



Practical Approaches to Climate Resilience in Reclamation Projects

American Society of Reclamation Sciences 42nd Annual Meeting
Butte, MT
June 2025



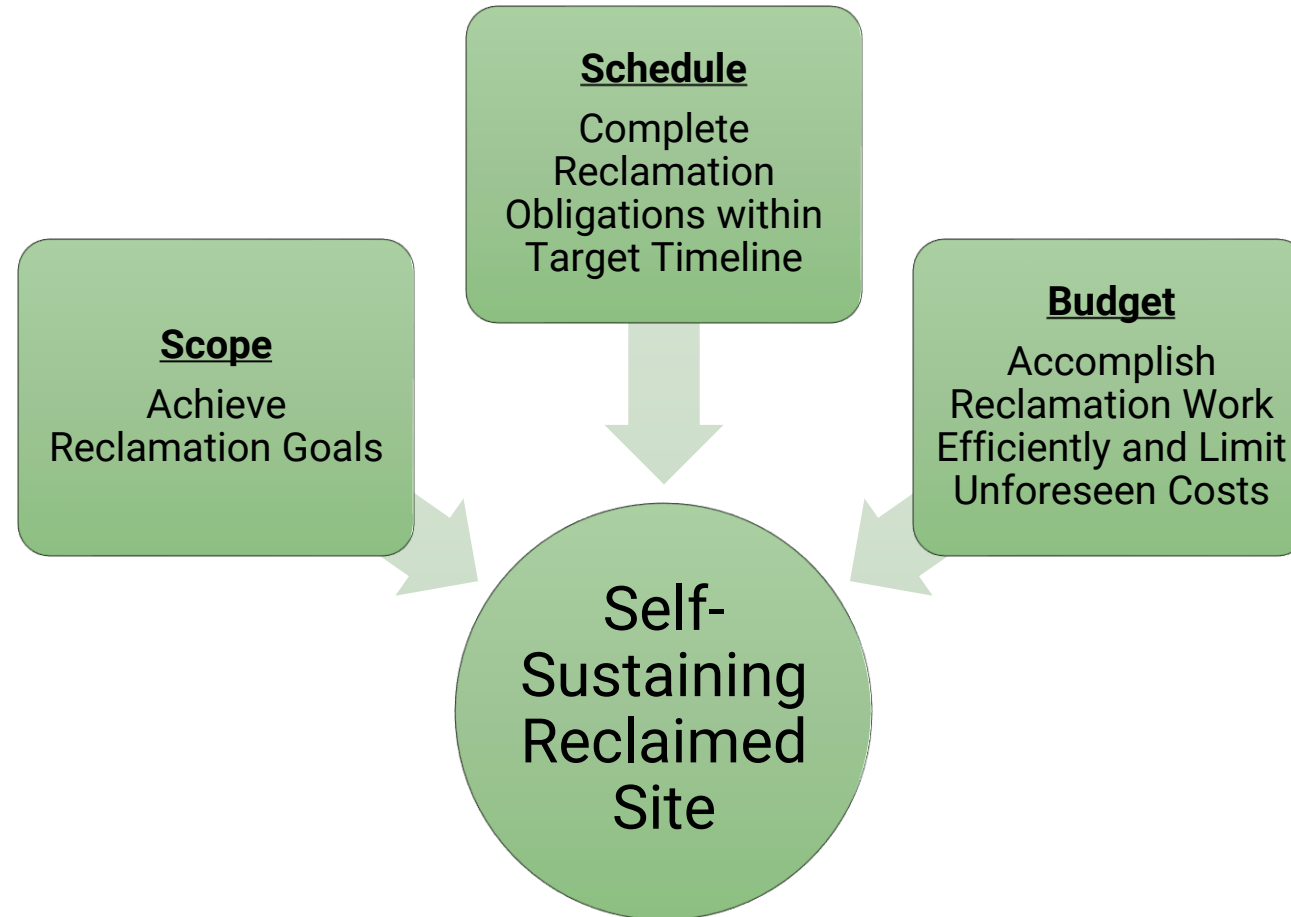
Agenda

- Drivers for Building Climate Resilience into Reclamation Projects
- Soils
- Water
- Vegetation
- Planning Tools and References

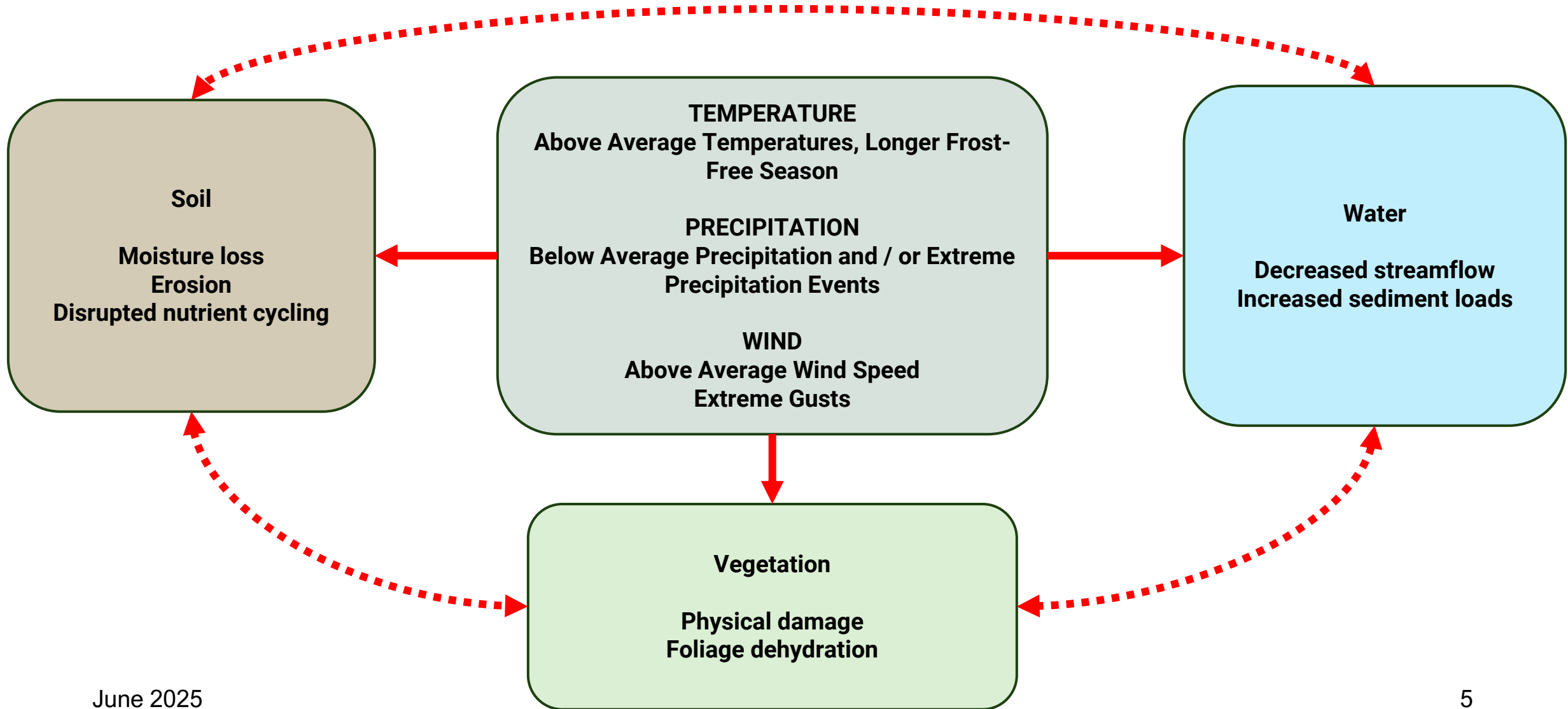


Drivers for Building Climate Resilience into Projects

In a Word ... Success



Weather Effects



Local Change – What Are We Adapting To?

Regional Climate Centers

Alaska
Hawai'i
Puerto Rico
May 2021

WESTERN REGIONAL CLIMATE CENTER

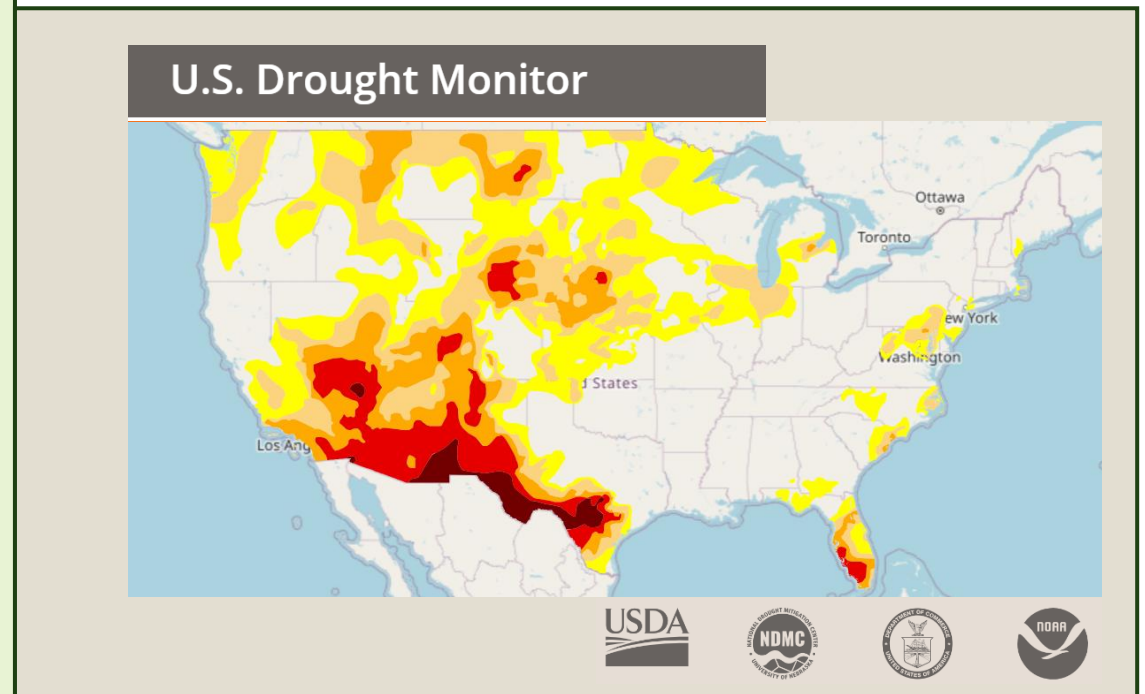
REGIONAL CLIMATE CENTERS
DRI
Desert Research Institute
NOAA
NATIONAL CENTERS FOR ENVIRONMENTAL INFORMATION

Terminology

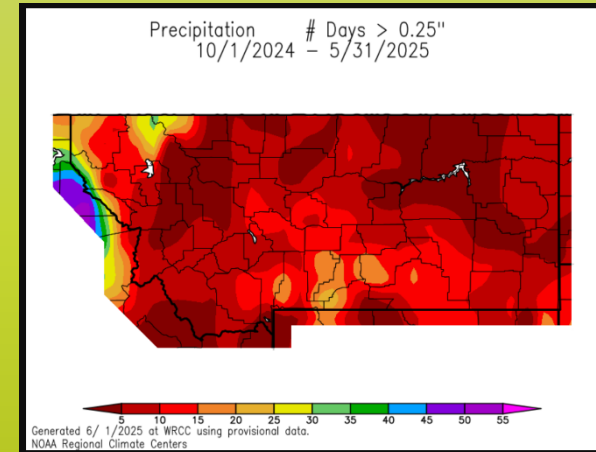
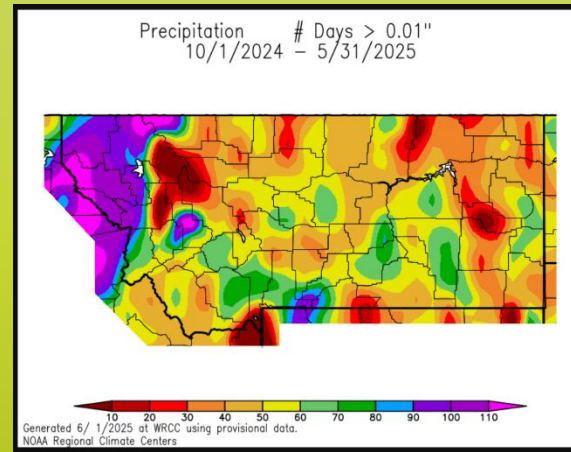
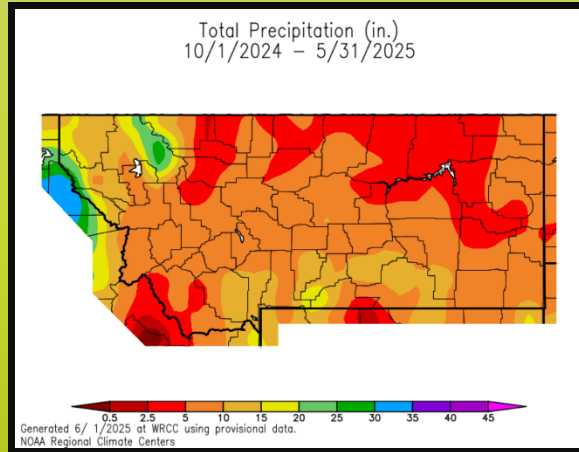
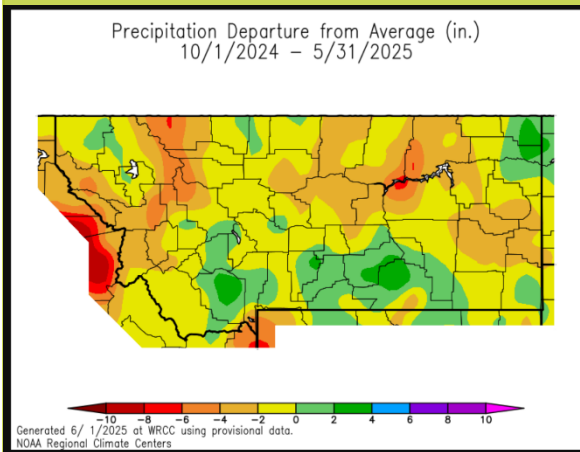
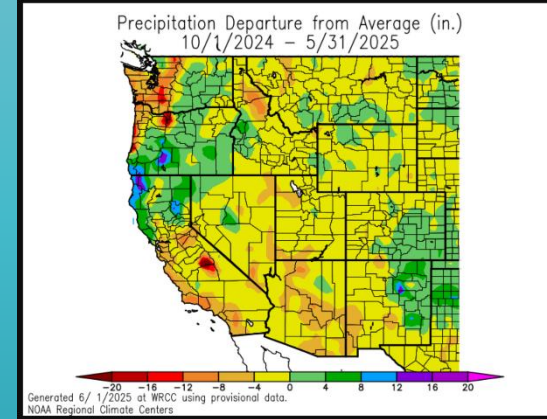
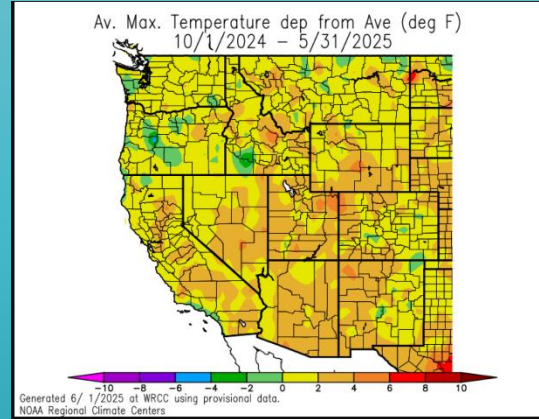
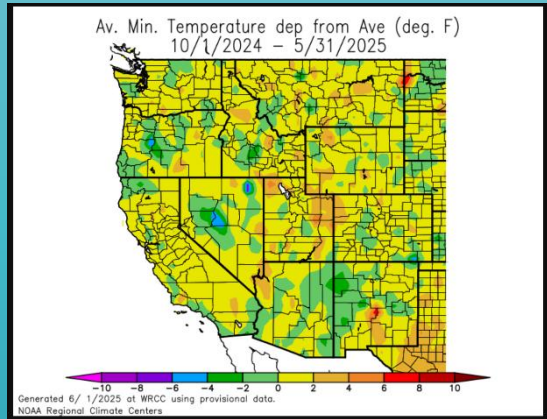
Climate: Average weather conditions over the long term

Weather: Atmospheric conditions at a specific time

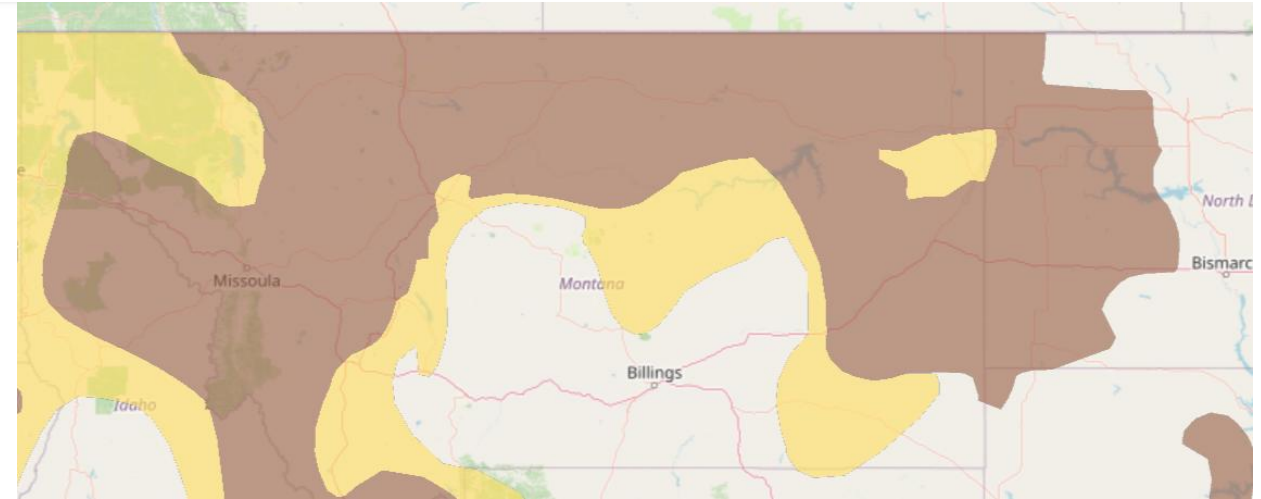
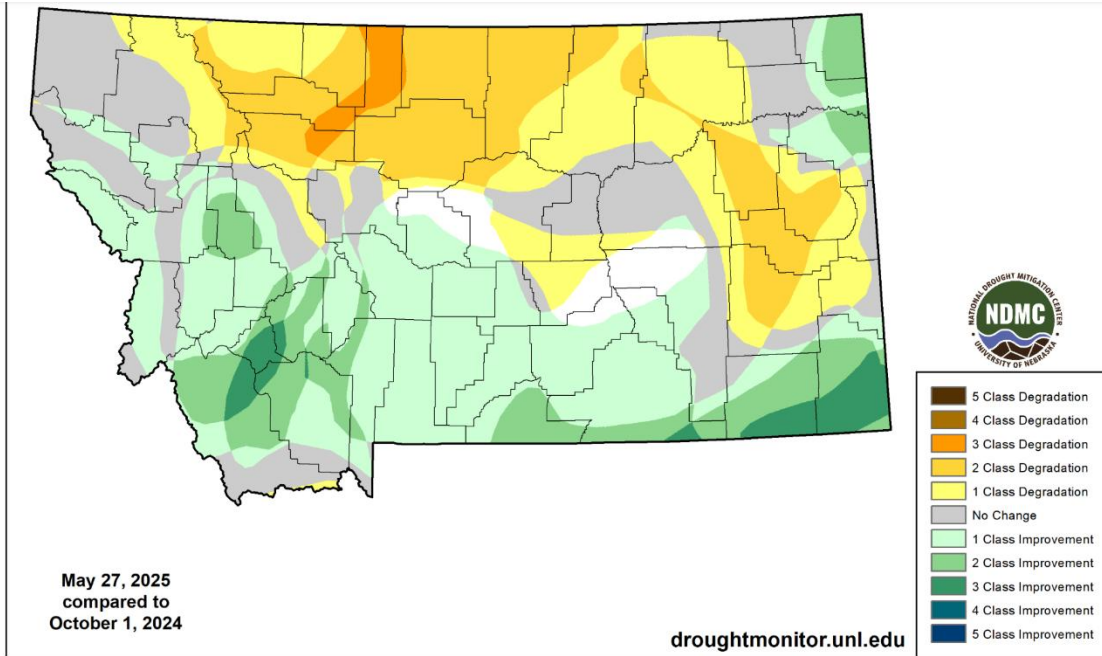
“Climate resilience” = Ability to withstand **changes in weather patterns** driven by climate change



WRCC Example



U.S. Drought Monitor Example



Seasonal Outlook

- Drought Persists
- Drought Remains but Improves
- Drought Removal Likely
- Drought Development Likely

Water Year to Date

**Help to answer the key questions:
What's the current condition ... and what
should we be planning for?**

Regulatory Drivers

Statutes, Rules, Codes, and Standards Commonly Relevant to Reclamation Projects

Federal

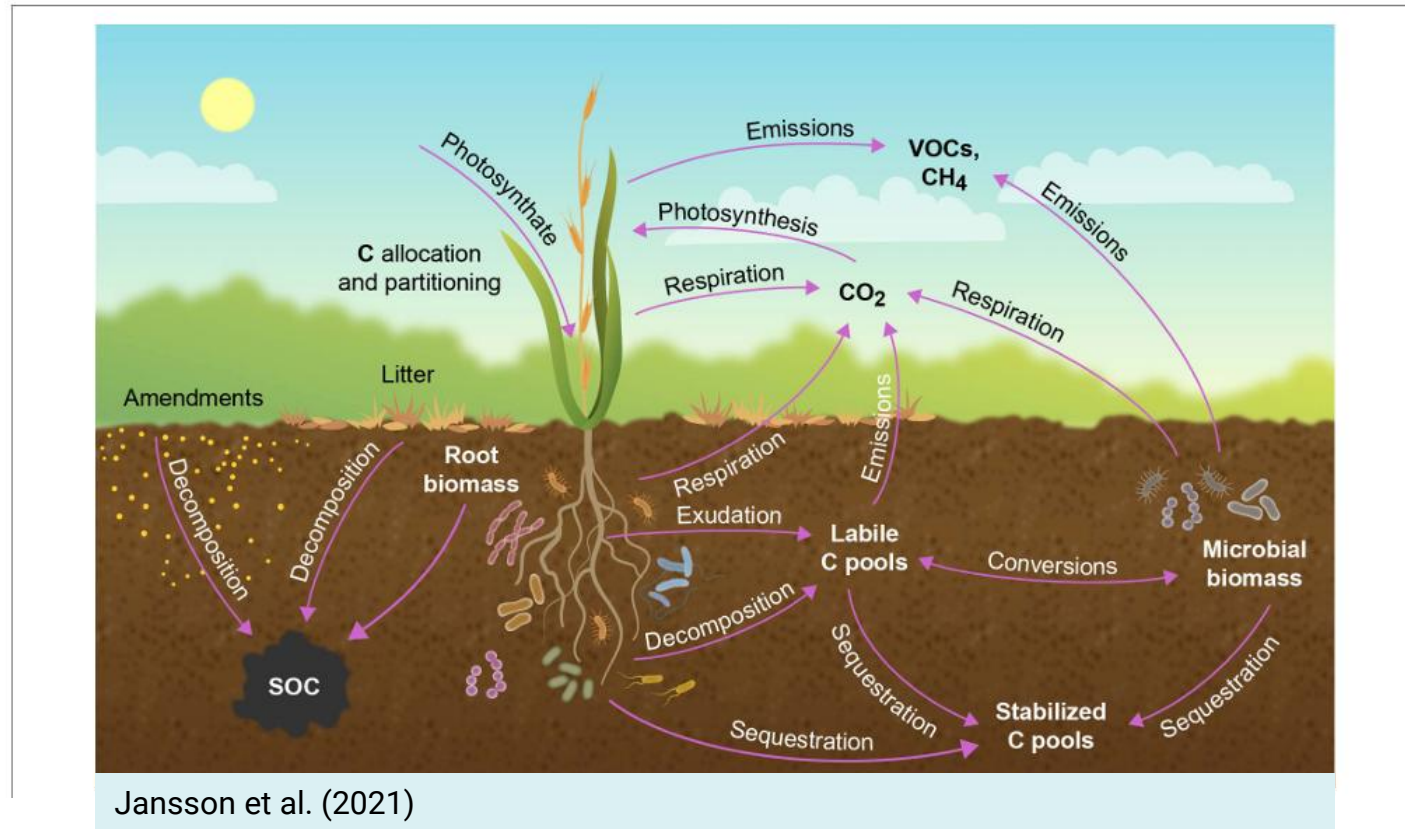
- National Environmental Policy Act
- Federal Land Policy and Management Act
- Forest Service Organic Administration Act
- Multiple-Use Sustained-Yield Act
- Forest and Rangeland Renewable Resources Planning Act
- National Forest Management Act
- Endangered Species Act
- Migratory Bird Treaty Act
- Bald and Golden Eagle Protection Act
- Clean Water Act
- Clean Air Act
- Federal Noxious Weed Act
- Federal Mining Laws
- Federal Agency Responsibilities to Federally-Recognized Tribes
- Executive Orders
- Secretarial Orders

State and Local

- Environmental Protection and Health Acts
- Water Quality Standards
- Groundwater Quality Standards
- Air Quality Rules
- Dam Safety Rules
- Surface Mining Acts
- Mined Land Reclamation Acts
- Planning and Zoning
- Flood Control
- Noxious Weed Control
- Fire Safety

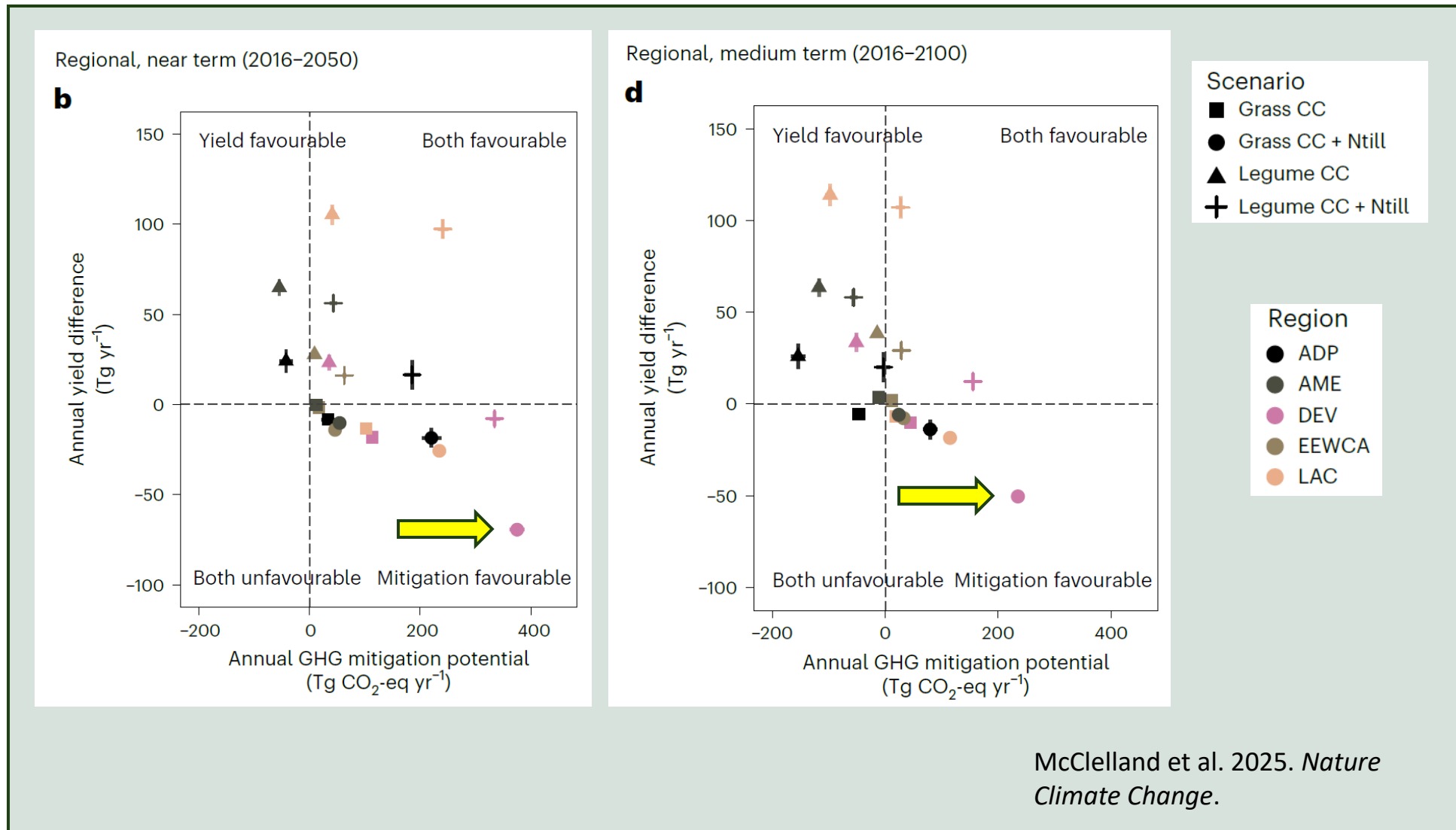
Planning for Climate Resilience Either Explicitly or Implicitly Required

Soil Organic Carbon Sequestration



- Land-based GHG emission mitigation opportunities for reclamation sites
- Consider soil characteristics and site management needs / future land uses

Soil Organic Carbon Sequestration





Soil

Soil Health

- USDA defines soil health as *“the continued capacity of soil to function as a vital living ecosystem that sustains plants, animals, and humans”*.

Key Functions of Soil:

Regulate water movement over land and to groundwater.



Provide structural support for plants.



Filter, buffer, immobilize and detoxify potential pollutants.



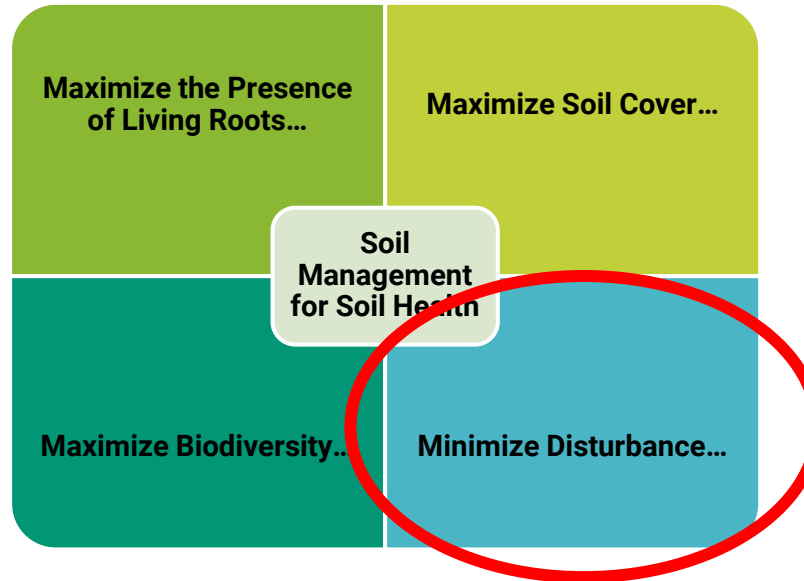
Cycle nutrients.



Soil Health

... To feed microbes in the rhizosphere.
... To improve water infiltration into the soil.

... To prevent disease and pest problems related to monocultures.
... To build a climate-resilient ecosystem.



... To prevent soil loss due to wind and water erosion.
... To increase soil organic matter and nutrients.

... To minimize compaction and protect soil structure.
... To decrease stormwater runoff.

Minimize Disturbance?!



Minimize Soil Erosion

- **Erosion Control Measures**

- Compost Blankets
- Geotextiles, Matting and Netting
- Land Grading
- Mulching
- Riprap
- Permanent Seeding
- Soil Retention
- Soil Roughening
- Temporary Slope Drains



Grading + Soil Roughening +
Hydroseeding + Matting



Grading + Compost Blanket + Matting



Grading + Soil Roughening +
Straw Mulch

USEPA National Menu of Best Management Practices (BMPs) for Stormwater (Construction and Post-Construction)

Minimize Sediment Loss

- **Sediment Control Measures**

- Fiber Rolls
- Filter Berms
- Sediment Basins and Rock Dams
- Sediment Filters and Sediment Chambers
- Sediment Traps
- Silt Fences
- Storm Drain Inlet Protection
- Straw or Hay Bales
- Vegetated Buffers

USEPA National Menu of Best Management Practices (BMPs) for Stormwater (Construction and Post-Construction)



Channel + Riprap
Fiber Rolls + Matting



Channel + Matting + Riprap Check
Dams
Fiber Rolls + Straw Mulch



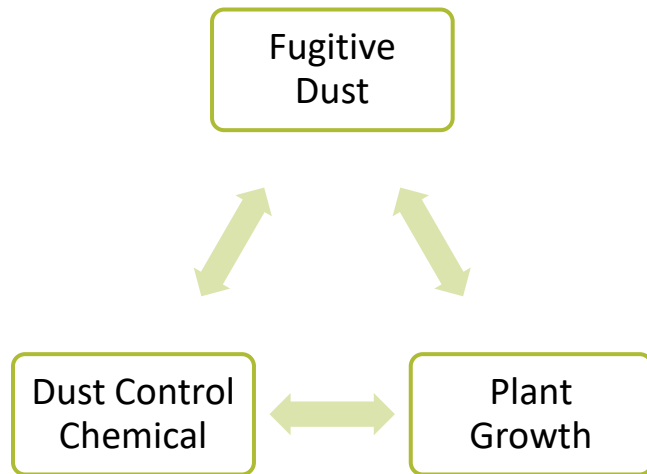
Riprap + Matting + Fiber Rolls
+ Silt Fencing

Minimize Fugitive Dust Emissions

- **Dust Control Measures**
 - **Revegetation areas**
 - **Site roads**



The huge Black Sunday storm — the worst storm of the decade-long Dust Bowl in the southern Plains — as it approaches Ulysses, Kansas, April 14, 1935. Daylight turned to total blackness in mid-afternoon. Sun-Times Media/Historic Adobe



May 16, 2025 Dust Storm
Wall of dust brings near-zero visibility and 60+ mph wind gusts to the region

- During the afternoon and evening of May 16, a dust storm developed near Bloomington, Illinois, and raced northeastward into the Chicago metropolitan area.
- Visibilities dropped to near zero and winds gusted over 60 mph within the worst of this dust storm.
- The dust storm was caused by strong winds originating out of a cluster of severe thunderstorms passing through central Illinois.

Selection of Measured Wind Gusts			
Harrison-Dever Crib <small>Maritime platform near Chicago</small>	78 mph	3 N Oxford, IN	75 mph
3 SW Midway Airport	64 mph	Midway Airport	60 mph
2 NNW Cissna Park	59 mph	Romeoville	54 mph

Elgin, Illinois. Photo courtesy of Patrick Corcoran

National Weather Service
Chicago, IL

National Oceanic and Atmospheric Administration
U.S. Department of Commerce

Soil Health at Your Site



What type of ecosystem is the end goal?

Restore native ecosystem

Support other land uses (e.g. grazing)

Develop mitigation wetlands

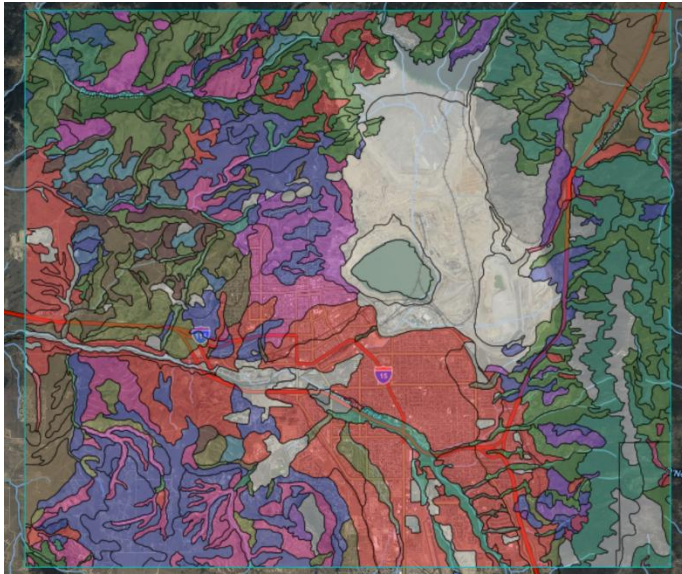
Vegetative cover for evapotranspiration

Plant species
Animal habitat

Requirements for healthy soil to support these

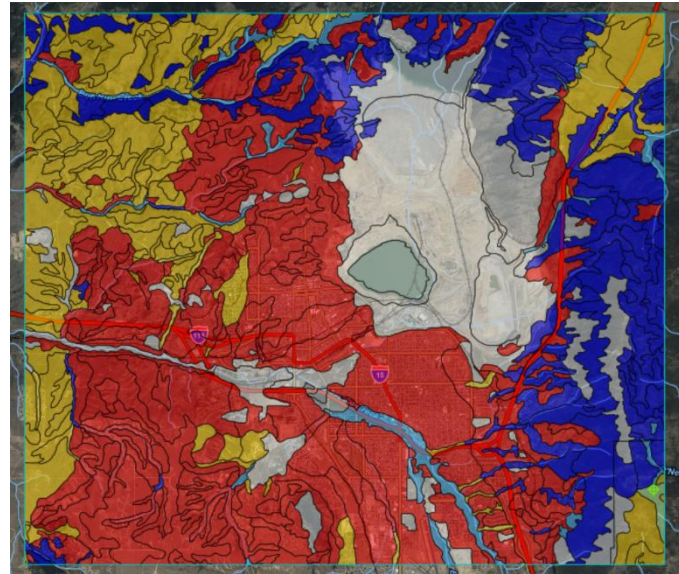


Soil Types



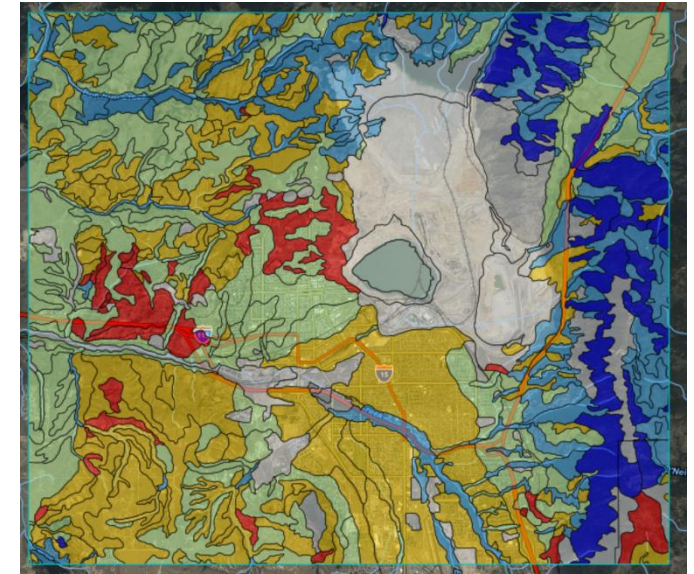
Texture

- | | |
|----------------------------|--------------------------------------|
| Ashy loam | Loam |
| Ashy sandy loam | Moderately decomposed plant material |
| Channery loam | Mucky peat |
| Clay loam | Sandy loam |
| Coarse sandy loam | Slightly decomposed plant material |
| Cobbly ashly sandy loam | Stony coarse sandy loam |
| Gravelly ashly loam | Very channery sandy loam |
| Gravelly coarse sandy loam | Very cobbly ashly loam |
| Gravelly loam | Very gravelly sandy loam |
| Gravelly loamy coarse sand | Not rated or not available |
| Gravelly loamy sand | |
| Gravelly sandy loam | |



Organic Matter (%)

- | |
|----------------------------|
| ≤ 2.50 |
| > 2.50 and ≤ 4.00 |
| > 4.00 and ≤ 50.00 |
| > 50.00 and ≤ 70.00 |
| > 70.00 and ≤ 75.00 |
| Not rated or not available |



Available Water Capacity (cm/cm)

- | |
|----------------------------|
| ≤ 0.08 |
| > 0.08 and ≤ 0.13 |
| > 0.13 and ≤ 0.19 |
| > 0.19 and ≤ 0.30 |
| > 0.30 and ≤ 0.45 |
| Not rated or not available |



Water

Storm Water Management

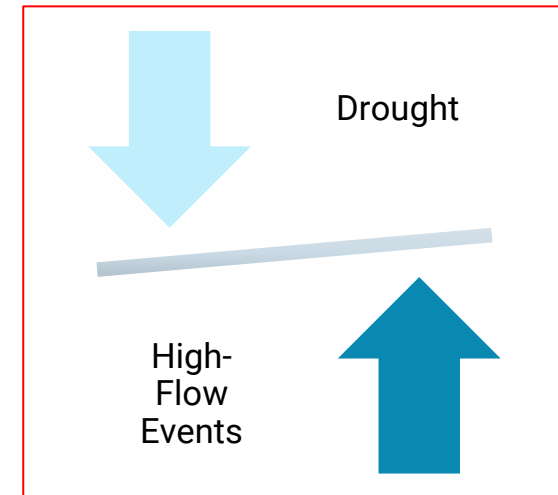
Runoff control measures for resilience to high-flow events include:

- Check Dams
- Grassed Swales and Channels
- Infiltration Basins
- Infiltration Trenches
- Land Grading

Detention / Retention measures for resilience to high-flow events include:

- Dry Detention Ponds
- Wet Extended Detention Ponds
- Constructed Wetlands

Retain for Onsite Use during Dry Periods



Wetlands

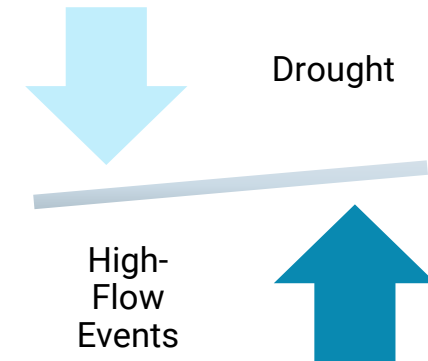
- Habitat
- Water quality improvement
- Resilience to flooding



TYPES OF WETLANDS

	MARSH	WET MEADOW	WET PRAIRIE	SWAMP
DESCRIPTION	Marshes are wetlands found at the edges of water bodies, dominated by rooted plants that grow underwater, float, or extend out of the water.	Wet meadows can occur in wetland depressions, swales, or in the transitional zone between marshes and other wetlands with less saturated soils.	Wet prairies are wetland ecosystems where the water level usually varies in wetness between wet meadows and dry prairies.	Swamps are dominated by woody vegetation, and are often found in basins or low-elevation floodplains along rivers or slow-moving streams.
WATER DEPTH	1-6 feet (standing or slow moving)	At or near soil surface	Saturated soils (0-1 feet below soil surface)	0-2 feet (standing or slow moving)
FREQUENCY	Permanent	Permanent or near permanent	Frequent	Permanent
PLANTS	Cattails, Bulrushes, Lotus, Sedges, Water Lily	Sedges, Grasses	Grass-like and Flowering plants, Orchids	Alders, Cypress, Ferns
	BOG	FENS & SEEPS	VERNAL POOL	PRAIRIE POTHOLE
DESCRIPTION	Bogs are isolated basin wetlands characterized by spongy peat-rich soils. They have nutrient poor, acidic waters with floating mats of vegetation that are fed by rainfall and snow melt.	Fens are peatlands that are fed by a calcareous groundwater source, resulting in an alkaline water chemistry. Seeps, or springs, are areas where the groundwater naturally comes to the surface at the base of slopes.	Vernal pools are shallow, isolated depressions that are filled each spring by rain and snow melt, then dry up since they are not connected to other water bodies. They serve as an essential breeding habitat for frogs and salamanders.	Prairie potholes are water-holding depressions of glacial origin. These isolated wetlands provide essential food and resting places to migrating waterfowl.
WATER DEPTH	Shallow lake basins	Saturated soils	0.5-3 feet	1-4 feet
FREQUENCY	Seasonal to Permanent	Seasonal to Permanent	Seasonal (Spring)	Seasonal to Permanent
PLANTS	Sphagnum Moss, Pitcher Plant, Tamarack, Cranberry	Sedges, Grasses, Orchids, Marsh Marigolds	Ferns, Irises, Mosses, Marsh Purslane	Water Lilies, Pondweeds, Bulrushes, Arrowhead

www.wetlands-initiative.org



Riparian Vegetation



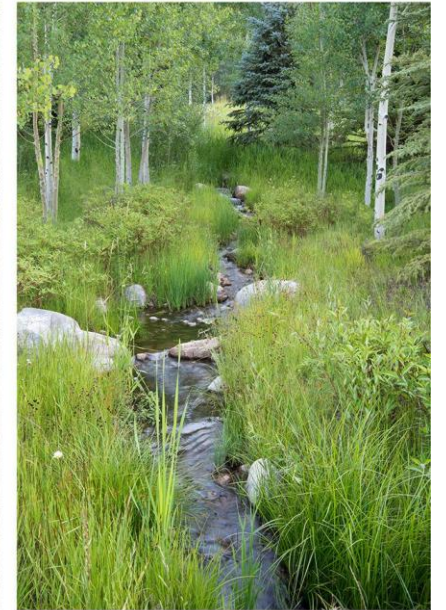
Steelhead



Chinook Salmon



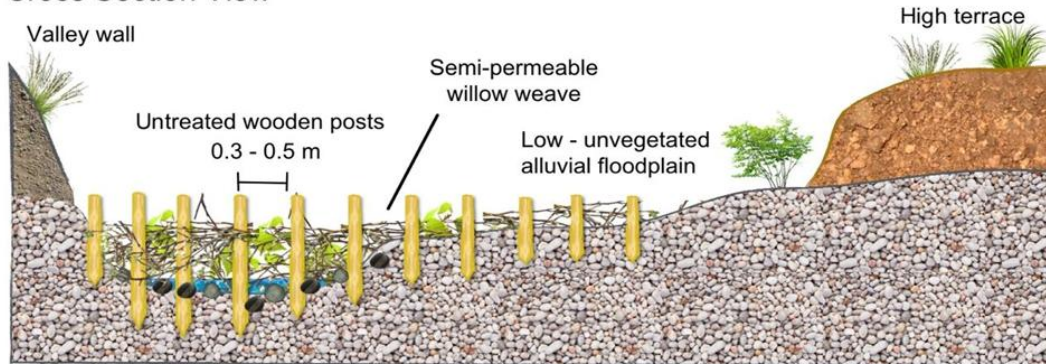
Bull Trout



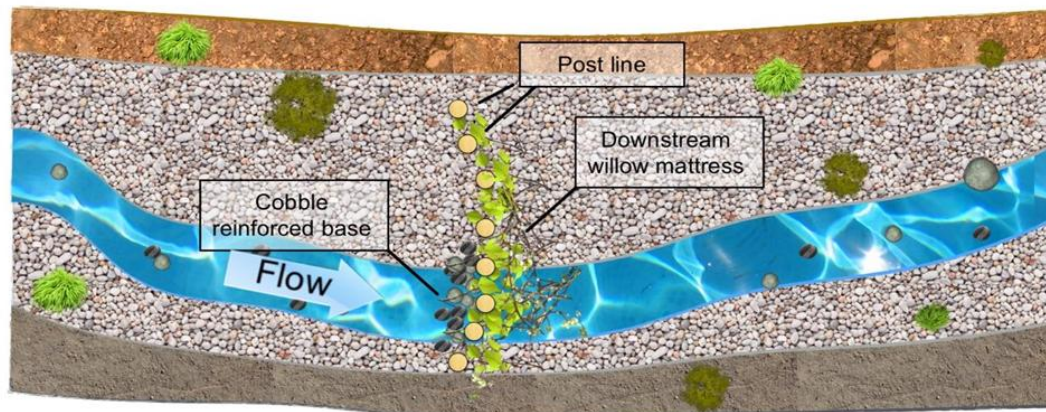
[American Society of Landscape Architects \(ASLA\)](#)

Beaver Dam Analogs

Cross Section View



Planform View



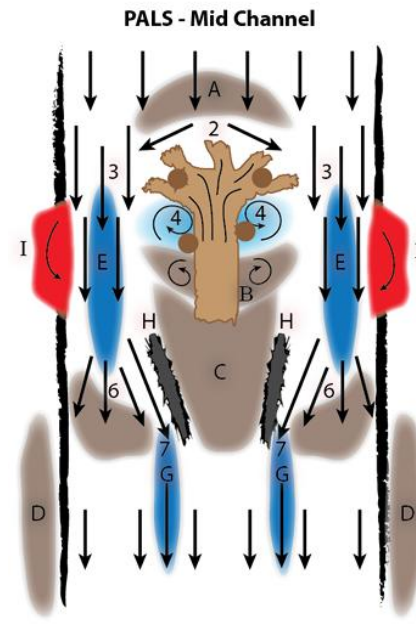
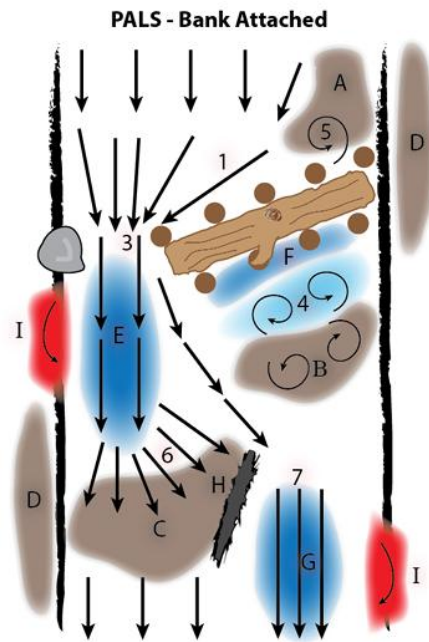
John Day River watershed, central Oregon.
Salmon habitat restoration.
Funded by Bonneville Power Administration.

Potential Improvements to:

- Carbon sequestration
- Biodiversity
- Water quality
- Water temperature
- Water quantity
- Fire resiliency
- Drought resiliency
- Flood resiliency
- Erosion protection
- Fish habitat



Post-Assisted Log Structures



Hydraulic	1. Shunting Flow
	2. Splitting Flow
	3. Convergent Jet Downstream
	4. Eddy Downstream
	5. Eddy Upstream
	6. Divergent Flow Downstream
	7. Convergent Flow Downstream
Geomorphic	A. Deposition Upstream
	B. Deposition in Wake
	C. Deposition Downstream
	D. Deposition Overbank
	E. Erosion at Convergent Jet
	F. Erosion by Plunge Hydraulics
	G. Erosion Forming Chute
	H. Erosion of Bar Edge
	I. Erosion of Outer Bank

	Eddy Pool		Channel Margin
	Deposition		Bank Erosion
	Pool-Forming Erosion		Flow Vector

Asotin Creek, southeast Washington. Steelhead habitat restoration. Supported by NOAA's Pacific Coastal Salmon Recovery Fund (PCSRF), Pacific States Marine Fisheries Commission (PSMFC), and Snake River Salmon Recovery Board (SRSRB).



Vegetation



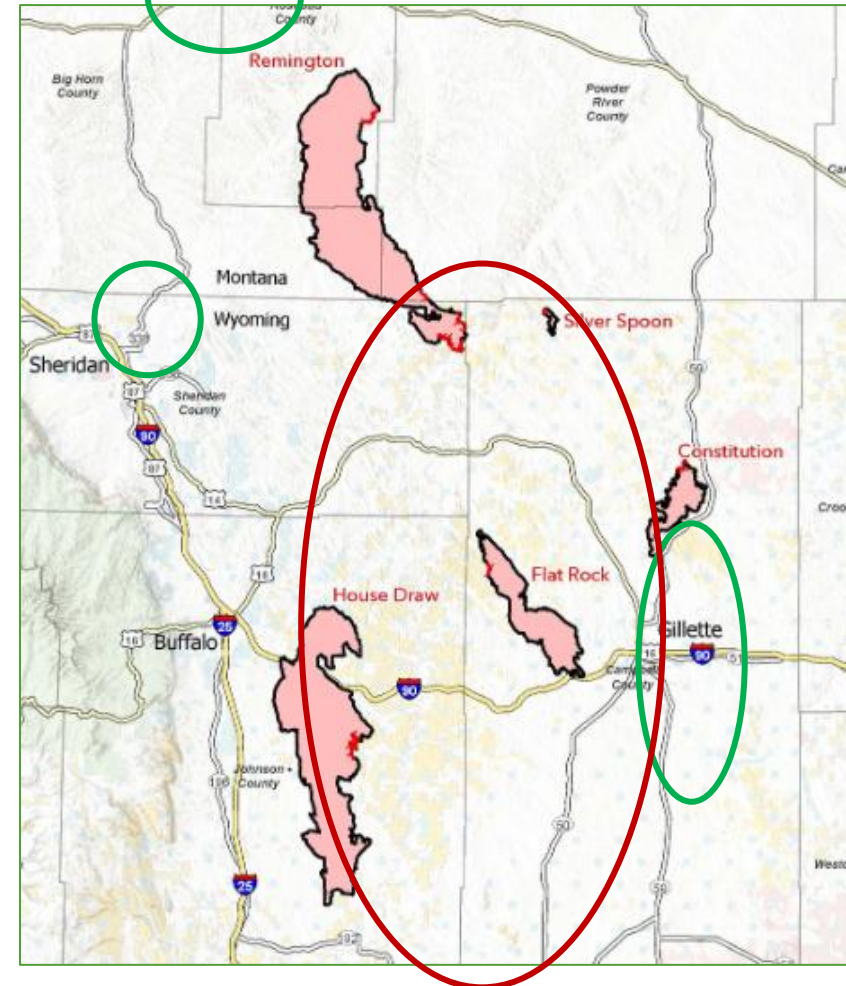
Seed Mix Design for Reclamation

- What species are we going to plant and how much of each?
- Reclamation goals supported by seed mix selection:
 - Return land to pre-disturbance land uses
 - Re-establish resilient, productive ecosystems
 - Meet regulatory standards
- Success depends on selecting species suited to site conditions and long-term resilience

Common Name	Scientific Name	Seeds/lb	Seeding Rate (PLS lbs/acre)	Seeds/ft ²	Percent of Seed Mix
Thickspike wheatgrass	<i>Elymus lanceolatus</i>	154,000	7.0	24.7	12.1%
Slender wheatgrass	<i>Elymus trachycaulus</i>	159,000	8.0	29.2	14.2%
Rough bentgrass	<i>Agrostis scabra</i>	113,000	0.1	0.3	0.1%
Mountain brome	<i>Bromus marginatus</i>	64,000	9.0	13.2	6.4%
Canada wildrye	<i>Elymus canadensis</i>	115,000	7.0	18.5	9.0%
Idaho fescue	<i>Festuca idahoensis</i>	450,000	2.0	20.7	10.1%
Annual ryegrass	<i>Lolium multiflorum</i>	227,000	8.0	41.7	20.3%
Canby bluegrass	<i>Poa secunda ssp. Canbyi</i>	926,000	2.0	42.5	20.7%
Yarrow	<i>Achillea millefolium</i>	2,770,000	0.1	6.4	3.1%
Lewis flax	<i>Linum lewisii</i>	170,000	1.0	3.9	1.9%
Silverleaf lupine	<i>Lupinus argenteus</i>	18,300	10.0	4.2	2.0%
		Total	54.20	205.2	100%

Climate Impacts to Revegetation

- Changing temperature and precipitation patterns affect seed germination and survival.
- Extreme weather events can disrupt early establishment.
- Long-term climate shifts may render traditional reclamation species less effective.
- Changing fire regimes to large, fast-moving fires



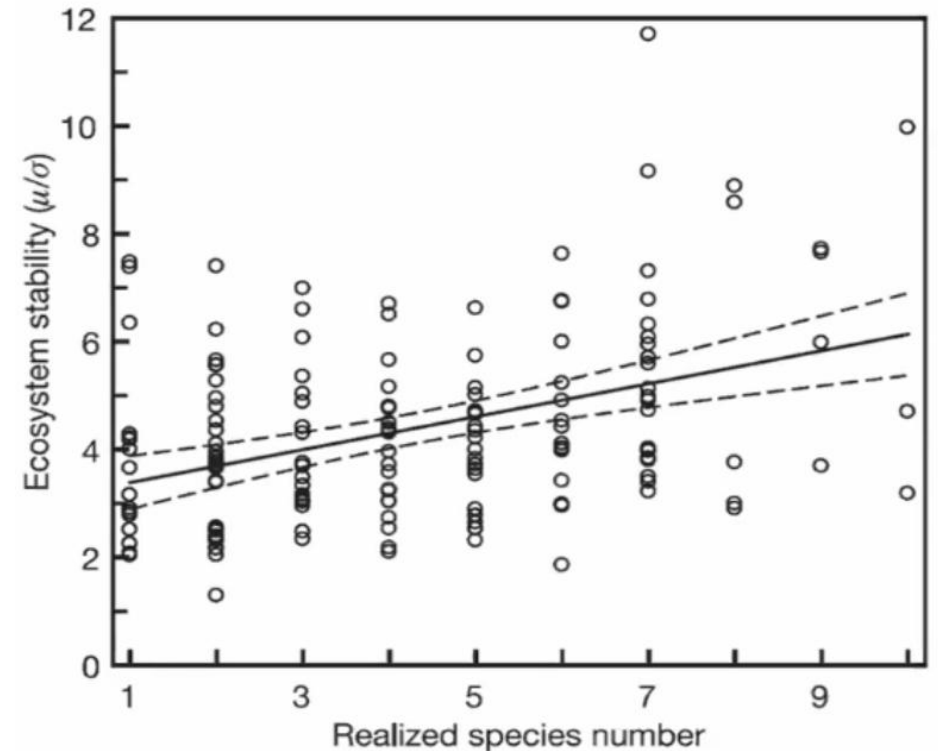
Challenges in the Commercial Seed Industry

- Native species often have narrow and unpredictable windows for seed maturation, which vary by region and year
- Early/late frosts affecting seed viability – both native and cultivated species
- Native species collection permits are difficult to acquire.
- Access and/or collection volume restrictions in harvest areas
- Requirements for species which are not commercially available
 - Low commercial incentive to grow species in low demand
- Seed mixes are often designed years or decades in advance of projects and do not build in flexibility
- Commercial availability and cost variable year to year



Reclamation Considerations

- Establishing diverse plant communities is key for long-term resilience
 - Invasives
 - Drought
 - High-precipitation events
- Increases in plant diversity have been shown to drive increases in diversity other life forms (Scherber et al. 2010. *Nature*)
- Use local seed sources when possible or varieties from similar environments
- Design mix for diversity, native species, etc. BUT ALSO climate anomalies to protect soil resources, etc.
 - Consider cover crops or non-natives for immediate stability
- If wildfire is a concern, prioritize natives adapted to post-fire recovery. Faster recovery equals more resilience to invasives.



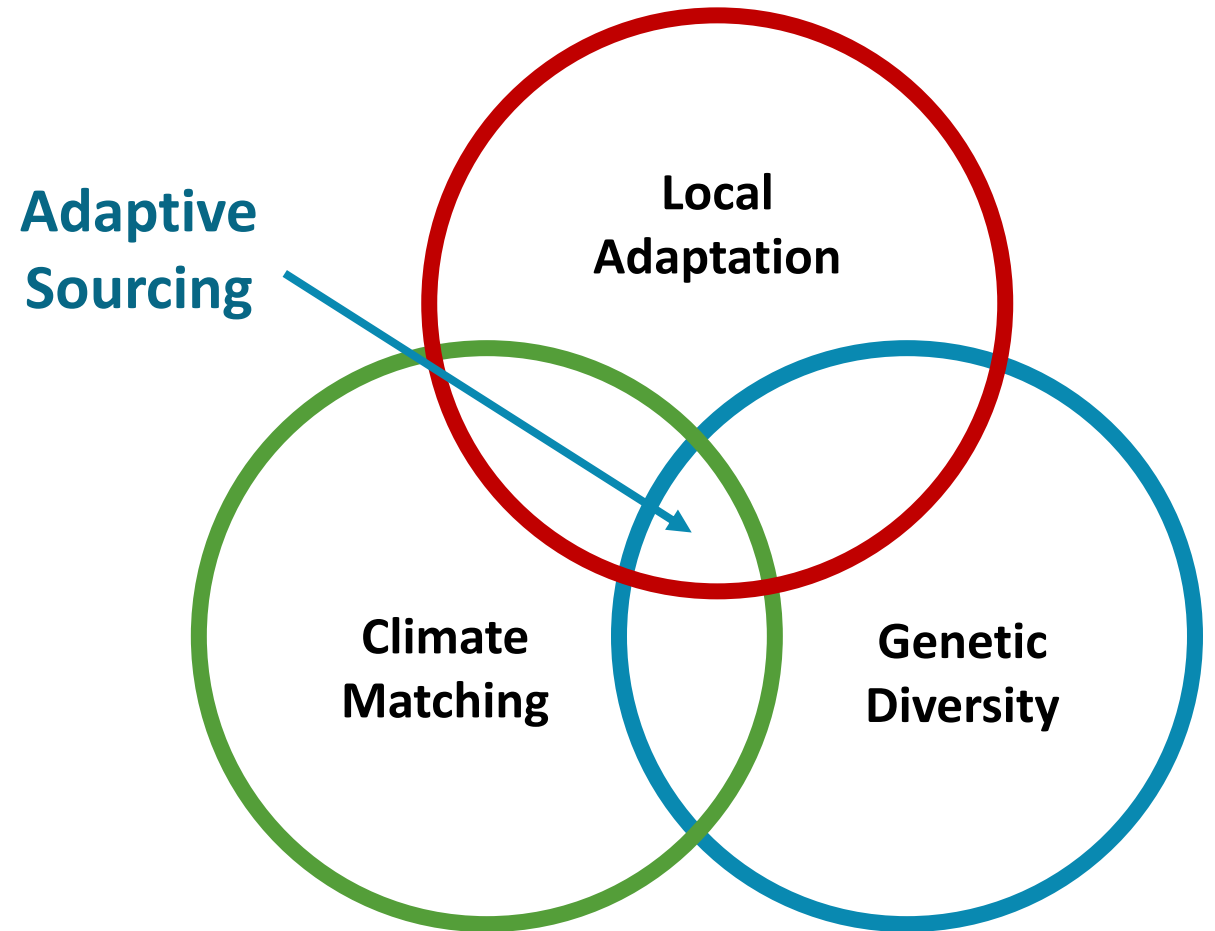
Tilman et al. 2006. *Nature*.

Adaptive Seed Sourcing

Local adaptations no longer local as climatic conditions change

Collect seed from:

1. Local sites for 'home site advantage'
2. Future climate-analog sites
3. Multiple sites to include genetic diversity





Planning Tools and References

Planning Tools Part 1

Western Regional Climate Center

- Climate anomaly maps.
<https://wrcc.dri.edu/>

U.S. Drought Monitor

- Drought, temperature, precipitation, streamflow, and vegetation conditions.
- Monthly and seasonal outlooks.
- Agriculture-specific information.
<https://droughtmonitor.unl.edu/CurrentMap.aspx>

USDA NRCS Web Soil Survey

- <https://websoilsurvey.nrcs.usda.gov/app/>





USEPA National Menu of Best Management Practices for Stormwater

- <https://www.epa.gov/npdcs/national-menu-best-management-practices-bmps-stormwater>

Climate Mapping for Resilience & Adaptation

- <https://resilience.climate.gov/>

Planning Tools Part 2

 U.S. Climate Resilience Toolkit	<ul style="list-style-type: none">• Case studies, trainings, funding sources, guidance on vulnerability and risk assessment tools and applications (e.g. data analysis and mapping) <p>https://toolkit.climate.gov/</p>
USEPA Climate Change Adaptation Resource Center (ARC-X)	<ul style="list-style-type: none">• Access to region-, topic-, and sector-specific EPA guidance <p>https://www.epa.gov/arc-x</p>
Utah State University Restoration Consortium	<ul style="list-style-type: none">• Design manuals, workshops, learning modules focusing on low-tech restoration methods <p>https://lowtechpbr.restoration.usu.edu/</p>
 Climate Hubs U.S. DEPARTMENT OF AGRICULTURE	<ul style="list-style-type: none">• Research and development, ag and forestry planning and risk assessment tools, webinars providing regional information on current drought status and impacts <p>https://www.climatehubs.usda.gov/</p>
 GIS for Climate Resilience	<ul style="list-style-type: none">• Models, planning tools, siting, watershed analysis <p>https://gis-for-climate-resilience-learnngis.hub.arcgis.com/</p>
 Seedlot Selection Tool	<ul style="list-style-type: none">• Match seedlots with planting sites based on climatic information (current and future). Focus on forestry. <p>https://seedlotselectiontool.org/sst/</p>

References

General

- McClelland, S.C., Bossio, D., Gordon, D.R. *et al.* Managing for climate and production goals on croplands. *Nat. Clim. Chang.* (2025).
- Jansson, C., Faiola, C., Wingler, A. *et al.* Crops for Carbon Farming. *Front. Plant Sci.* 12:636709. (2021)

Water

- **Riparian Shade:** Fuller, M.R., Leinenbach, P., Detenbeck, N.E., *et al.* Riparian vegetation shade restoration and loss effects on recent and future stream temperatures. *Restoration Ecology* Vol. 30, No. 7, e13626 (2022).
- **PALS:** Bennett, S., Keksi, E. & Bouwes, N. (2020). Asotin Creek Intensively Monitored Watershed Annual Progress Report: 2020.
- **BDAs:** Wathen, G., Weber, N., & Bouwes, N. (2019). Evaluation of Steelhead Responses to Implementation of Beaver Dam Analogs in Bear Creek, OR. – 2019 Year - End Monitoring Report. Eco Logical Research, Inc., Bend, OR.

Vegetation

- Scherber, C., Eisenhauer, N., Weisser, W. *et al.* Bottom-up effects of plant diversity on multitrophic interactions in a biodiversity experiment. *Nature* 468, 553–556 (2010).
- Tilman, D., Reich, P. & Knops, J. Biodiversity and ecosystem stability in a decade-long grassland experiment. *Nature* 441, 629–632 (2006).

Comments and Questions

Thank you for your participation.

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