From Extremes to Ex-Streams: Ecological Drought Adaptation Brief

This management brief summarizes the results of a project evaluating the scientific body of research on climate adaptation actions relevant to ecological drought. This adaptation science assessment evaluated strategies developed and prioritized by participants at regional adaptation workshops by synthesizing supporting evidence from the literature. The brief presents findings on the benefits and limitations of these climate adaptation options from the accompanying report, Extremes to Ex-Streams: Ecological Drought Adaptation in a Changing Climate.

Ecological Drought in a Changing Climate

Ecological drought refers to an "episodic deficit in water availability that drives ecosystems beyond thresholds of vulnerability, impacts ecosystem services, and triggers feedbacks in natural and/or human systems" (Crausbay et al. 2017). Climate change will increase the risk of ecological drought with projected changes likely to result in cascading impacts on species, habitats, and ecosystem services, including tree mortality, increases in wildfires, and altered water and nutrient cycling processes. These impacts will exacerbate current resource management challenges such as conflicts over water resources, land use and degradation, invasive species, maintaining agricultural yields, and managing wildfires. This project evaluates and synthesizes the scientific body of research relevant to climate adaptation actions used to address ecological drought in priority ecoregions and ecosystems of the Northwest in order to identify benefits and limitations of specific management approaches.

Many ecological drought adaptation options are already in use by managers across the Northwest to meet different goals and objectives. Managers may also choose to alter the implementation of existing management actions to adapt to changing conditions, or develop novel approaches to respond to the challenges of ecological drought.

Continue Existing Management Action

Protect and restore existing forest habitat

Alter Implementation of Existing Management Action

Restore forest habitat using drought-tolerant species

Develop and Implement Novel Actions

Create/protect forest habitat at higher elevations likely to maintain cooler, moister conditions

Ecological Drought Adaptation Approaches

Resistance

Strategies that limit the effects of climate change on a resource and/or bolster a resource's capacity to retain fundamental processes and functions by maintaining relatively unchanged conditions over time.

Resilience

Strategies that help a resource withstand the impacts of climate change by avoiding the effects of or recovering from changes to enable a return to prior conditions.

Response

Strategies that intentionally accommodate change and/or enable resources to transition to a new state through adaptive responses.

Knowledge

Strategies aimed at gathering more information about climate impacts or the effectiveness of management actions.

Collaboration

Strategies to help coordinate efforts and/or capacity across landscapes or organizations.

Resistance Strategies: Benefits (+) and Limitations (–)

Reduce water withdrawals	+ May reduce the effects of drought on wildlife and habitats + Limiting groundwater withdrawals, particularly during droughts, may retain cool-water springs to support vulnerable fish species – Requires coordination and collaboration across management goals and landscapes
Use exclosures and fences to protect groundwater-dependent habitats and associated species	+ Reduce access to sensitive habitats and help reduce damage in and adjacent to water sources + Exclosures have been linked to higher soil infiltration rates, higher wetland species, and higher recruitment and survival of the Columbia spotted frog +/– Fencing can reduce browsing pressure on drought-stressed habitats but exclosures over large areas may be cost-prohibitive
Enhance ecologically available water supply via environmental watering	+ Watering can maintain post-restoration sites and improve post-fire seedling survival + Dams can be modified to mimic natural flow regimes to support downstream habitats +/– Water sourced from natural rivers is typically more beneficial than water sourced from artificial irrigation channels – Complications associated with engineered environmental flows include loss of flow diversity and reduced access to critical habitats for fish species – May improve the spread of exotic aquatic weeds and invasive fish species
Reduce tree density and fuel loads through thinning and prescribed burns	+ Thinning increases individual tree growth and reduces tree water stress, can increase soil moisture per tree or per leaf area, and has been shown to improve the condition of remaining trees by increasing canopy growth and nutrient uptake and increasing growing space for trees +/– Prescribed burning may be more effective than thinning at controlling juniper encroachment over the long term, but results in more immediate loss of sagebrush and sage grouse habitat +/– Prescribed burning and thinning are effective at increasing soil nutrient and water availability, but may lead to invasion of exotic annual grasses – Regeneration treatments may indirectly increase stand vulnerability to drought by increasing evaporative losses and understory competition for soil moisture – Prescribed burns generate soil heat, which can reduce water infiltration and may create hydrophobic soils – Extended droughts can reduce opportunities to use prescribed fire as particularly dry conditions can make fires difficult to control – Thinning may increase leaf-to-sapwood area ratios, which can cause increased individual tree water demand

Resilience Strategies: Benefits (+) and Limitations (–)

Restore habitats by maintaining native vegetation cover and removing invasive species	+ Restoration of natives and removal of invasives linked to overall ecosystem health + Removing invasives that consume more water (e.g., *Tamarix* and western juniper) can reduce ecological drought effects – Western juniper removal has increased site susceptibility to invasion by exotic grasses (e.g., cheatgrass and Japanese brome), while tamarisk removal has been linked to invasions of exotic forbs in the Southwest
Enhance natural water storage (e.g., beaver dams/dam analogs, large woody debris, green infrastructure)	+ Beaver dams and beaver dam analogs (BDAs) impound water and retain sediment, promoting higher water tables and groundwater recharge, increased water storage in surrounding soils, increased water residence time + Large woody debris (LWD) slows water flows and raises water tables, increases groundwater infiltration, and provides mesohabitats for fish + Green infrastructure promotes groundwater infiltration and recharge + Rock structures (e.g., one-rock dams, media lunas) slow water flows, reduce erosion, and enhance infiltration +/– Effect of LWD varies depending on size of debris relative to size of water body
Maintain and enhance infiltration, water storage capacity, and/or health of forest soils	+ Maintaining organic carbon in soils improves water retention and water use efficiency + Masticated materials can reduce soil water evaporation and increase water availability for deeply rooted trees, and may help retain snowpack in alpine and subalpine habitats + Biochar application increases soil water retention and has supported enhanced growth and nutrient uptake of drought-stressed plants – Soil compaction from recreation, forest operations, and grazing can restrict the movement and storage of water +/– Restricting timing of access may only limit impacts in low-use areas as the maximum impact of human trampling occurs rapidly
Restore and reconnect floodplains	+ Increases water retention and storage potential + Restoration of meadow floodplains has been shown to significantly increase baseflow and groundwater storage in Sierra Nevada Mountains
Use livestock rotation and diversification to reduce pressure on vegetation and soils	+ Livestock rotation can reduce grazing pressure and expedite post-drought recovery + Grassbanking has been successfully used to incentivize ranchers to rest areas of pasture on their property in exchange for grazing access on other properties + Diversifying livestock can ameliorate the effects of drought while maximizing production capacity (e.g., sheep and goats are more heat tolerant and require less water than cattle) +/– Pastures may need to be completely rested for several seasons after drought and grazing may need to be delayed until after herbaceous forage plants have produced mature seed
Consider species type, timing, and location	+ Biological and genetic diversity maximizes the ability of species to survive + Considering species from a range of climatic and altitudinal gradients broadens the source of seeds and seedlings that may be better adapted to drier conditions +/– Maintaining a mix of older and younger trees of diverse sizes may reduce vulnerability to disturbances; more mature trees in species mixtures may be less vulnerable to drought but more vulnerable to pests – Limited studies exist on changing the timing of seeding and planting
Create or enhance water supply (e.g., wildlife water developments, constructed wetlands, canopy manipulation, snow fencing)	+ Wildlife water developments reduce the distance animals need to travel for water +/– Water developments concentrate livestock and grazing pressure in specific areas – Developments may increase competition between wild and domestic animals and trap and kill animals, and require capital investment and long-term maintenance + Constructed wetlands are used as opportunistic habitat and may support population persistence during dry periods + Snow accumulation can be enhanced via thinning treatments in snow-dominated coniferous forests and maintaining trees in even spatial distribution – Fire suppression maintains or increases canopy cover, which can reduce snow accumulation on the ground + Snow fences and vegetation barriers concentrate snow, recharge local soil water content, and can augment local water supply

Response Strategies Benefits (+) and Limitations (–)

Identify and protect drought refugia	+ Sites, such as those associated with higher and longer soil moisture retention rates, include topographically shaded slopes, thinner stands, areas of low bulk-density soils, valley bottoms, and riparian zones; mesic areas within dry forest habitats, such as gullies; intact floodplains with stable water availability from groundwater sources and flooding; and springs with topographic shading and sheltering at higher elevation, north- and northeast-facing slopes +/– Refugia at smaller scales (e.g., side channels) may be less resistant to disturbance than refugia at larger scales (e.g., wide floodplain areas, oxbow lakes) +/– Man-made water bodies can act as refugia and migration but water quality may limit their use by some species
Plant and store seed from drought-tolerant species and individuals	+ Successful trials have been conducted to establish whitebark pine outside of its current range – Existing seed transfer guidelines lack climate-informed temporal and spatial considerations to support decision-making +/– Lodgepole pine trials in western Canada have demonstrated that southern edge populations demonstrated the highest drought tolerance and could be good candidates for northward transplanting +/– Treatment sites as part of the Adaptive Silviculture for Climate Change project are evaluating different adaptation options; in Montana, managers are evaluating if and how the introduction of ponderosa pine into western larch forest stands may help larch survive in a warmer, drier climate
Protect vulnerable species through assisted migration and improved habitat connectivity	+ Fish translocations are most effective during wet periods + Maintaining waterhole connectivity can support wide-ranging species during periods of drought +/– Mixed evidence that translocations successfully increased juvenile growth rates of Carmel River steelhead populations in California, while translocations of fish species in Australia had limited effectiveness due to rapid onset and scale of critical water shortages – Potential hybridization of native and non-native species, introduction of diseases and parasites, and potential extirpation of species – Risks tend to increase with distance of transfer

Knowledge Strategies: Benefits (+) and Limitations (–)

Improve understanding of ecological drought impacts and adaptation options	+/– There is evidence supporting the use of several strategies and actions to respond to and recover from ecological drought impacts; however, there are still knowledge gaps and areas for future research to support more informed decision making.

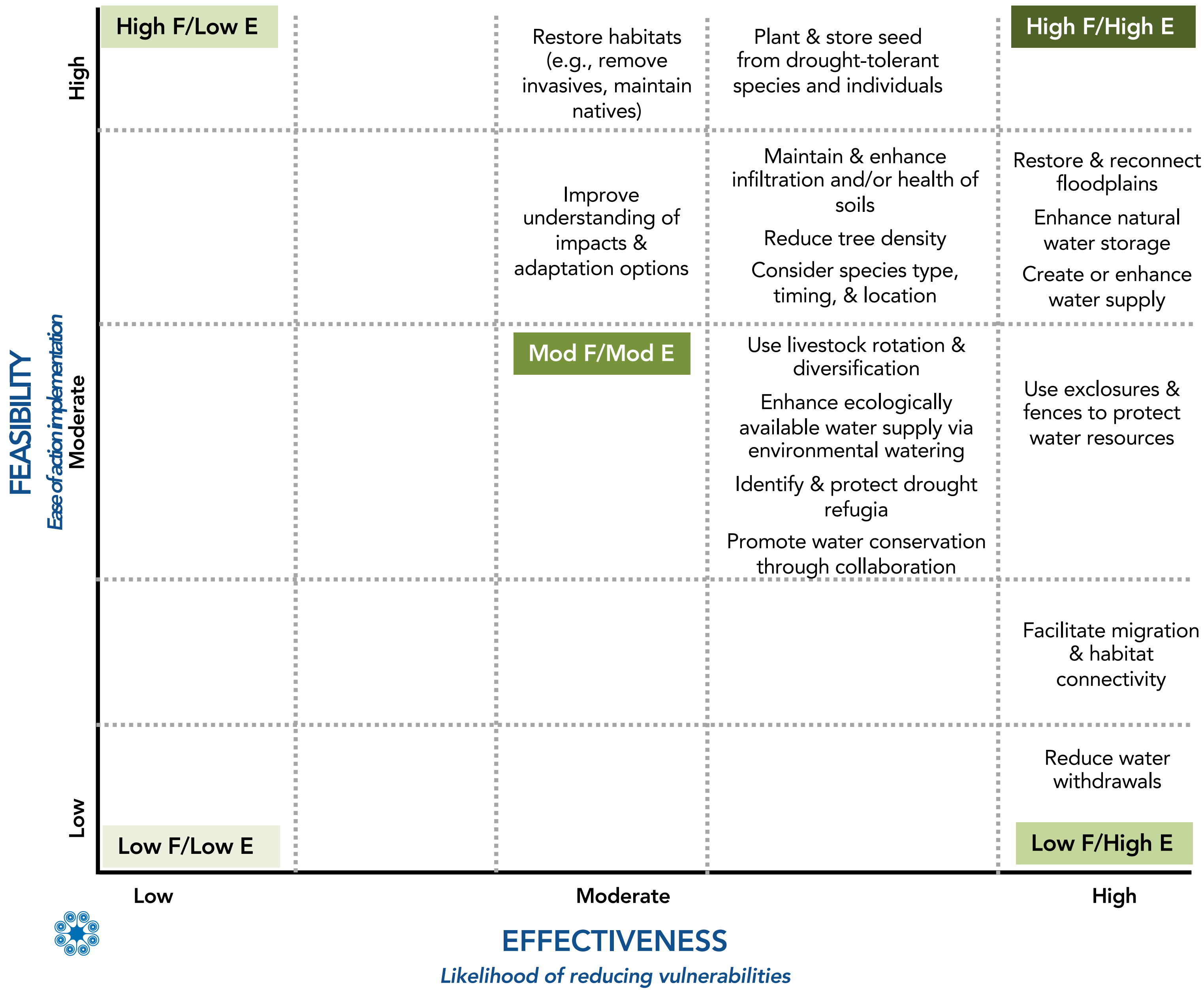
Collaboration Strategies: Benefits (+) and Limitations (–)

Promote water conservation through collaborative agreements (e.g., water banking, water trading, voluntary reductions)	+ Water banking has been used to address ecological impacts from hydroelectric activity in the Columbia Basin and to restore natural water flows to the Yakima and Dungeness rivers + Water conservation collaboratives have been used to conserve water and restore riparian habitats, and balance the needs of conservation practitioners, ranchers, farmers, and municipalities through voluntary water use restrictions and water banking +/– Improving irrigation efficiency may limit water loss at diversions and ditches, maximize water absorption by plants and soil, and restore flows to benefit wildlife, but may lead to increased water consumption, ultimately exacerbating water shortages – Many drought management plans consider the ecological impacts of drought as triggered by streamflow variation, which encourages managers to prioritize reactive rather than proactive, long-term strategies

Prioritizing Adaptation Options for Implementation

When selecting adaptation actions for implementation, managers should consider both *effectiveness* (action reduces vulnerability) and *feasibility* (action capable of being implemented). An action with high effectiveness is very likely to reduce associated vulnerabilities and may benefit additional management goals or resources whereas an action with low effectiveness is unlikely to reduce vulnerability and may have negative impacts on other resources. An action with high feasibility has no obvious barriers and a high likelihood of implementation whereas an action with low feasibility has obvious and/or significant barriers to implementation that may be difficult to overcome.

The following figure and tables present feasibility and effectiveness rankings, which are based on evidence in the literature and/or expert opinion (e.g., manager-provided rankings during adaptation workshops). These tools can help managers prioritize strategies and actions for implementation (e.g., actions with high feasibility and high effectiveness), better target management efforts toward specific challenges (e.g., actions with low or moderate feasibility but high effectiveness), and/or evaluate whether to proceed with implementation (e.g., actions with high feasibility but low effectiveness).



Specific adaptation actions were identified from a review of regional adaptation workshop results and literature. The following tables present actions that received the highest (e.g., moderate-high or high) rankings for implementation feasibility and effectiveness in reducing ecological drought vulnerabilities. A complete list of actions are available in the full report, *Extremes to Ex-Streams: Ecological Drought Adaptation in a Changing Climate*. Actions are classified by ecosystem relevance: Forest (FO), Grassland/Shrubland (G/S), Freshwater (FW), and Marine/Coastal (M/C).

Adaptation Strategy	Associated Action(s)	Feasibility	Effectiveness
Enhance ecologically available water supply via environmental watering	Manage water levels to maintain hydrologic function and supply proper soil moisture to vegetation adjacent to the stream during critical periods (e.g., by manipulating existing dams and water control structures or through restoration of natural dynamic water fluctuations) (FW)	***Mod-High***	***High***
Reduce tree density and fuel loads	Promote age class, species, structural, and/or spatial (e.g., forest gaps) diversity across the landscape using a variety of management tools (e.g., prescribed and wildland fire, regeneration harvest, thinning) (FO)	***Mod-High***	***High***
	Reduce density via variable means (e.g., thinning, prescribed fire, wildfire use, girdling, falling and leaving trees), with density and structural goals based on projected future conditions (FO)	***Mod-High***	***Mod-High***
Consider species type, timing, and location in management activities	Consider using genetically improved (e.g., insect- or disease-resistant) seedling stock to increase resilience to disturbance such as drought (FO, G/S)	***Mod-High***	***High***
	Favor or establish more drought- and heat-tolerant species on narrow ridge tops, south-facing slopes with shallow soils, or other sites that are expected to become warmer and drier (FO, G/S)	***High***	***Mod-High***
	Prioritize removal of stressed, damaged, or unhealthy trees in order to promote the survival of those expected to fare better (FO)	***Mod-High***	***Mod-High***
	Protect trees that exhibit adaptation to water stress (e.g., trees with low leaf area:sapwood ratio) (FO)	***High***	***Mod-High***
Create or enhance water supply	Manage gaps and forest openings to increase snow catch accumulation, and use techniques to shade snow such as mulching with wood chips to extend the retention of snowpack and enhance water availability during the growing season (FO)	***High***	***High***
	Use snow fences and reflective tarps to retain snowpack and enhance water availability during the growing season (FO, G/S, FW)	***High***	***High***
	Use wildlife water developments to ameliorate loss of naturally-occurring water sources for the benefit of wildlife, game species, and livestock (FW)	***High***	***Mod-High***
Enhance natural water storage	Add wood to streams to enhance natural water storage (FW)	***Mod-High***	***Mod-High***
	Enhance natural water storage through the use of beaver dam analogs (FW)	***Mod-High***	***High***
	Reintroduce, enhance, and maintain beaver populations to improve water storage (FW)	***Mod-High***	***High***
	Slow water flows and increase soil infiltration with rock structures (e.g., one-rock dams, media lunas) (G/S, FW)	***High***	***Mod-High***
	Utilize green infrastructure (e.g., bioswales, permeable pavement) (FW)	***Mod-High***	***High***

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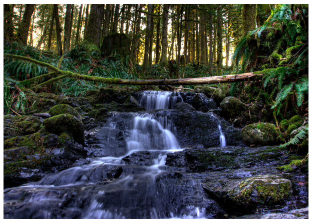
Adaptation Strategy	Associated Action(s)	Feasibility	Effectiveness
Maintain and enhance infiltration, water storage capacity, and/or health of soils	Maintain soil productivity through appropriate silvicultural practices (e.g., fuels treatments) (FO)	*High*	*High*
	Plant deep-rooted perennials to reduce runoff and improve infiltration (FO)	*High*	*Mod-High*
	Retain coarse woody debris in the uplands and riparian areas to maintain moisture, soil quality, and nutrient cycling (FO, FW)	*Mod-High*	*High*
Restore and reconnect floodplains	Increase aquatic habitat structure, complexity, and connectivity to refugia in stream channels, off-channels, channels fed by wetlands, and floodplains (FW, M/C)	*High*	*High*
	Reconnect streams to floodplains/alluvial fans to improve hyporheic and base flow conditions (FW, M/C)	*Mod-High*	*High*
	Remove and/or modify roads to control erosion and runoff and restore floodplain and hydrological connectivity (FW, M/C)	*Mod-High*	*Mod-High*
Restore habitats by maintaining native vegetation cover and removing invasive species	Monitor, remove, control, and prevent the spread of non-native species as well as introduction/dispersal vectors (FO, G/S, FW, M/C)	*Mod-High*	*Mod-High*
Use livestock rotation and diversification to reduce pressure on vegetation and soils	Manage livestock grazing to restore ecological function of riparian vegetation and maintain streambank conditions (FW)	*High*	*High*
Plant and store seed from drought-tolerant species and individuals	Collect seed from trees that exhibit adaptation to water stress for future regeneration (FO)	*High*	*High*
	Plant native species that are well-adapted to drought and/or have a broader moisture tolerance range (FO, G/S, FW, M/C)	*High*	*Mod-High*
	Plant stock from seeds collected from healthy trees in warmer or drier locations in the region (FO)	*High*	*Mod-High*
	Seed or plant drought-resistant genotypes of commercial species where increased drought stress is expected (FO)	*High*	*Mod-High*
Identify and protect drought refugia	Identify and protect a network of sheltered mountain slopes, valleys, or forests with continuous shading canopy (FO)	*Mod-High*	*Mod-High*
Improve understanding of ecological drought impacts and adaptation options	Develop watershed models to describe forestry and climate change (e.g., snowpack, precipitation, temperature) interactions in order to identify ways to maximize water retention (FO, FW)	*Mod-High*	*High*
	Evaluate the long-term adequacy of water delivery infrastructure to ensure that changes in hydrological patterns can be anticipated and managed effectively (FW)	*High*	*Mod-High*
	Examine how restoration project maintenance may need to be restructured in drought years (FO, G/S, FW, M/C)	*High*	*Mod-High*

How were the ecological adaptation options identified?

Strategies and actions were sourced directly or modified from the Adaptation Partners' Climate Change Adaptation Library; Northern Institute of Applied Climate Science Adaptation Workbook; adaptation plans from the Stillaguamish Tribe of Indians, Puyallup Tribe of Indians, Yakama Nation, Jamestown S'Klallam Tribe, and Lummi Nation; and adaptation workshop results from the Nez Perce-Clearwater National Forests and Southern California Climate Adaptation Projects, among others.

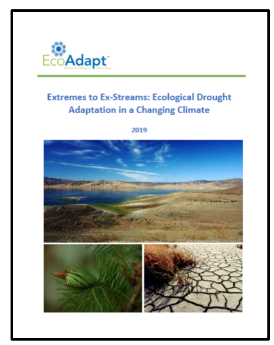




What are some on-the-ground examples and tools I should explore?

- *Restoring Ecosystem Services Tool (REST):* A computer model designed to assist managers in selecting species for restoration projects based on functional traits that best match specific management objectives, such as drought tolerance (bit.ly/RestoringEcosystemServices)
- *Grass-Cast:* Integrates climate change projections into forage productivity outlooks to support flexible stocking decisions before, during, and after droughts (http://grasscast.agsci.colostate.edu)
- *Embracing Change: Adapting Conservation Approaches to Address a Changing Climate* presents some examples of how conservation practitioners are applying adaptation on the ground (bit.ly/WCSEmbracingChange)
- *Adaptive Silviculture for Climate Change Project* (www.adaptivesilviculture.org): A nationwide series of experiments to evaluate resistance, resilience, and response treatments across different forest types. One such site is the western larch-dominated forests located in Montana's Flathead National Forest/Coram Experimental Forest where managers are creating forest stands that are more tolerant of a warmer, drier future climate, and using adaptive management to make modifications as needed. These adjustments may include introducing additional species or actively facilitating a transition to a hardwood forest or woodland if western larch can no longer survive in the area.

Where can I find more information?

- *Extremes to Ex-Streams: Ecological Drought Adaptation in a Changing Climate*
- Case studies, resources, and tools on the Climate Adaptation Knowledge Exchange (CAKEx.org)
- SNAPP Ecological Drought Team products: https://snappartnership.net/teams/ecological-drought/
- Crausbay SD et al. 2017. Defining ecological drought for the twenty-first century. Bulletin of the American Meteorological Society 98:2543–2550.



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