Mulching and Soil Depressions for Revegetation of Oil and Gas Wells in Arid Ecosystems





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U.S. Department of the Interior
U.S. Geological Survey

Today's talk

1. Brief origin of our research interests in oil and gas reclamation

2. "BLM Reclamation Review": findings about mulch & soil depressions

3. "WPRR": Collaborative field research project
   - Study design
   - Results comparing mulching and soil depressions

4. Research Conclusions

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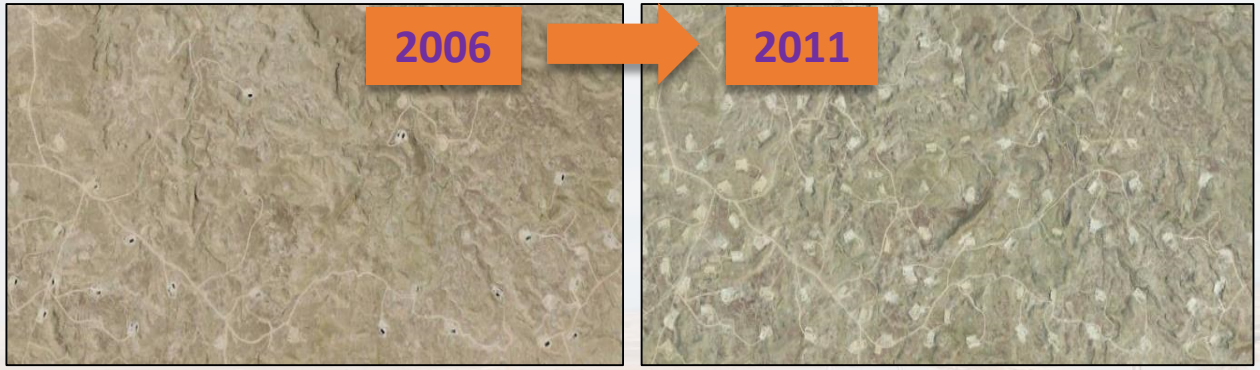
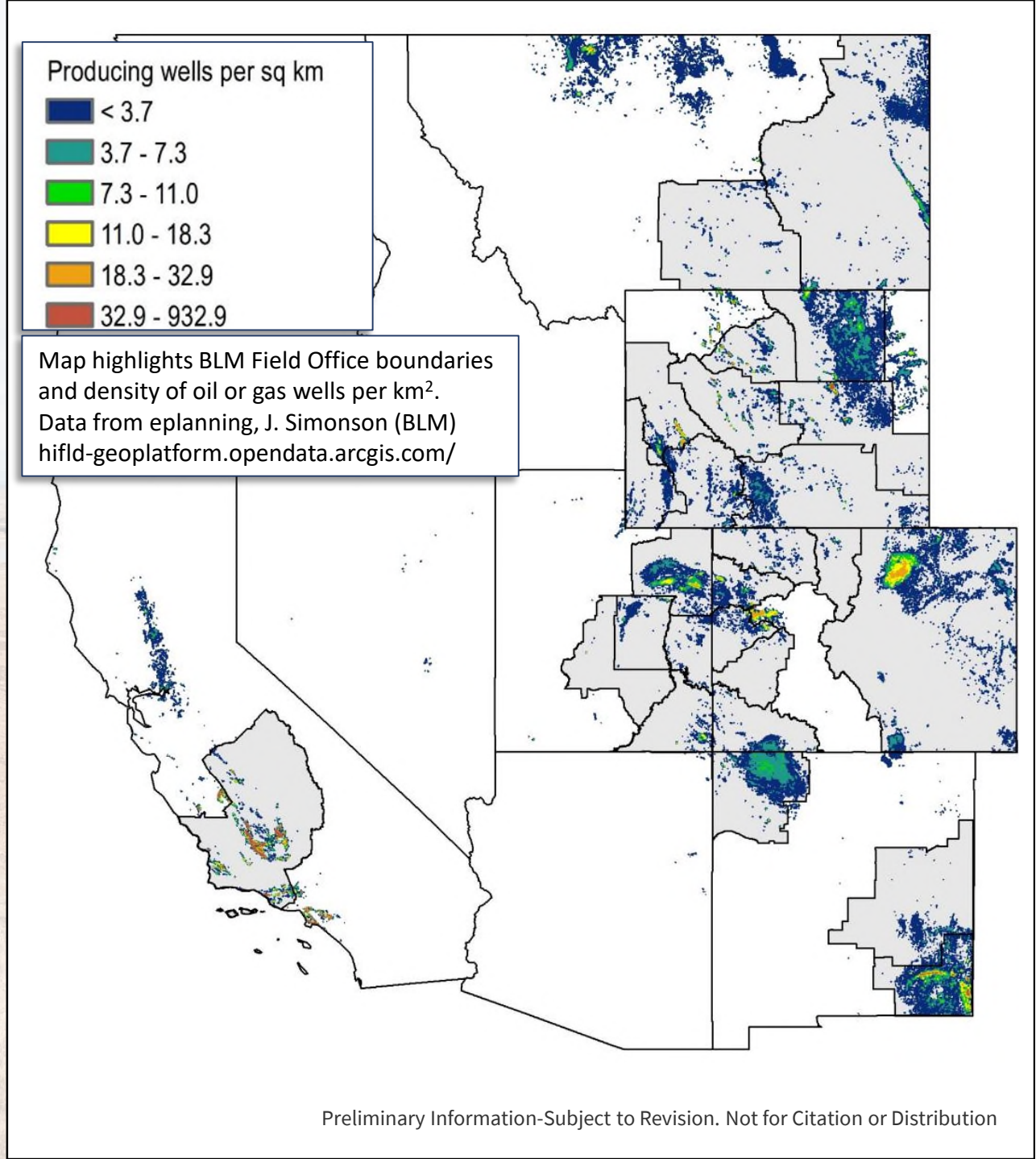
Energy & mineral development on arid Public land in the Intermountain West



	# Wells	Acres
Existing	69,000	275,000
In Progress	221,000	1.2 million
TOTAL	**290,000**	**1.5 million**



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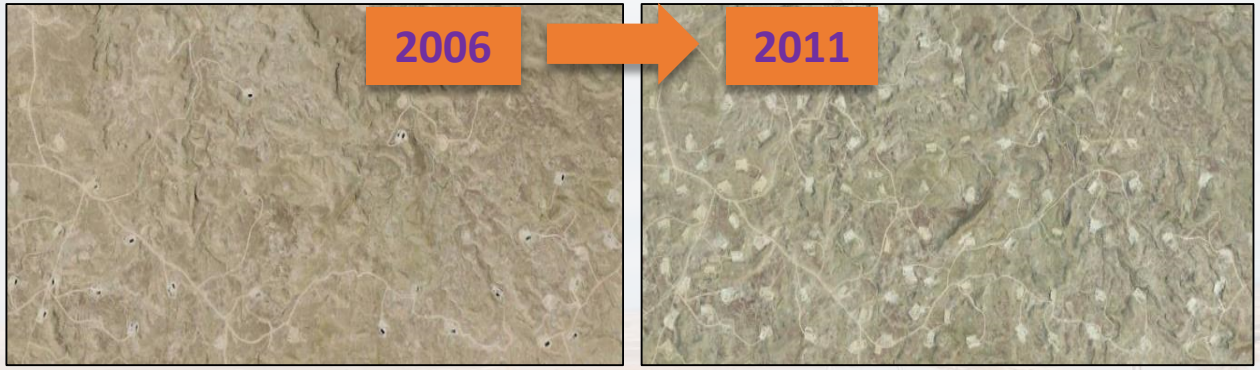
Energy & mineral development on arid Public land in the Intermountain West



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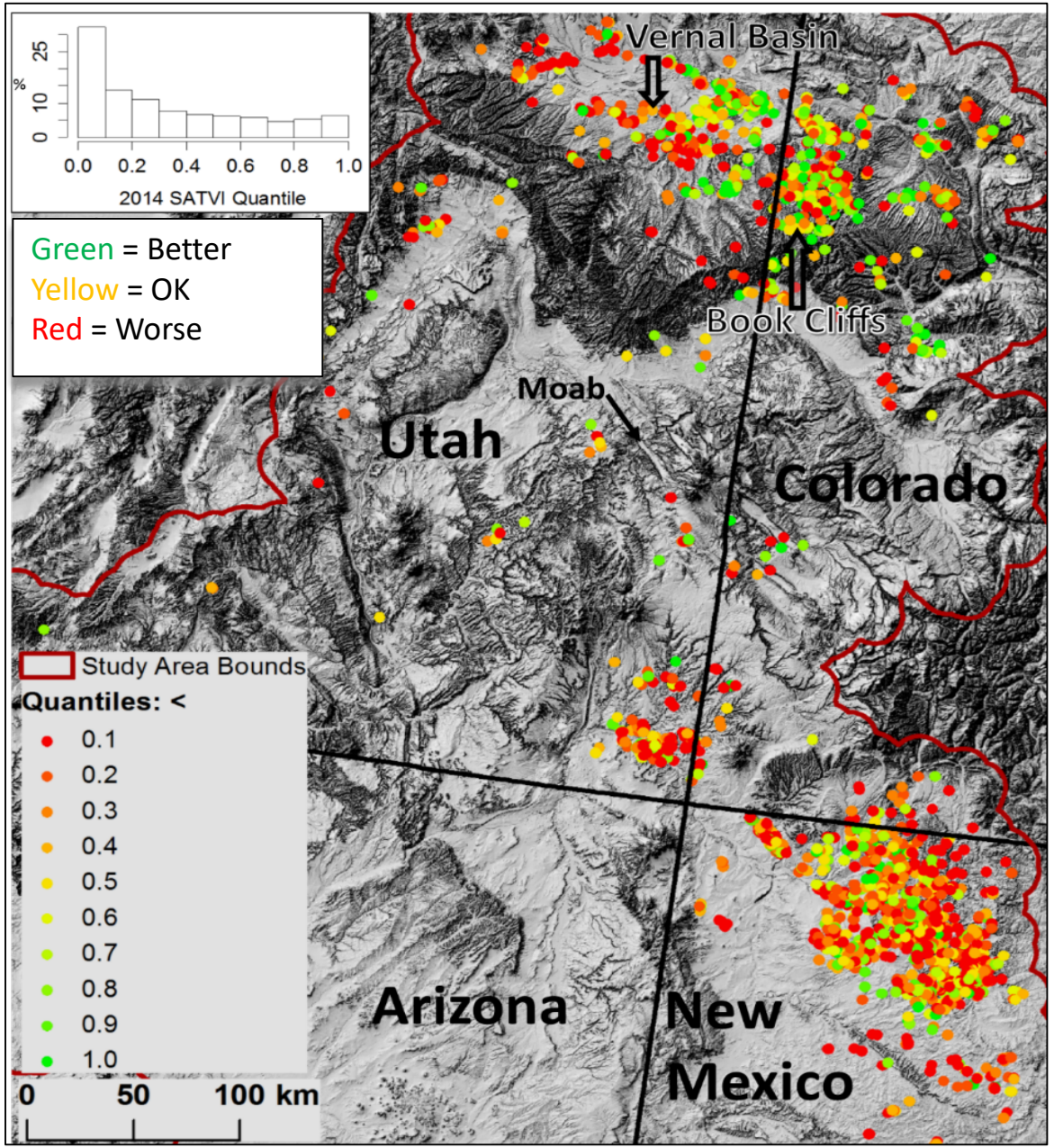

Nauman, T. W., M. C. Duniway, M. L. Villarreal, and T. B. Poitras. 2017. Disturbance automated reference toolset (DART): Assessing patterns in ecological recovery from energy development on the Colorado Plateau. Science of The Total Environment **584–585:476-488.**

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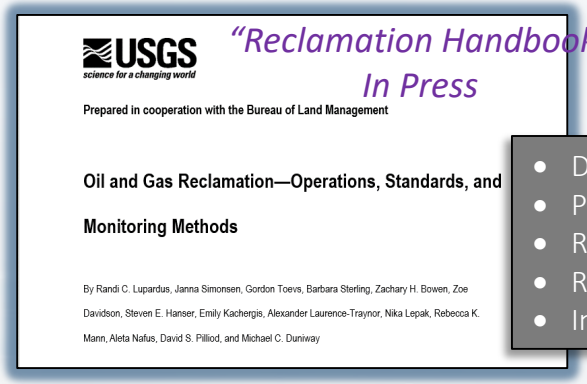
USGS Southwest Energy Development & Reclamation ("SWEDR") & BLM Support

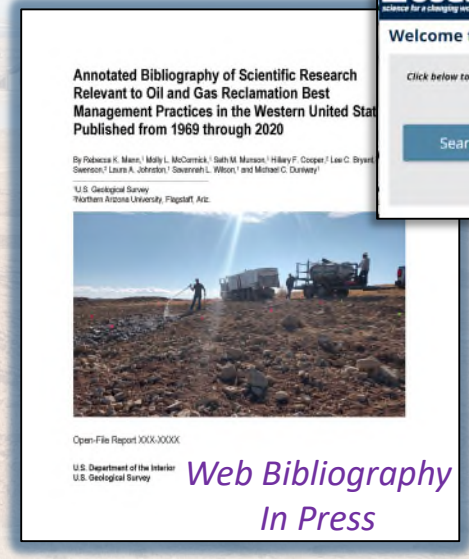
Goals

- Understand past and current energy development impacts on the social-ecological systems of the Colorado Plateau
- Identify strategies to mitigate deleterious consequences of these activates now and into the future
- Create relevant technical resources for managers, practitioners, and scientists

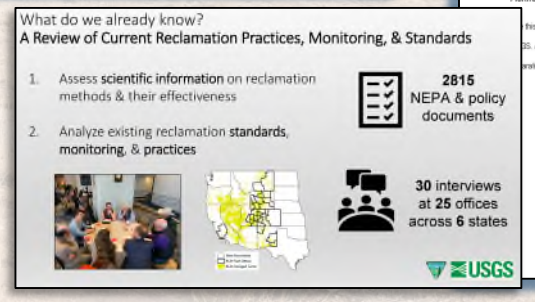


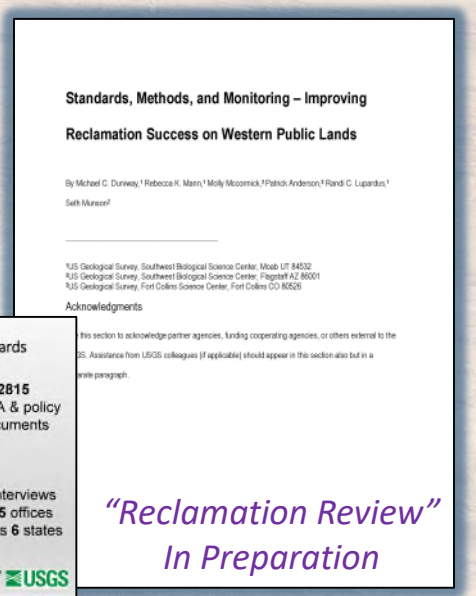
"Reclamation Handbook"
In Press

- Data-driven benchmarks, standards
- Pre-development planning
- Reclamation BMPs
- Reclamation monitoring
- Interpreting data



Web Bibliography
In Press





"Reclamation Review"
In Preparation

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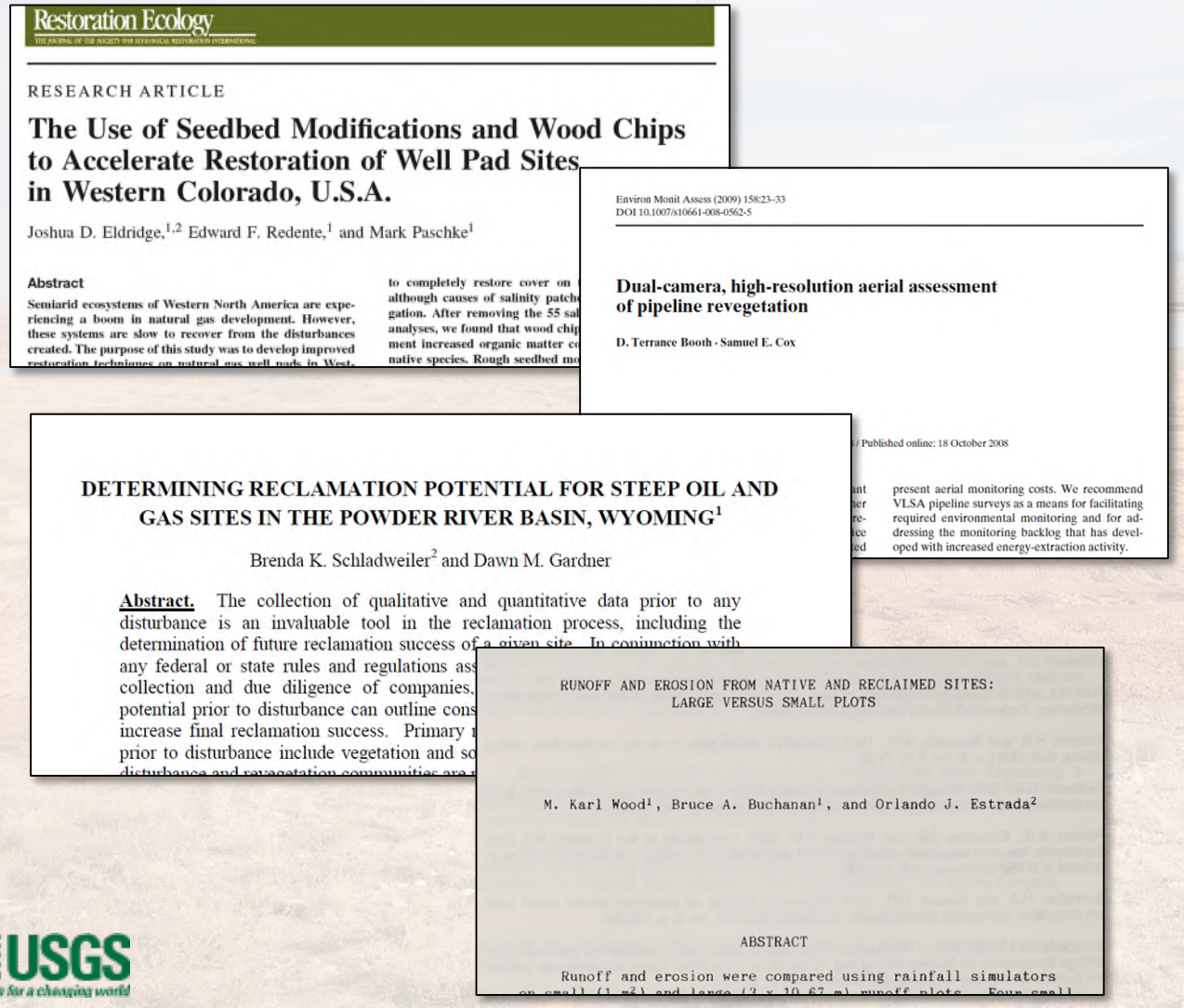
Reclamation Review:

Assess all accessible ***scientific information***



Publication search

3,207 papers identified

692 papers
Met quality & relevance criteria

387 papers
Relevant to Oil & Gas Reclamation Practices

Mulching evaluated: 45 papers (12% of papers)

Soil depressions evaluated: 15 papers (4% of papers)

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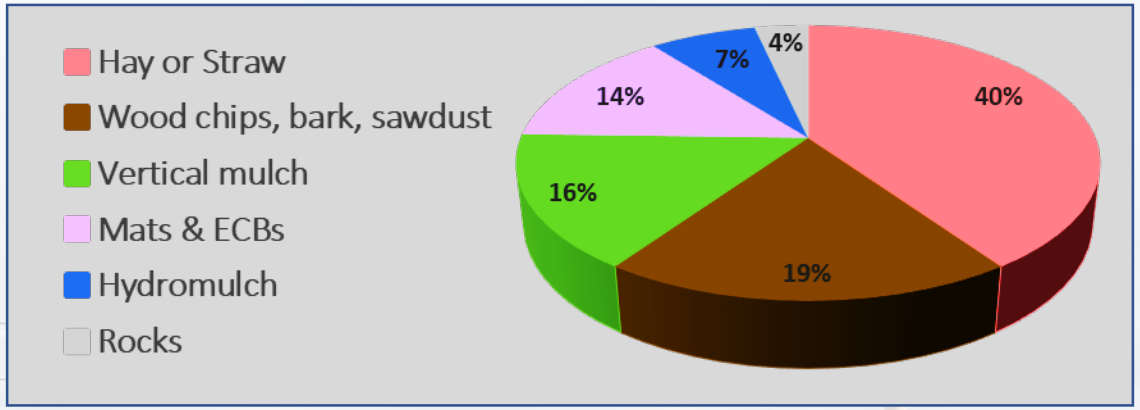
Literature Review: **Mulching**

Summary of articles' statements and findings



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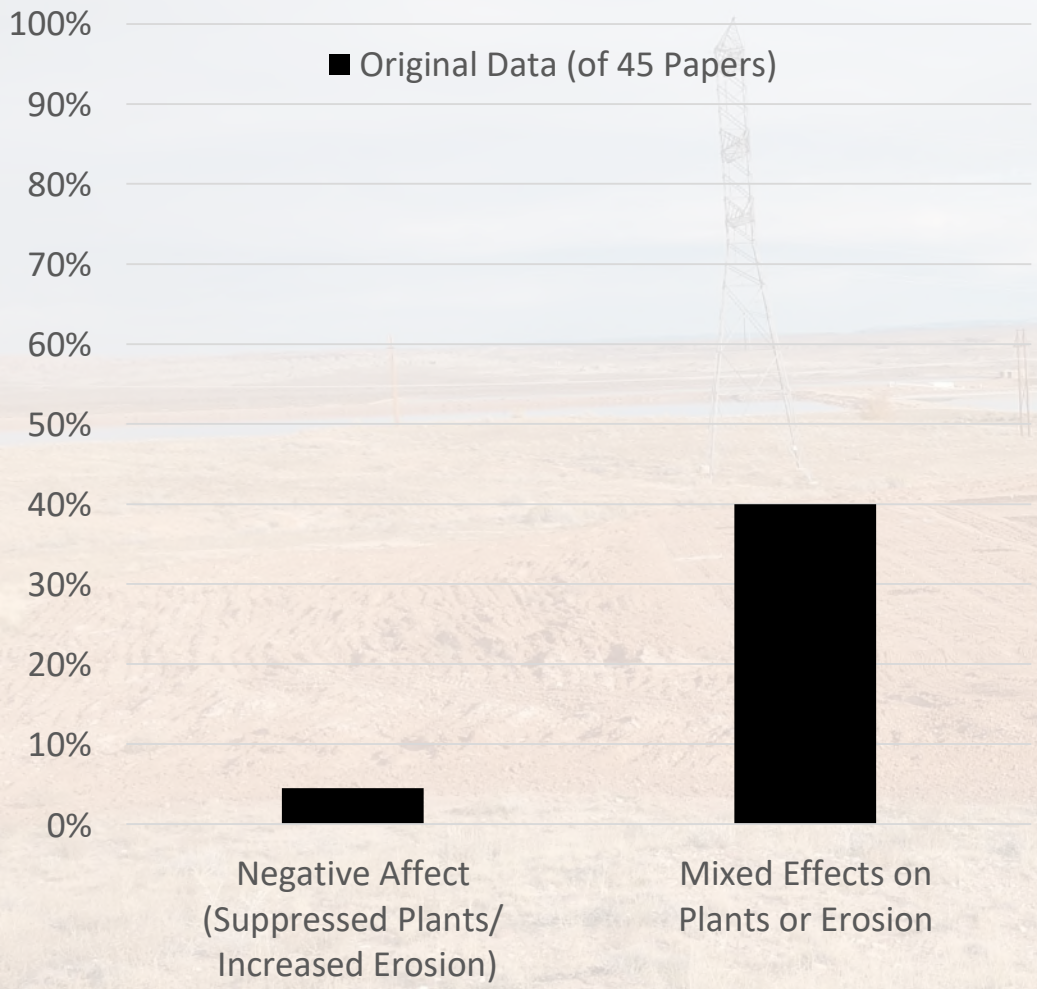
Literature Review: **Mulching**

Drawbacks & Inconsistencies



Drawbacks/Inconsistencies	#Works	*(% of mulch papers)*
Suppressed plants or increased erosion	3	*7%*
No effects noted	10	*22%*
Species differences	6	*13%*
Metrics differed *(e.g. germination ≠ survival ≠ biomass)*	3	*7%*
Site mattered	3	*7%*
Mulch type mattered	2	*4%*
Mulch depth mattered	2	*4%*
Time since reclamation mattered	2	*4%*
Precipitation mattered	1	*2%*
Non-natives increased	1	*2%*

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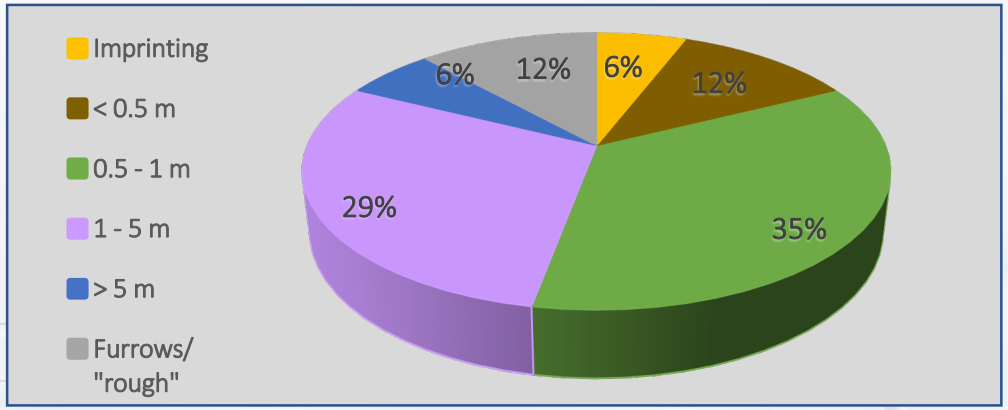
Literature Review: **Soil depressions**

Summary of articles' statements and findings



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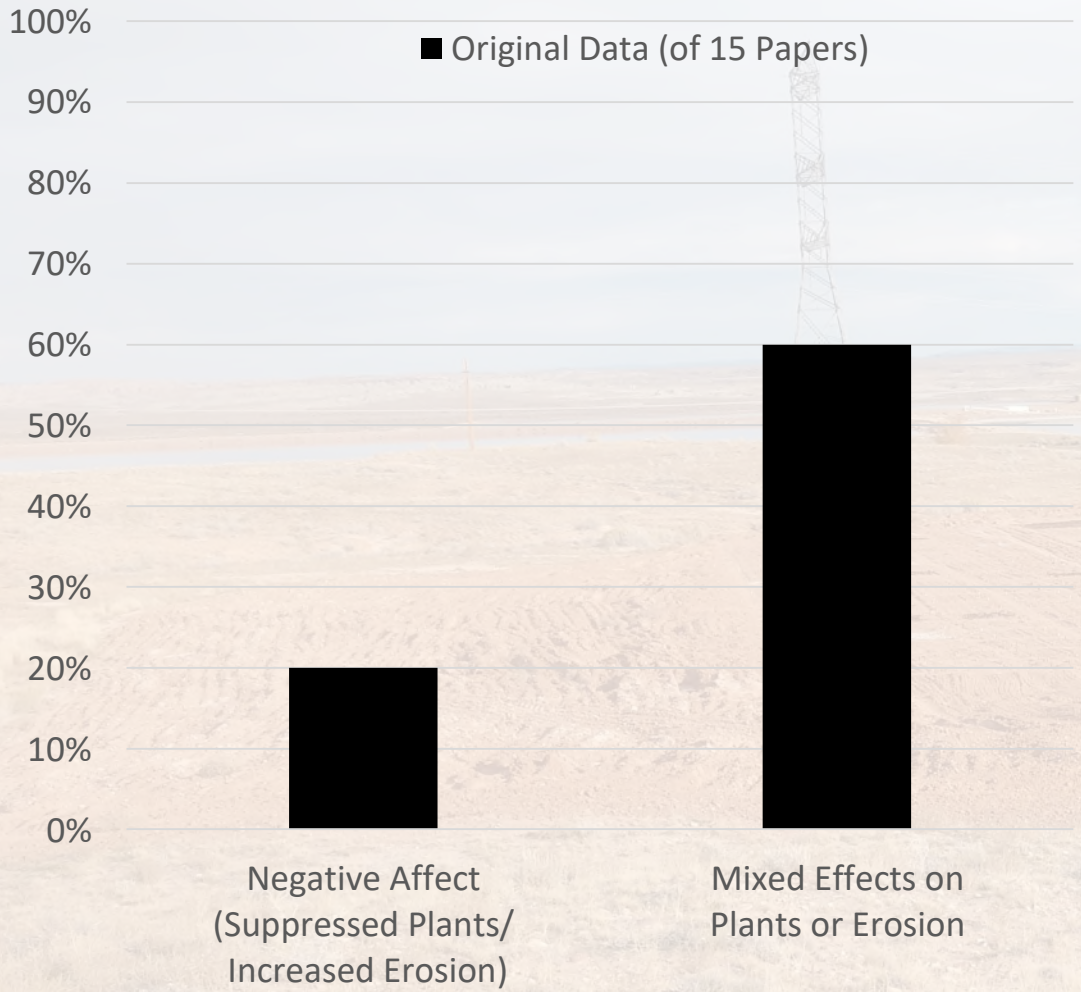
Literature Review: **Soil depressions**

Drawbacks & Inconsistencies



Drawbacks/Inconsistencies	#Works & *% of "pit" papers*	
Suppressed plants or increased erosion	4	*27%*
No effects noted	5	*33%*
Species differences	3	*20%*
Metrics differed *(e.g. germination ≠ survival ≠ biomass)*	1	*7%*
Site mattered	4	*27%*
Pitting type mattered	1	*7%*
Soil type mattered	1	*7%*
Time since reclamation mattered	2	*13%*
Precipitation mattered	3	*20%*
Non-natives increased	0	*0%*

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Today's talk

1. Brief origin of our research interests in oil and gas reclamation

2. "BLM Reclamation Review": findings about mulch & soil depressions

3. "WPRR": Collaborative field research project
   - Study design
   - Results comparing mulching and soil depressions

4. Research Conclusions

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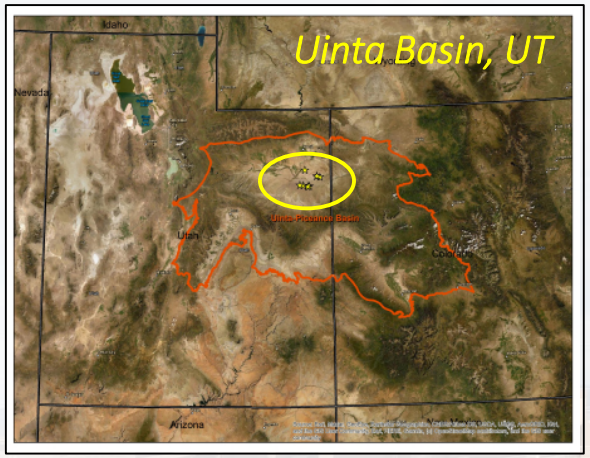
USGS Well Pad Reclamation and Research Project ("WPRR")

Collaborative Field Studies

In areas of concentrated oil & gas development

BLM
USFWS
USGS

Operators
Contractors



Goals

- **Integrate & expand on current knowledge**
  Collaborate with BLM and operators
- **Understand factors limiting success**
  Strategically test across years/sites
- **Identify effective & affordable reclamation strategies**
  For common plant communities and soils types
  For specific areas of interest
- **Use monitoring data to assess reclamation trajectories**
  First vs. last year responses

USGS Well Pad Reclamation and Research Project ("WPRR")

Key factors affecting disturbed arid landscapes

Reclamation Challenges

Severely Altered Biota

- ↓ *Native Plants, Seed Bank*
- ↓ *Seedling Safe Sites*
- ↓ *Pollinators, Invertebrates*
- ↑ *Exotic Species*

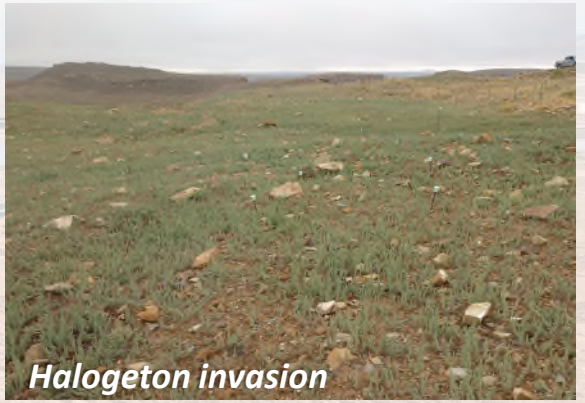
Severely Altered Soil

- ↓ *Microorganisms*
- ↓ *Nutrients, Organic Matter*
- ↑ *Compaction, Crusting*
- ↑ *Destabilization, Erosion*
- ↑ *Salinization*

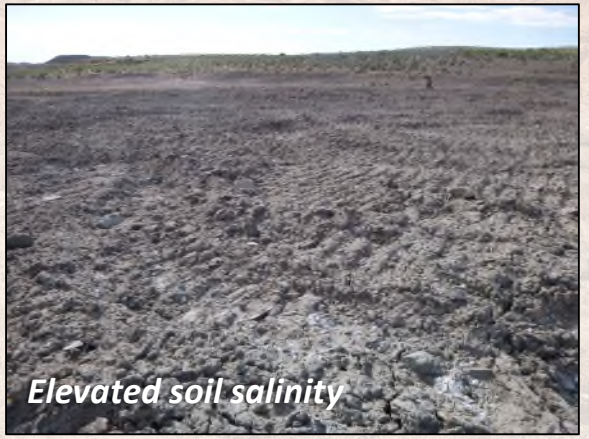
Severely Altered Hydrology

- ↓ *Water Holding Capacity*
- ↑ *Runoff*

Bare soil, no seedling "safe sites"



Halogeton invasion



Elevated soil salinity

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Key factors affecting disturbed arid landscapes

Reclamation Challenges		Reclamation Opportunities
Severely Altered Biota	↓ *Native Plants, Seed Bank*	*Seed Rates*
	↓ *Seedling Safe Sites*	*Safe Sites*
	↓ *Pollinators, Invertebrates*	*Seed Mix Diversity*
	↑ *Exotic Species*	*Apply Weed Control*
Severely Altered Soil	↓ *Microorganisms*	*Microbial Inoculation*
	↓ *Nutrients, Organic Matter*	*Fertilizer/Compost*
	↑ *Compaction, Crusting*	*Chiseling*
	↑ *Destabilization, Erosion*	*Tackifier, Mulch*
	↑ *Salinization*	*Amendments*
Severely Altered Hydrology	↓ *Water Holding Capacity*	*Soil pitting*
	↑ *Runoff*	*Organic Matter*

Tactic Comparisons

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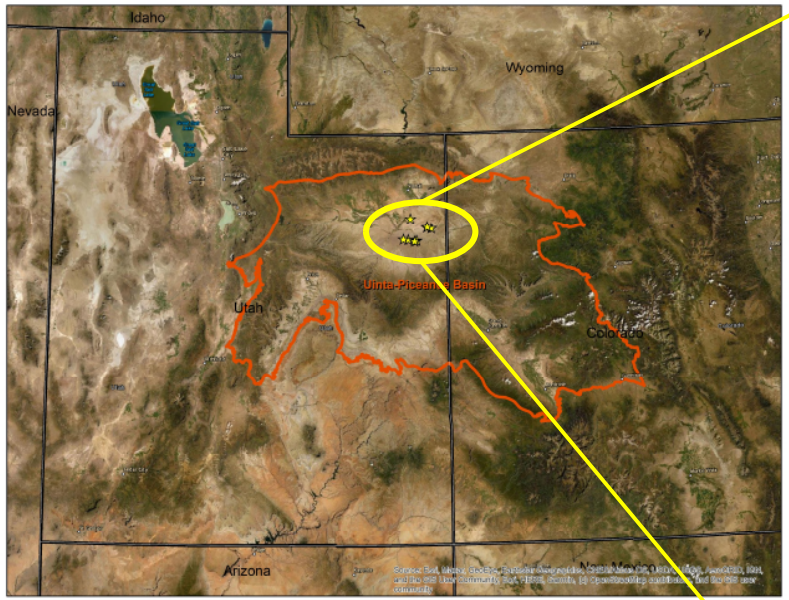
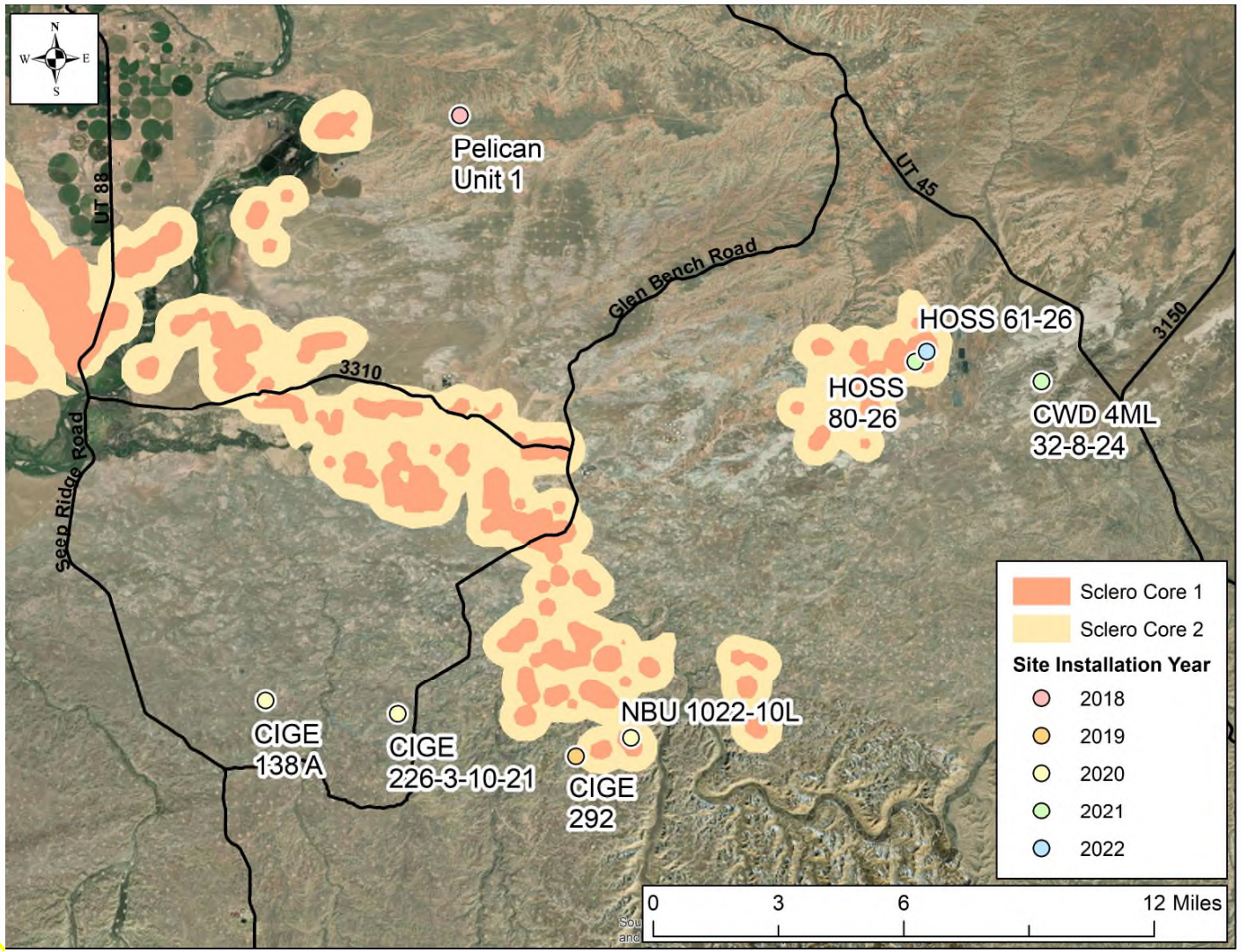
Identification of study locations

Uintah Basin:
Oil & Gas hot spot



6-9" Mean Annual Precipitation @ sites
14.6°C (58 °F) Mean Temperature @ sites

8 study sites, stratified by priority units



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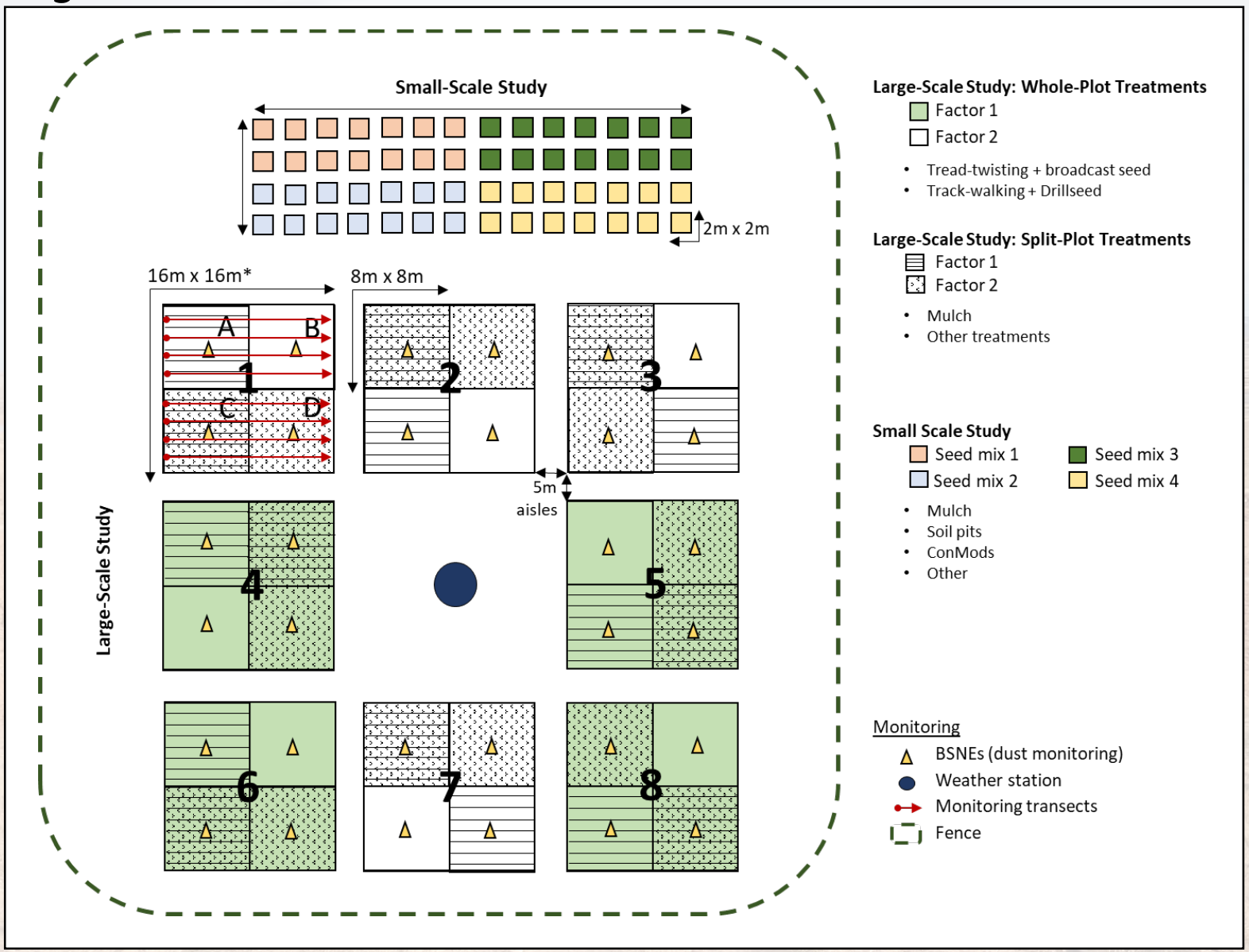
Two-part study design



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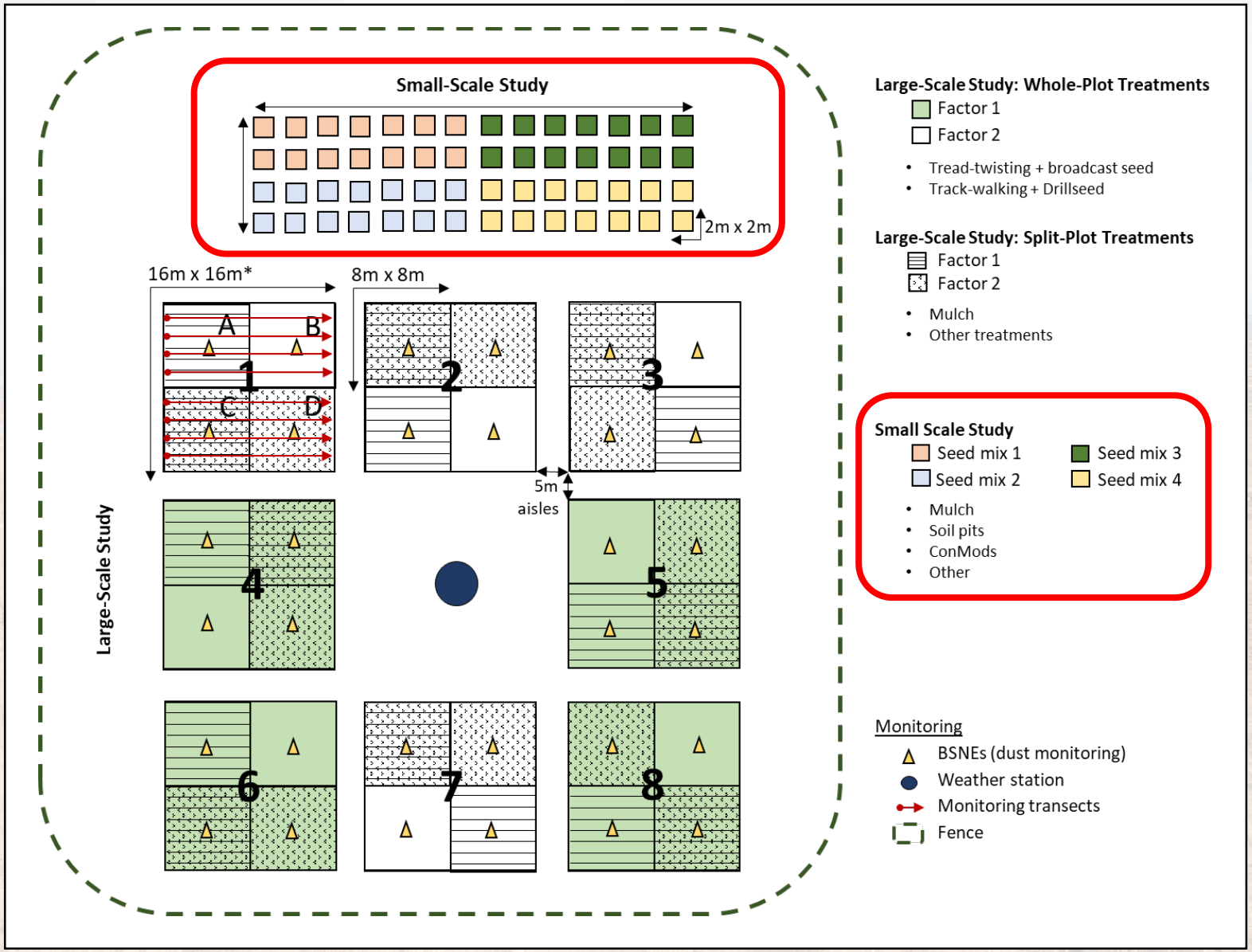
Small-scale component



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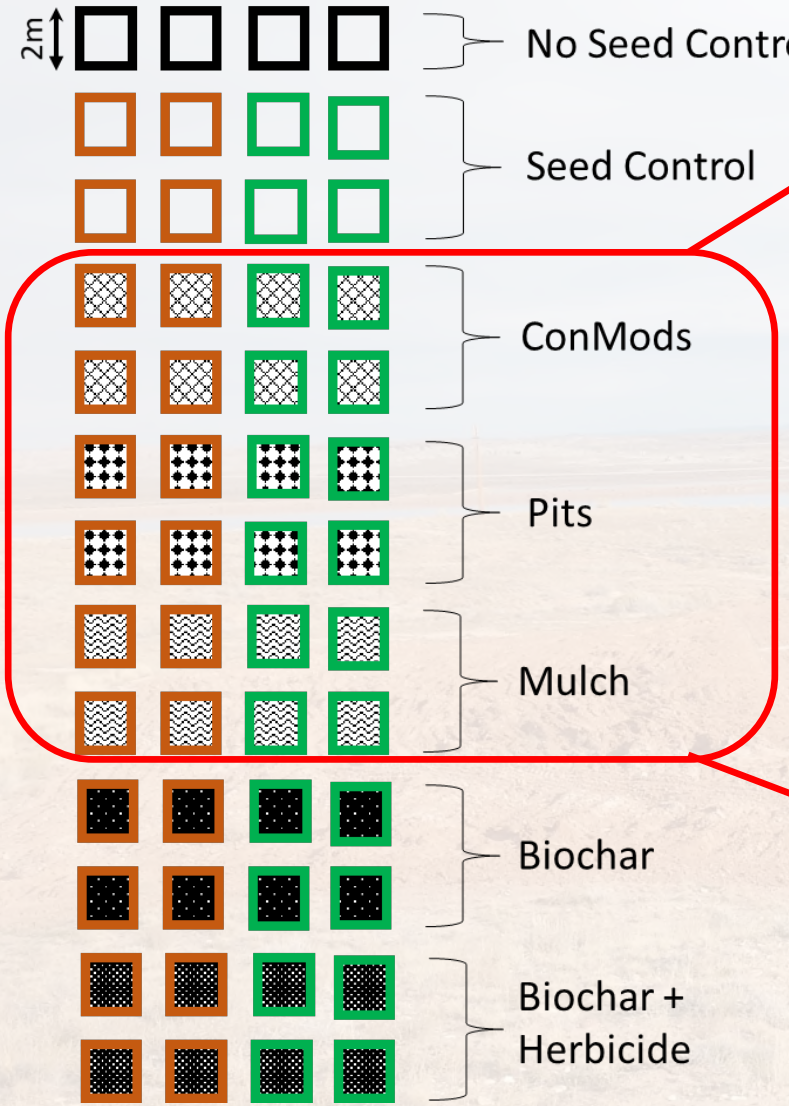

Treatments

x

Seed mix

= Species with warm/dry distributions

= Species with cool/wet distributions

Randomized Layout

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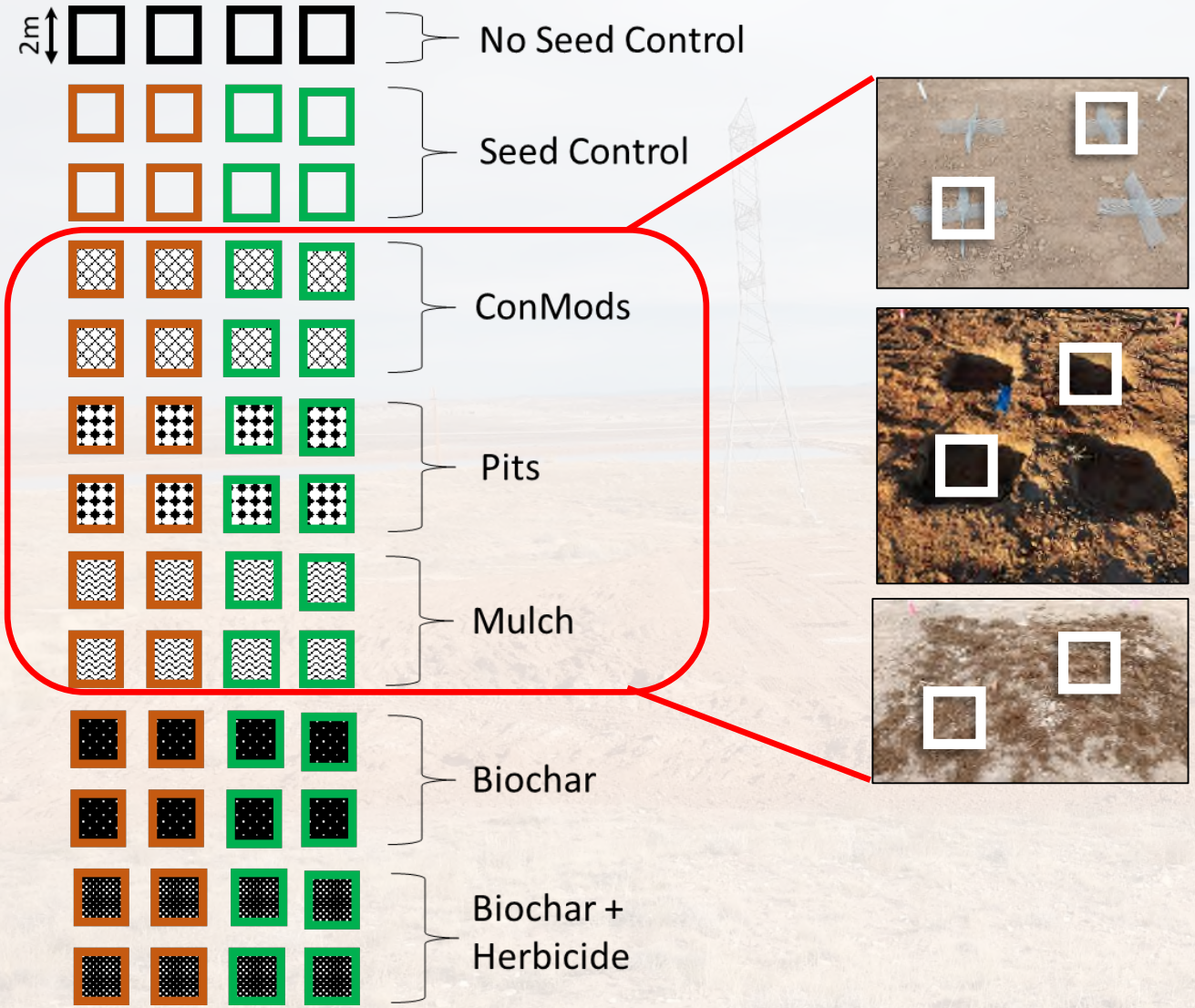
USGS Well Pad Reclamation and Research Project ("WPRR")

Small-scale component



Monitoring

- Annual plant density counts
- 2 quadrats/plot
- Species data are summed by functional groups *(e.g. seeded species)*

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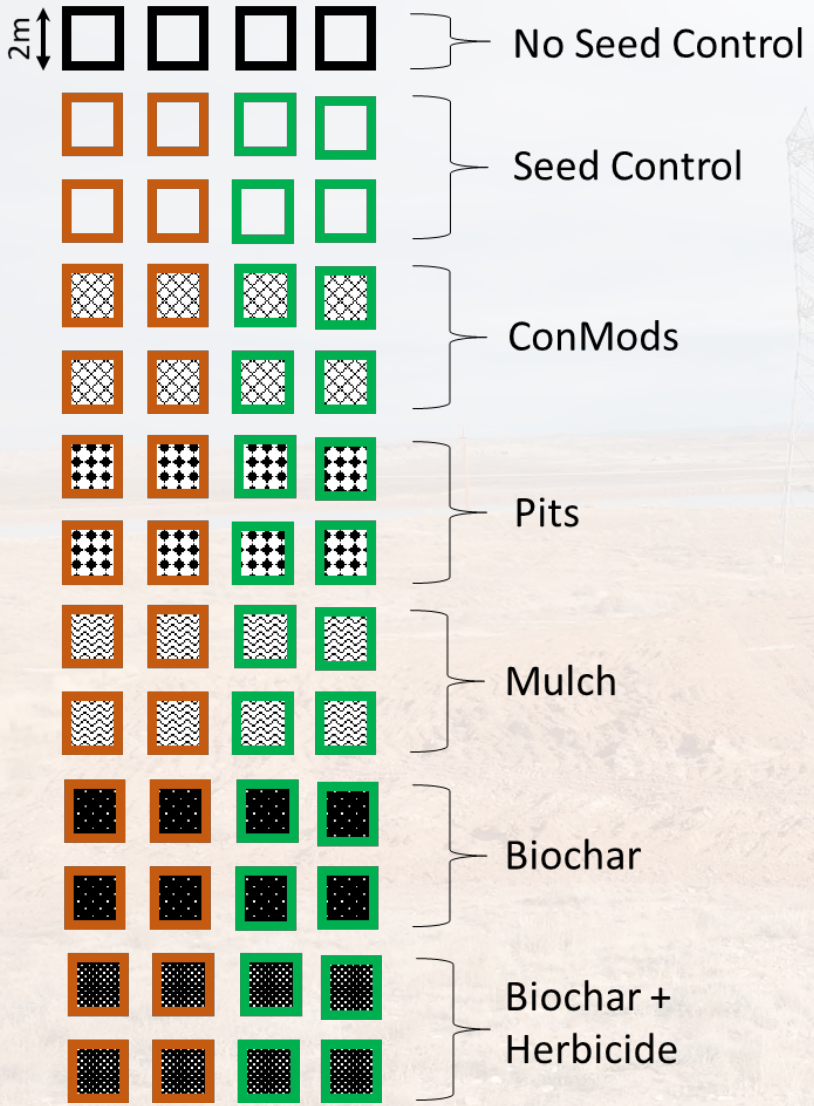
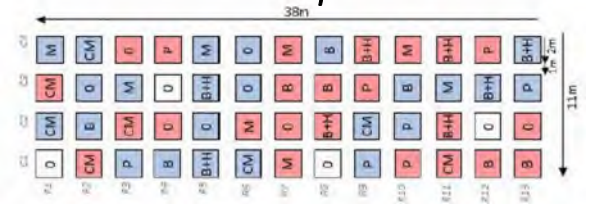
USGS Well Pad Reclamation and Research Project ("WPRR")

Small-scale component

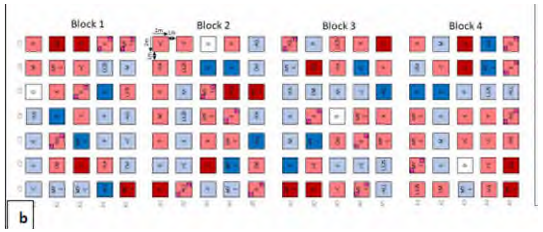


Site-specific randomization

Two Sites: ***Complete Randomized (4 replicates, 2 years data)***



Two Sites: ***Randomized Block*** *(4 blocks, 2 years data)*



Two Sites: ***Randomized Block (6 blocks, 1 year data)***

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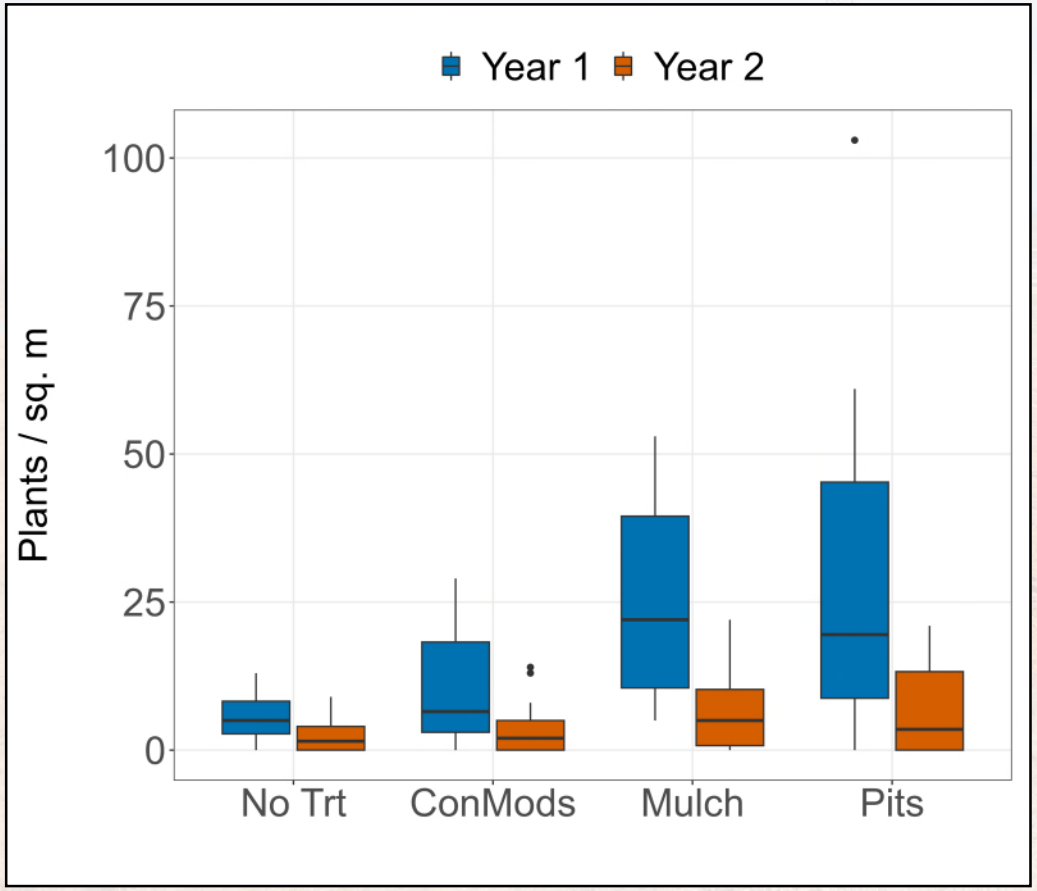
Small-scale component

Complete Randomized Sites

Year 1 & 2 Data



Sites installed 2018, 2019

Model

*density~ modifier*year + (1|site) + (1|seedmix)*

Zero-inflated hurdle model using a Poisson distribution

	Estimate	Std. Error	z value	Pr(>|z|)
Conditional Model:				
(Intercept)	3.04049	0.54106	5.620	1.92e-08 ***
ConMods	0.02204	0.34765	0.063	0.949442
Mulch	1.17976	0.31448	3.751	0.000176 ***
Pits	1.45608	0.31205	4.666	3.07e-06 ***
Year	-1.18563	0.21007	-5.644	1.66e-08 ***
Year*ConMods	0.31637	0.26000	1.217	0.223667
Year*Mulch	-0.01529	0.23623	-0.065	0.948400
Year*Pits	-0.11396	0.23517	-0.485	0.627970

Zero-inflation model:

No significant effects

R^2*(marginal) = 0.514*

R^2*(conditional) = 0.877*

Preliminary Results

- Years differed from one another
- Significant treatment effects:
  Pits (more likely to affect plants) > Mulch > ConMod = No Treatment

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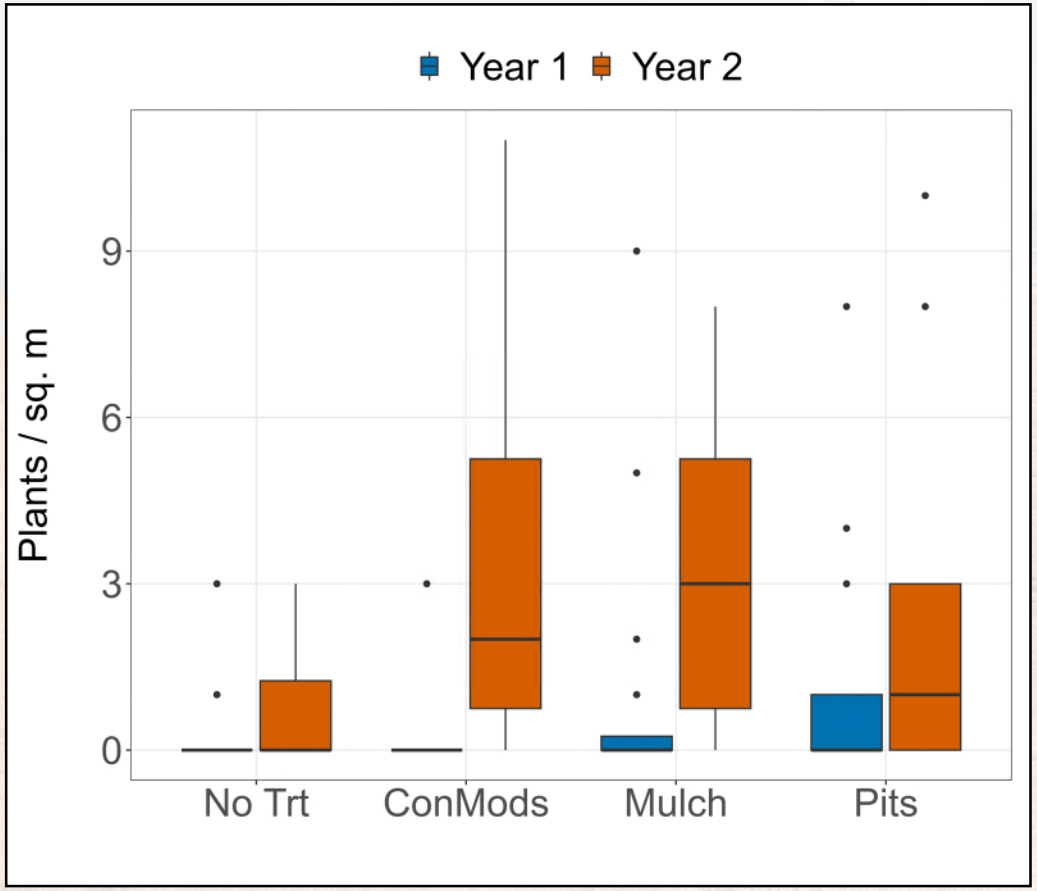
USGS Well Pad Reclamation and Research Project ("WPRR")

Small-scale component

Randomized Block Sites

Year 1 & 2 Data



Sites installed 2020

Model

*density~ modifier*year + (1|site/block) + (1|seedmix)*

Zero-inflated hurdle model using a Poisson distribution

	Estimate	Std. Error	z value	Pr(>|z|)
Conditional Model:				
(Intercept)	-0.55611	1.36046	-0.409	0.683
ConMods	0.45973	1.91596	0.240	0.810
Mulch	1.13849	1.41203	0.806	0.420
Pits	0.75976	1.45412	0.522	0.601
Year	0.26813	0.74287	0.361	0.718
Year*ConMods	0.40064	1.01877	0.393	0.694
Year*Mulch	0.08169	0.79705	0.102	0.918
Year*Pits	0.18933	0.81899	0.231	0.817

Zero-inflation model: R^2*(marginal) = 0.473*

No significant effects

Preliminary Results

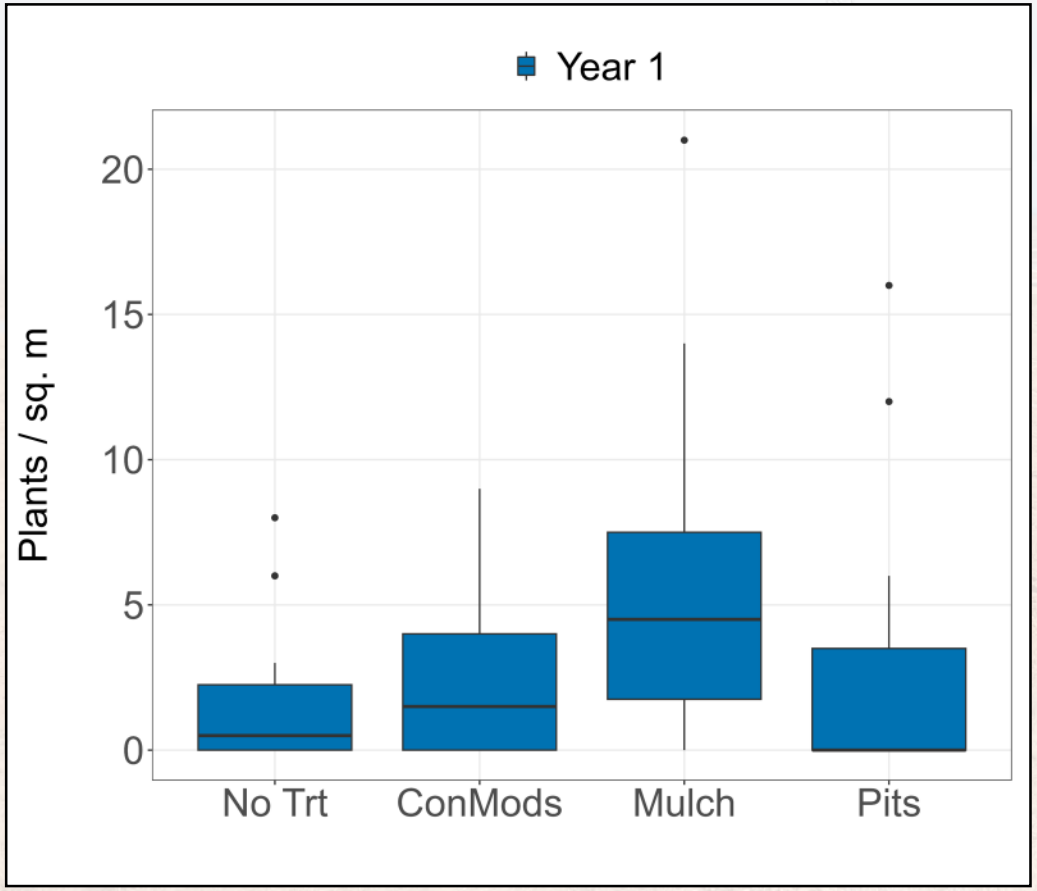
- No significant effects.
- Low precipitation following seeding -> Very little plant growth overall
- Establishment increased yr 2 but not enough to see treatment effects

USGS Well Pad Reclamation and Research Project ("WPRR")

Small-scale component

Randomized Block Sites

Year 1 Data



Site installed 2021

Model

*density~ modifier*year + (1|site/block) + (1|seedmix)*

Zero-inflated hurdle model using a Poisson distribution

	Estimate	Std. Error	z value	Pr(>|z|)
Conditional Model:				
(Intercept)	1.06372	0.20516	5.185	2.16e-07 ***
ConMods	0.08508	0.25656	0.332	0.7402
Mulch	0.74703	0.19200	3.891	9.99e-05 ***
Pits	0.52513	0.21982	2.389	0.0169 *
Zero-inflation model:				
(Intercept)	-0.2480	1.1246	-0.220	0.8255
ConMods	-0.9996	1.0022	-0.997	0.3186
Mulch	-2.0970	0.8918	-2.352	0.0187 *
Pits	0.4595	0.7665	0.599	0.5489

R^2(marginal) = 0.281

Preliminary Results

- Mulch increases likelihood of a plant being present
- If plants are present

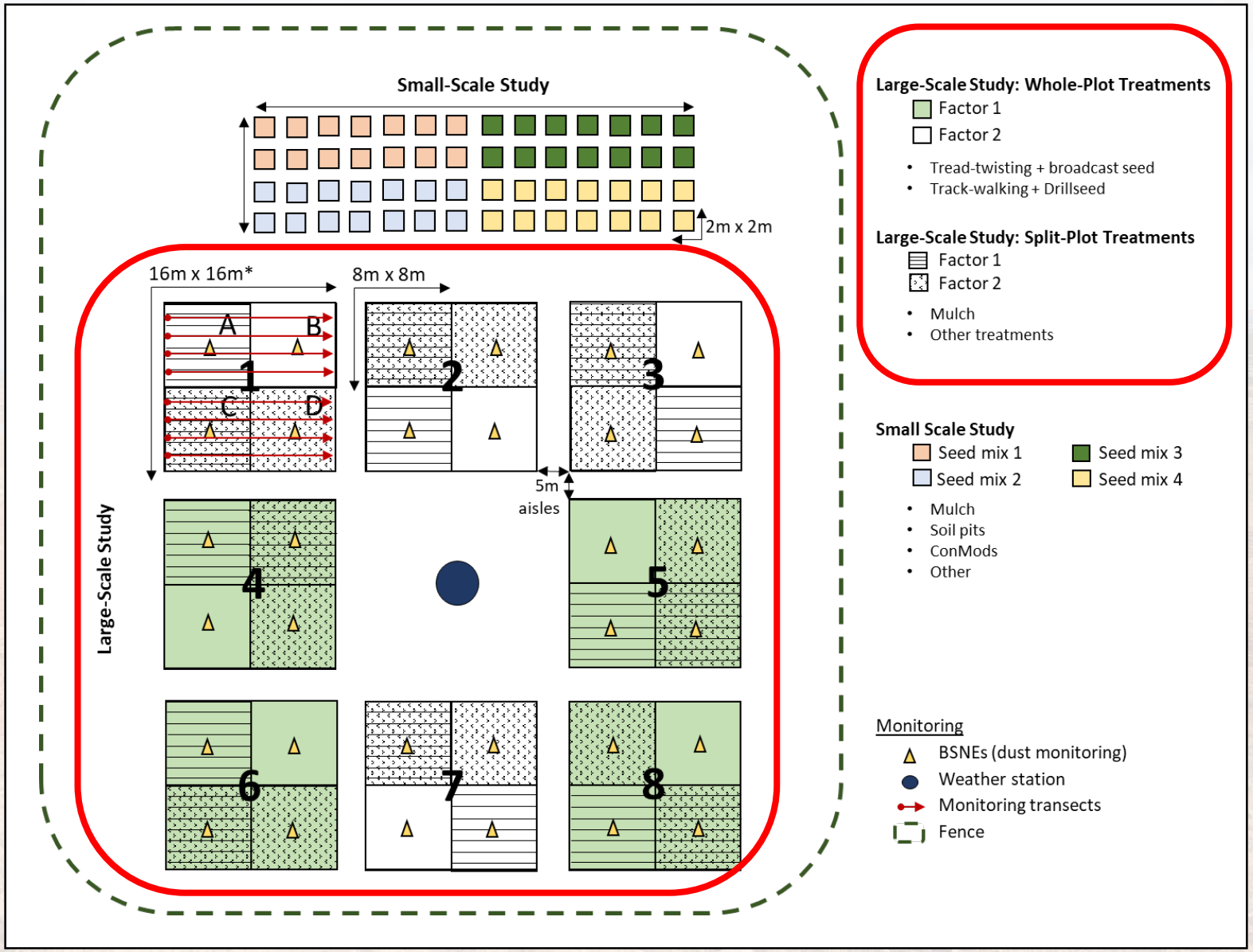
  Mulch (more likely to affect plants) > Pits > ConMod = No Treatment

USGS Well Pad Reclamation and Research Project ("WPRR")

Large-scale component

Rough surface & broadcast seed

Flatten surface and Drill-seed



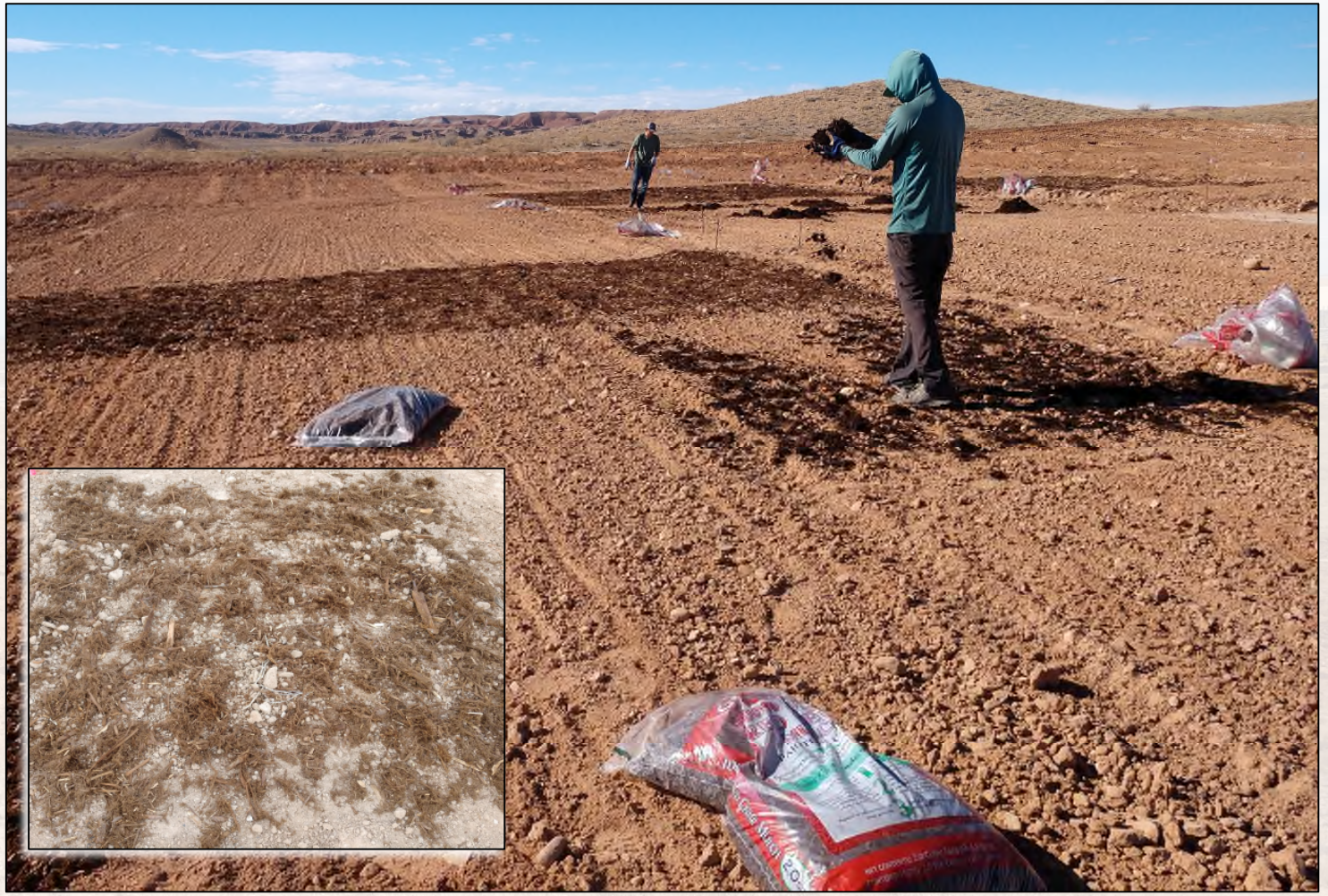
USGS Well Pad Reclamation and Research Project ("WPRR")

Large-scale component

Rough surface & broadcast seed

Flatten surface and Drill-seed

+/-



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USGS Well Pad Reclamation and Research Project ("WPRR")

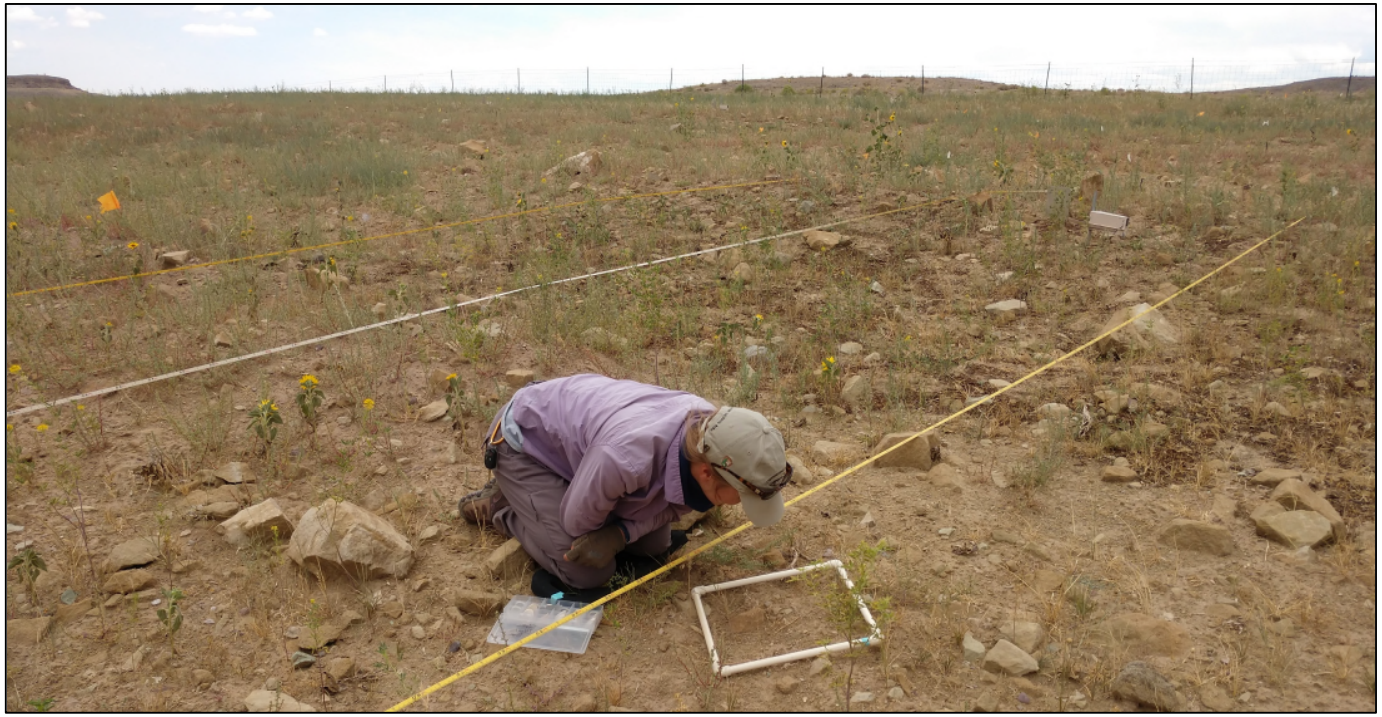
Large-scale component

Rough surface & broadcast seed

Flatten surface and Drill-seed

Monitoring

- Annual plant density counts
- 10 quadrats/plot
- Species data are summed by functional groups *(e.g. seeded species)*



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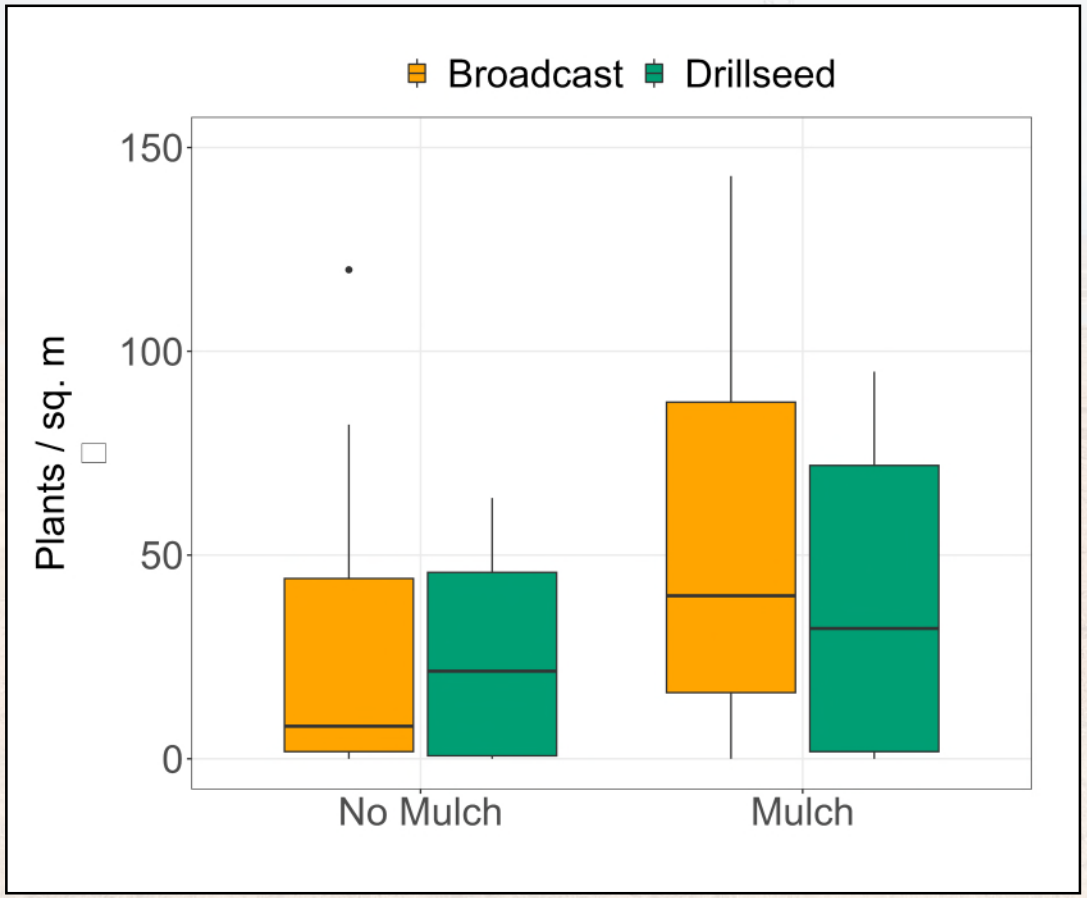
USGS Well Pad Reclamation and Research Project ("WPRR")

Large-scale component

Year 1 – Seeded Plant Density



Four sites, installed 2019-2021

Model

*Sqrt(density) ~ treatment*seed method + (1|site/block)*

Linear mixed effects model with a square root transformation

	Chisq	*Df*	*Pr(>Chisq)*
Mulch	28.8221	1	7.934e-08 ***
Seed Method	6.1854	1	0.01288 *
Seed Method*Mulch	3.2234	1	0.07259 .

R-sq (marginal)	0.08296
R-sq (conditional)	0.92870

Preliminary Results

- Most variance explained by site
- Significant treatment effects

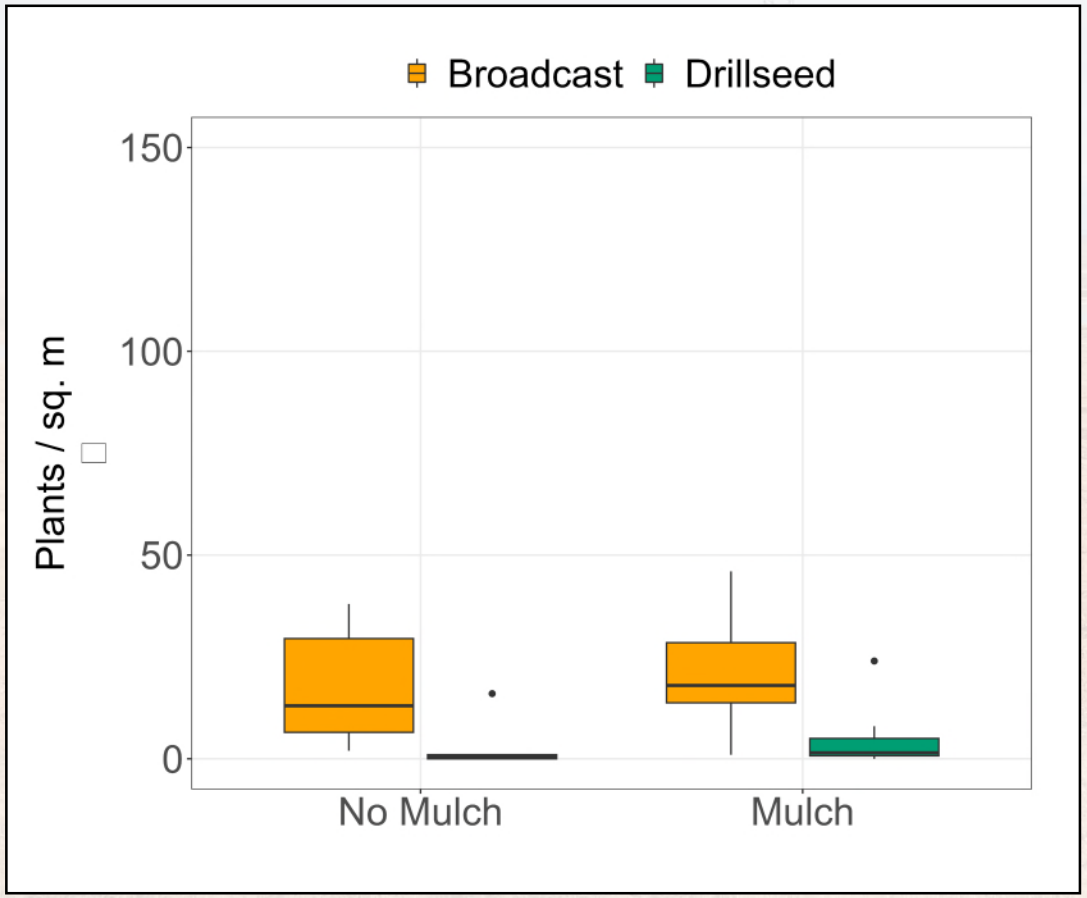
  Mulch > no mulch

  Broadcast + rough surface > Drill-seed + flat

USGS Well Pad Reclamation and Research Project ("WPRR")

Large-scale component

Year 2 – Seeded Plant Density



Four sites, installed 2019-2021

Model

*Sqrt(density) ~ treatment*seed method + (1|site/block)*

Linear mixed effects model with a square root transformation

	Chisq	*Df*	*Pr(>Chisq)*
Mulch	3.5465	1	0.05967 .
Seed Method	21.2112	1	4.114e-06 ***
Seed Method*Mulch	0.0939	1	0.75933

R-sq (marginal)	0.27484
R-sq (conditional)	0.65186

Preliminary Results

- High seedling mortality
- Significant treatment effects

  Mulch (marginally) > no mulch – however:
  Strong lasting effect of broadcast + rough surface

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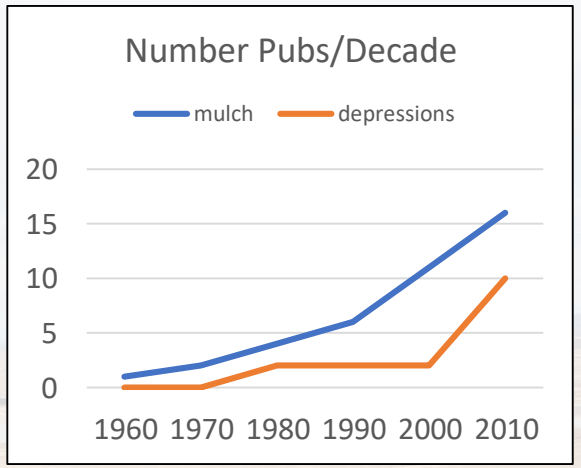
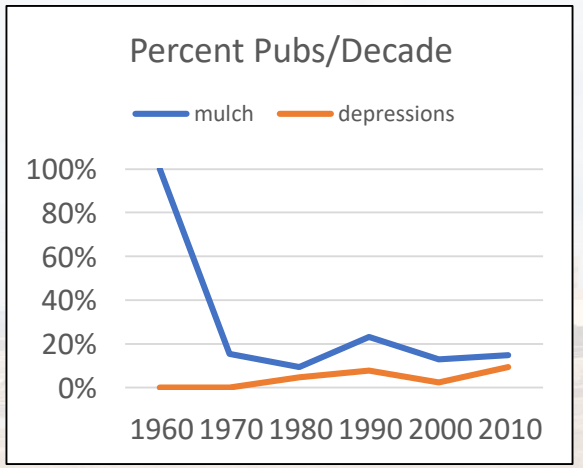
Collaborative Reclamation Research

Reclamation Literature Review

- Mulch, soil depressions studied, used for reclamation
  Only 14% & 4% of studies respectively, but on the rise
- Mulch & depressions can benefit plants
  Through water retention, microclimate modification, improving OM/structure/chemistry
- Neither treatment is consistent
  22% of mulch & 33% of depression papers found no effect
  mixed results due to treatment factors, sites, species, year





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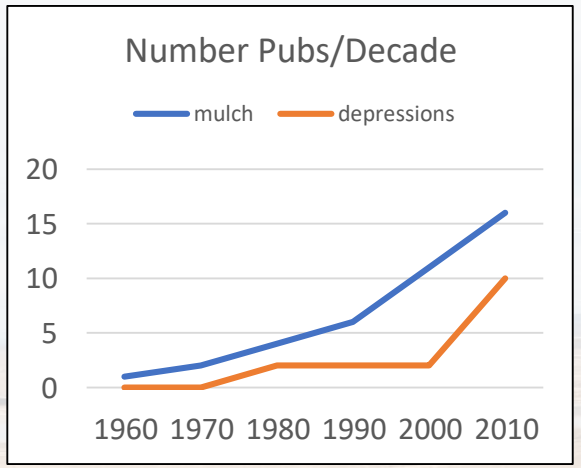

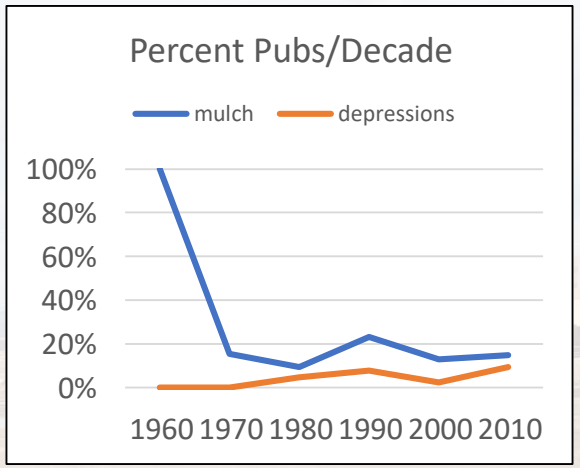

Small Scale Study (plot-level)

- Early results: Mulch or Pits? Site/year dependent
- No effects when precipitation is exceptionally low

Large Scale study (landscape-scale)

- Mulch > no mulch
- Rough surface/broadcast seeding: lasting effects
- Cost-effective solutions needed

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Thank You!

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