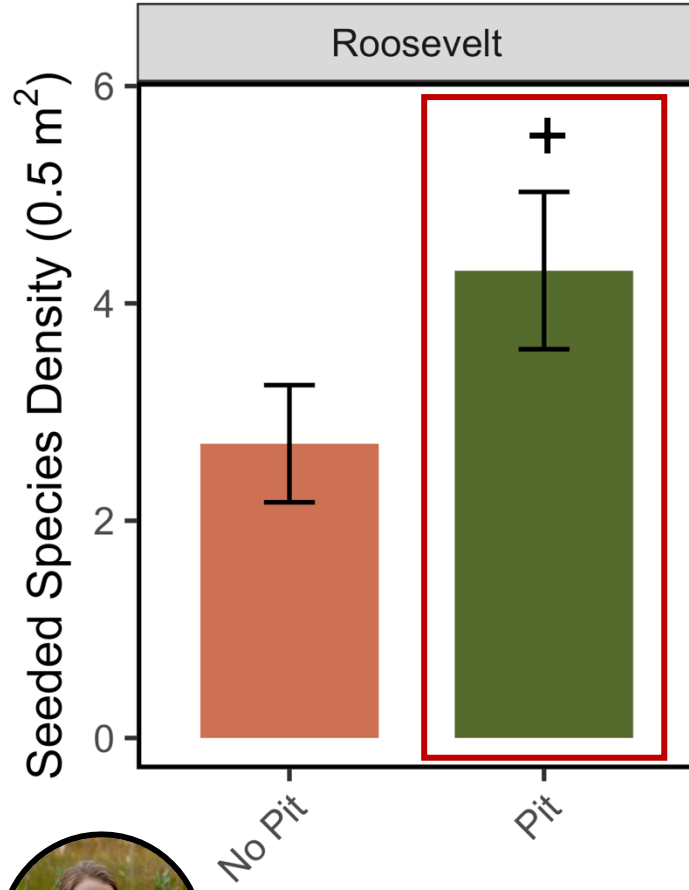
Treatment effects have been constrained by drought



Pitting increased density at sites characterized by pulse precipitation

Most Arid

Least Arid



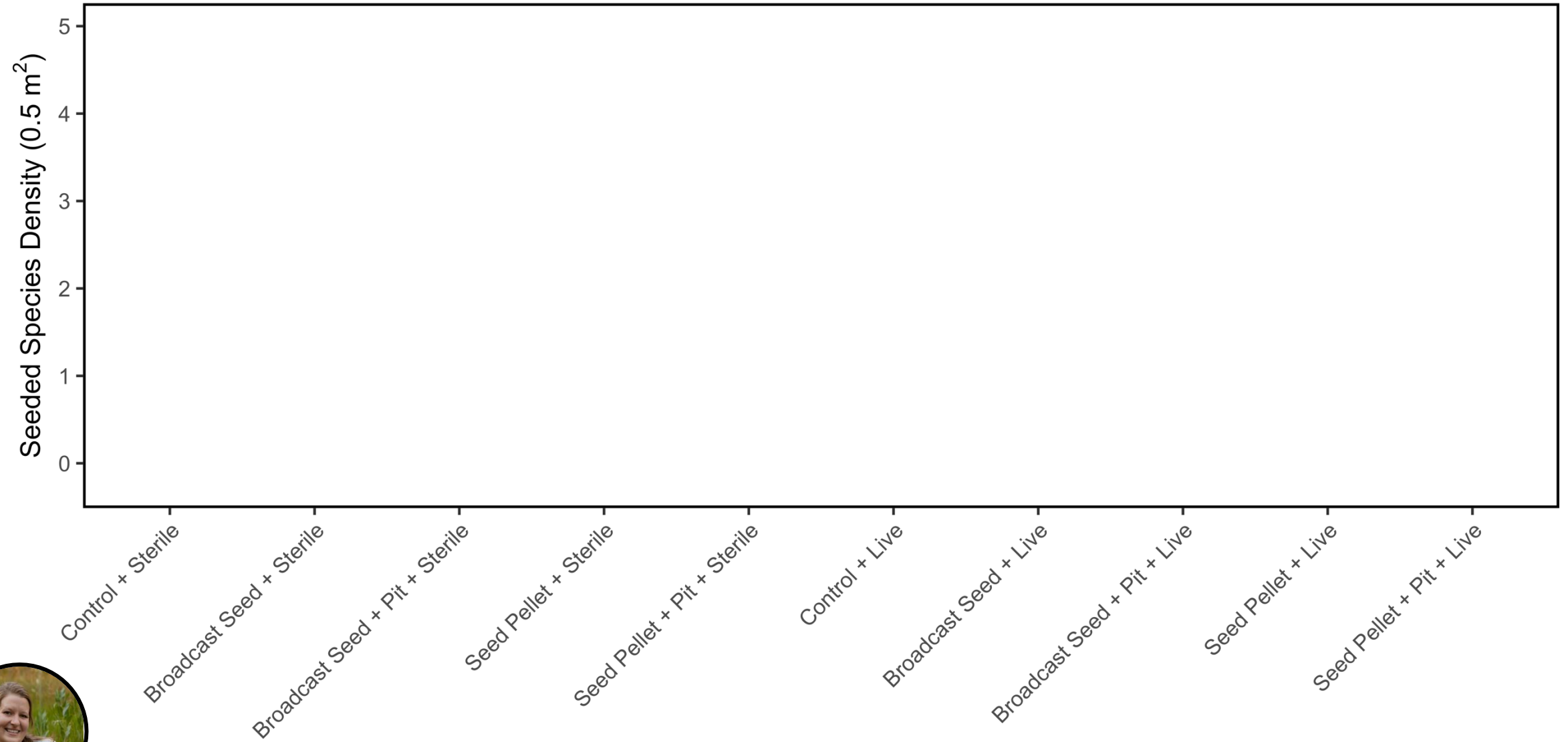
Targeted livestock treatment overall had neutral effects on seedling density

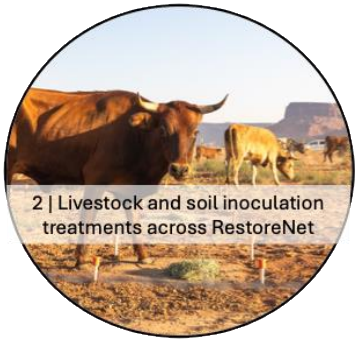


Active seeding increased desirable species density, but soil inoculum and seed pellets had neutral effects



Soil inoculation





Take aways

- Environmental conditions (drought, again!) likely constrained treatment impacts
- Soil moisture retention through pitting showed promise, while seed pellets, soil inoculum and livestock treatment had largely neutral effects
- Layered restoration interventions did not increase success under drought conditions. More is not more when the conditions are wrong.



How can we use community-engaged precision restoration to restore degraded drylands?



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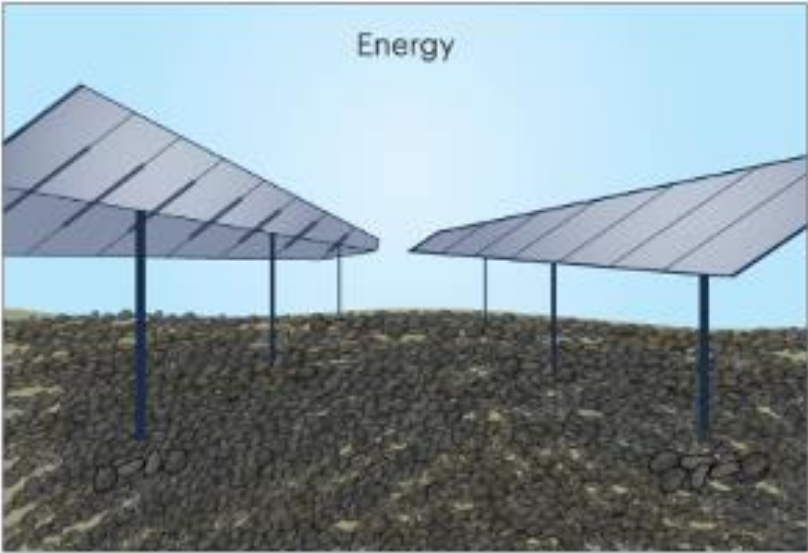
3 | Harnessing change for opportunity

Wrap

Dryland solar development – a double-edged sword for dryland restoration?

Photovoltaics

Energy



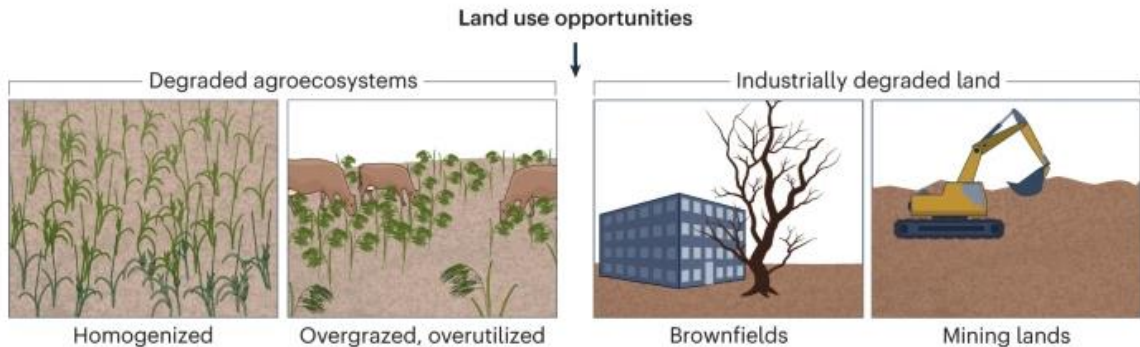
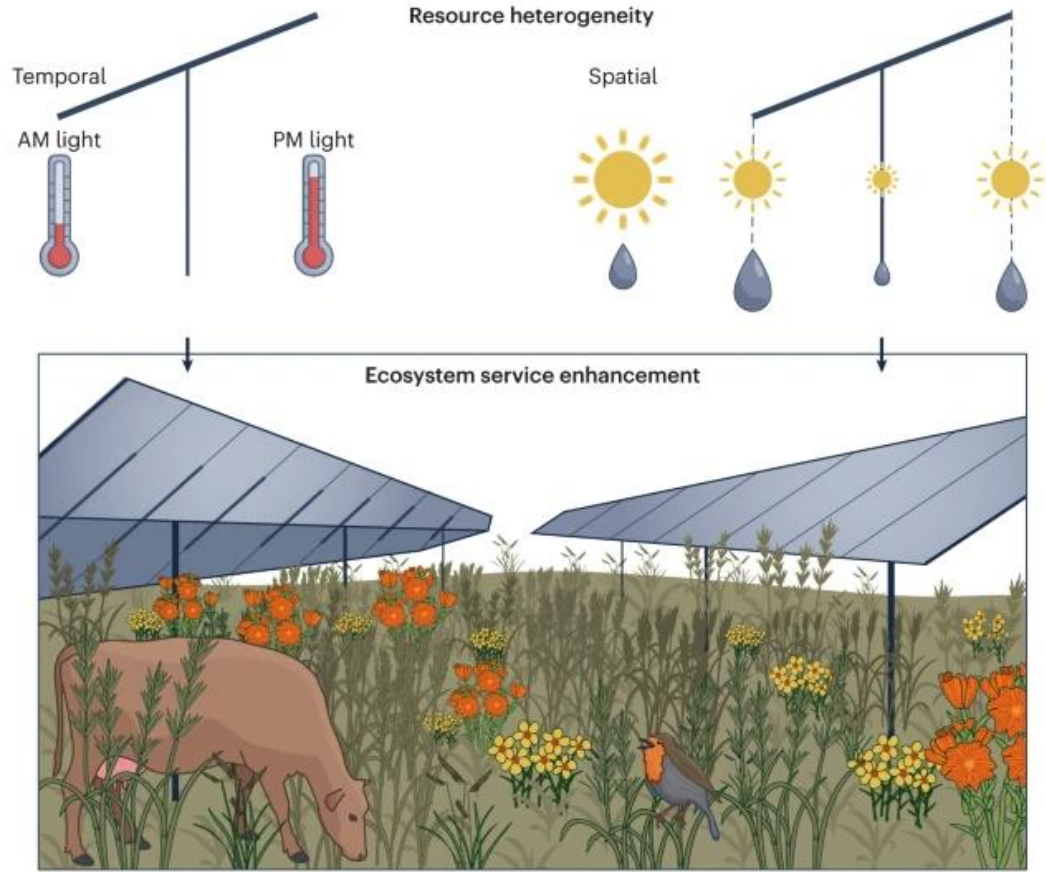
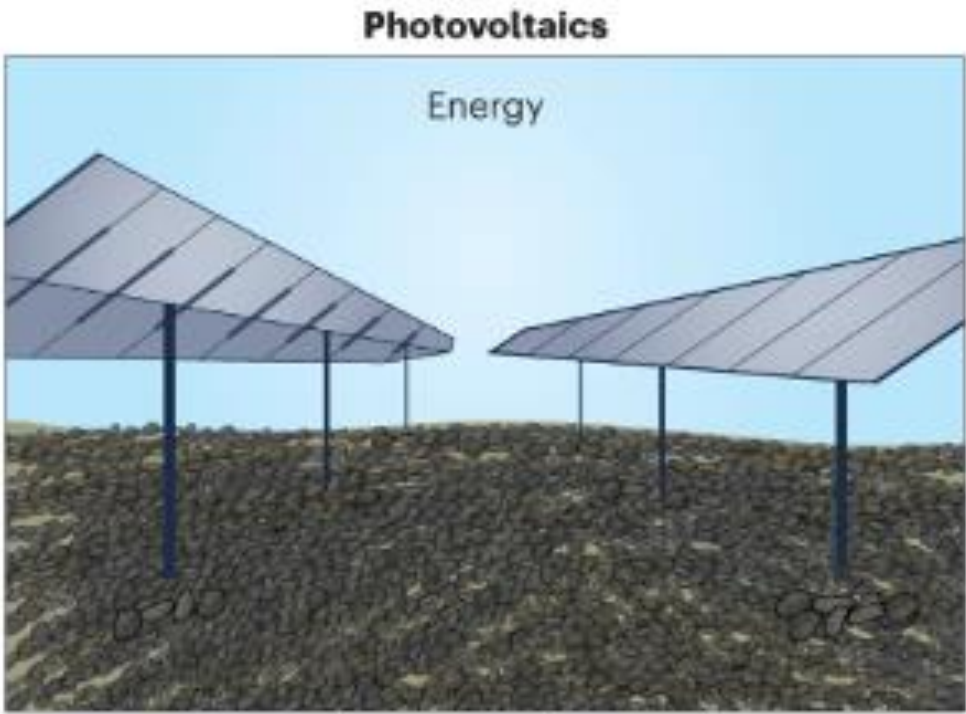
Sun Bear Project





Photo | Pivot Energy

Ecovoltaics



Sturchio & Knapp (2023)

Exploring potential synergies between PV systems and dryland restoration

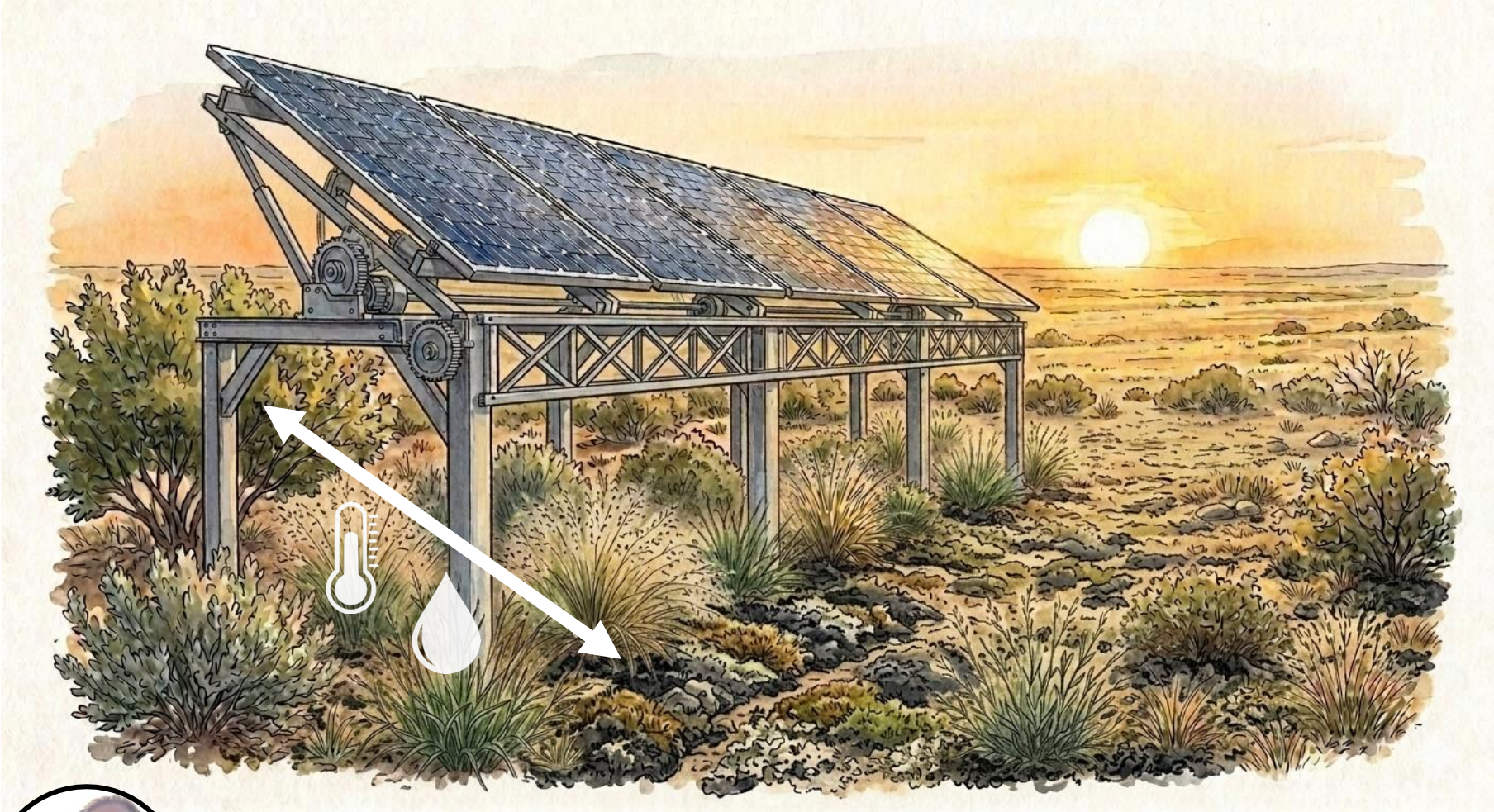


Figure generated with Google AI (Nano Banana 2)



Precision restoration, sustained engagement, and creativity are key to tackling barriers to dryland restoration



1 | Collaborative precision restoration in southwestern Colorado

Co-producing science with local communities supports improved decision-making, resource allocation, and restoration success



2 | Livestock and soil inoculation treatments across RestoreNet

Stories of low success are important too, and support resource allocation, and next steps of collaborative learning



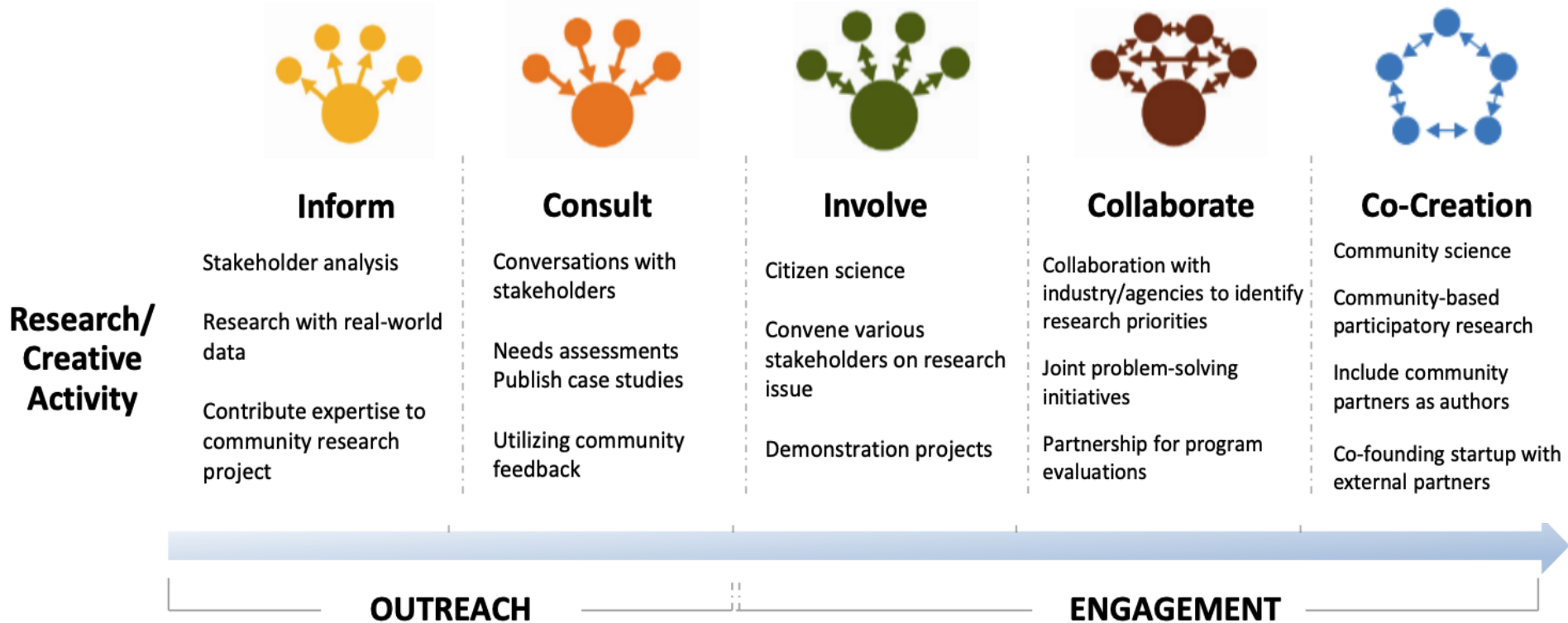
3 | Ecovoltaics: Harnessing the upsides of change?

Change is hard. But some changes may also provide opportunity



Continuum of Engaged Scholarship

Engagement can be a means for accomplishing, informing and enriching research, teaching and service outcomes. This continuum outlines a variety of engaged activities with progressively increasing levels of involvement with external partners and the community.



Adaptation of Colorado State University's Continuum of Engaged Scholarship (2019)



Questions? | Get in touch



Check out our lab!

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