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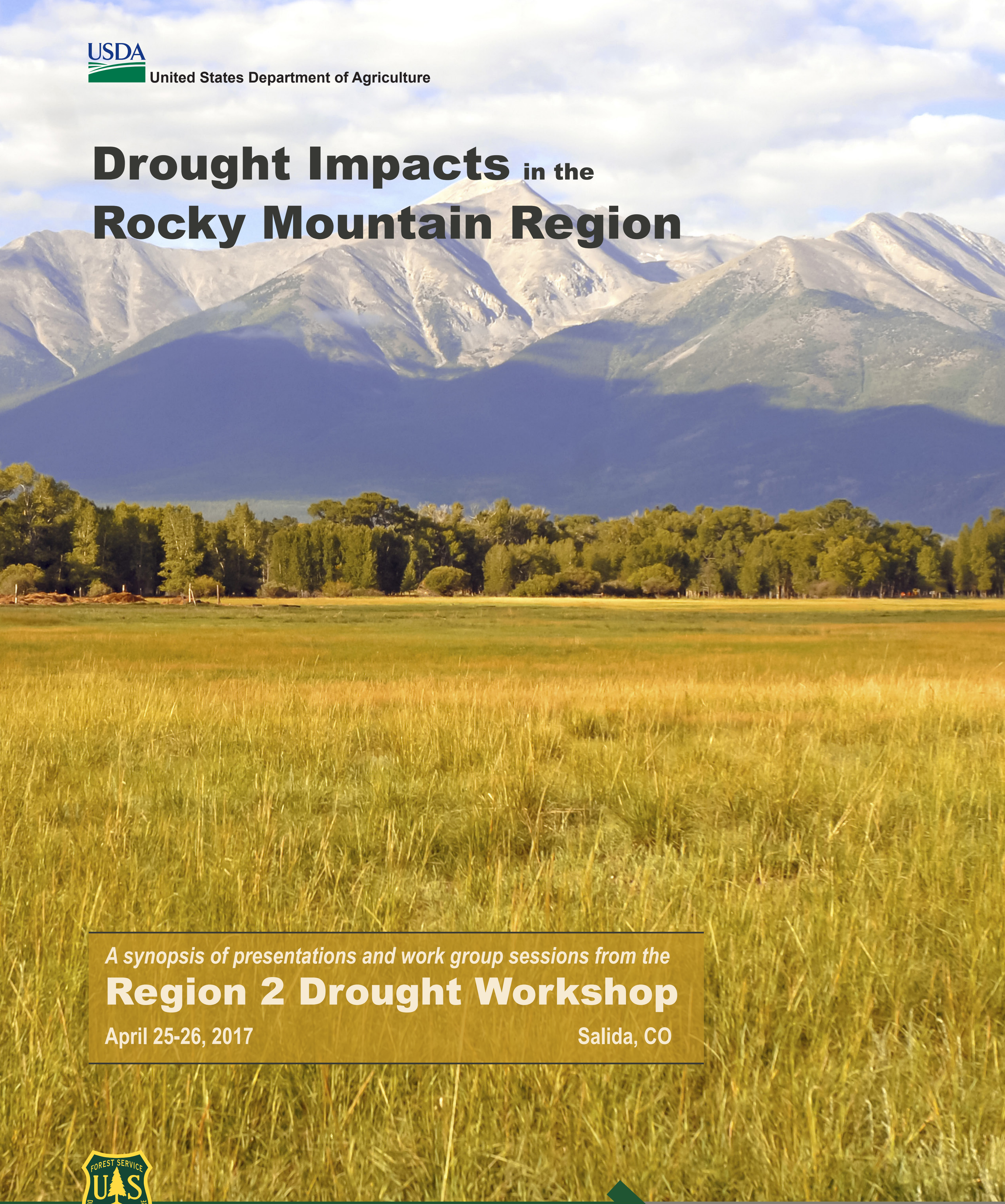

# Drought Impacts in the Rocky Mountain Region

*A synopsis of presentations and work group sessions from the*

## Region 2 Drought Workshop

April 25-26, 2017 Salida, CO

Forest Service Washington Office September 2017 Office of Sustainability and Climate

USDA Northern Plains Climate Hub
U.S. DEPARTMENT OF AGRICULTURE

# Drought Impacts

## in the Rocky Mountain Region

### Background

Drought influences ecological processes and disturbances at all scales, such as with increased insect and disease outbreaks, aquatic die-offs, invasive species infestations, altered tree growth, competition, and area burned. In Colorado, observed ecological trends and impacts include increased tree mortality; more large wildfires and more burned area since the 1980s; historically unprecedented bark beetle infestations; plant/ animal phenology shifting earlier in the year; and plant and animal ranges shifting upslope/north (Averyt et al. 2011).

To promote stronger drought resilience on federal lands, the National Drought Resilience Partnership was initiated in 2016. As a part of this effort, the Forest Service held a series of focused workshops across the country to understand the management opportunities and constraints imposed by drought conditions, as well as the challenges of floods and changing precipitation patterns on forest and rangeland resources.

In April 2017, the Forest Service hosted a two-day drought adaptation workshop in Salida, Colorado.  The 60 workshop participants came from the Regional Office, Washington Office, and Colorado forests including the Grand Mesa, Uncompahgre, and Gunnison; Pike and San Isabel; and Rio Grande National Forests. Topics included an overview of drought conditions and climate trends in Colorado, and the impacts of drought on forest vegetation, rangelands, recreation, aquatic systems, and terrestrial wildlife. This fact sheet summarizes presentations and work group recommendations, and provides additional research as supporting documentation.

### Drought in the Rocky Mountain Region

Drought is a familiar phenomenon in the Rocky Mountain Region (Colorado, Nebraska, Kansas, Wyoming, and South Dakota). Throughought the 20th century, the Rocky Mountain Region had significant periods of drought in the 1930s to early 1940s (the Dust Bowl droughts), the 1950s, mid-1960s, late 1970s, and early 1990s (Doesken et al. 2000). The beginning of the 21st century saw drought in 2002-2007 and 2012-2015.

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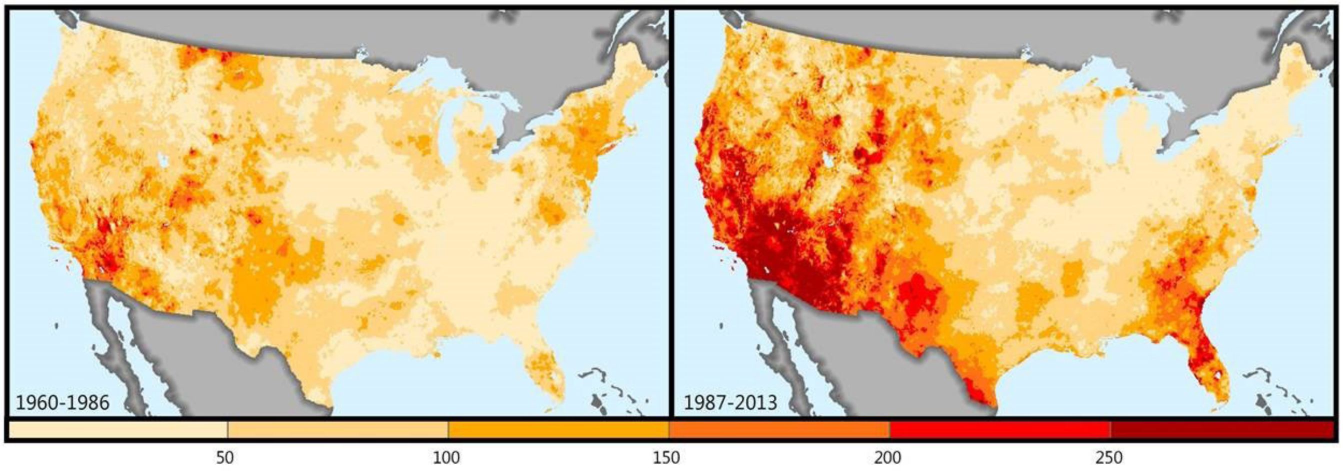
Definitions of drought include:

- ***Meteorological*** **–** degree of dryness over a defined period of time. Most types of drought relate to meteorological conditions due to lack of precipitation or excess evapotranspiration (Vose et al. 2016);
- ***Hydrological*** **–** precipitation deficits and their effect on the hydrologic system, (e.g., lakes, and stream volume, and flow reductions);
- ***Agricultural*** **–** links meteorological drought with agricultural impacts (e.g., reduced commodity production, crop failures); and
- ***Socio-economical*** **–** human needs (e.g., electrical power production, recreation, wildlife) exceeds supply due to weather/ climate-related water shortfall (Vose et al. 2016; Wilhite and Glantz 1985).

***Ecological drought*** is a water deficiency that drives ecosystems beyond thresholds of vulnerability and causes impacts to the services they provide to people, such as carbon sequestration and available drinking water (Crausbay et al. 2017).

Humans also contribute to or alleviate drought by modifying hydrological processes (e.g., through land use change, irrigation, and dam building) (Van Loon et al. 2016).

*Figure 1 - Drought Over Time. Cumulative Drought Severity Index maps compare intensity and frequency of drought over two 27-year time periods. The map below shows droughts in many areas became more severe and frequent. (Click for an interactive version.)*




Average temperatures in Colorado have increased 2 degrees Fahrenheit between 1977 and 2006 (Lukas et al. 2014). Temperatures are projected to increase by another 2.5 to 6.5 degrees Fahrenheit by mid-century (Lukas et al. 2014).

In the past 30 years, annual precipitation has stayed about the same. Climate model projections for future precipitation are unclear if and how annual precipitation will change by 2050 (Lukas et al. 2014). The likelihood of decreasing precipitation appears to be higher for the southern part of Colorado.

Trends in snowpack have been below-average since 2000 in all of Colorado's river basins. Since 1977, snowmelt and spring runoff has been occurring earlier in the spring by one to four weeks due to lower snow water equivalent, warmer spring temperatures, and greater solar absorption from dust on snow (Lukas et al. 2014). See Figure 4.

Global climate models project a reduced spring snowpack in Colorado, and that by mid-century heat waves, droughts, and wildfires will increase in frequency and severity (Lukas et al. 2014).

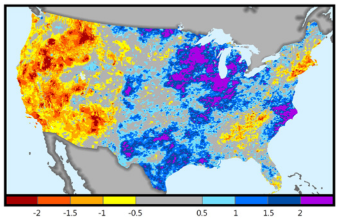



*Figure 2 - The Moisture Deficit and Surplus 2000-2016 map shows the changes in moisture across a 19-year period. Each 3-year time period shows moisture patterns that can contribute to drought, flooding, or a combination of the two. (Click for an interactive version.)*

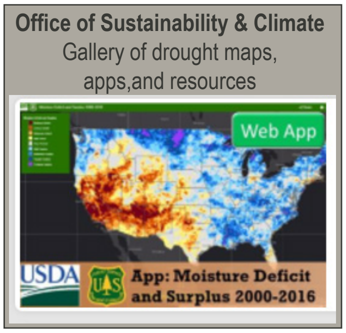
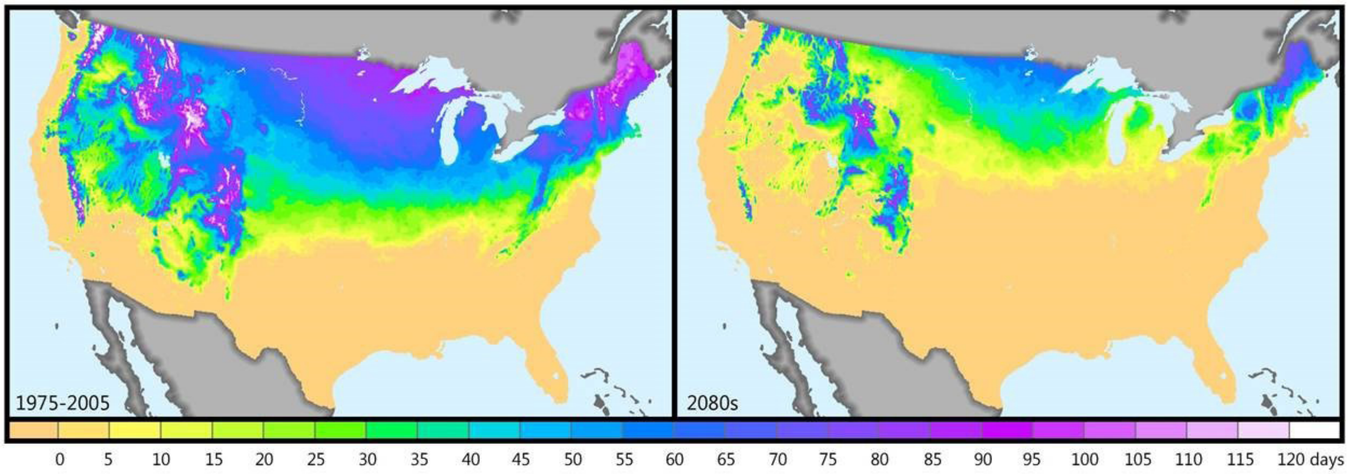



*Figure 3 - The OSC Drought Gallery has interactive maps showing historic versus 2080 temperature and precipitation maps; time series maps for drought patterns; and other resources. (Click to visit the gallery.)*

## Forest Vegetation

In the Rocky Mountain Region, tree growth and survival are limited by water availability and worsened by increased temperatures (Smith et al. 2015). Snowpack plays a significant role to the Region's climate and affects the natural regeneration of forests.

*Figure 4 - Historical and projected snow residence times in days. The maps compare days with snow residing between 1975 and 2005 versus a projected map of 2080. (Click on map for an interactive version.)*



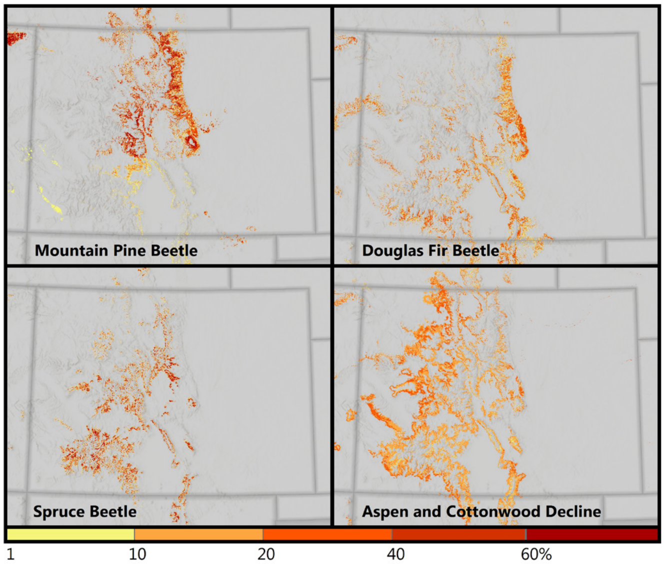

Shallow snowpack affects the growing season of lodgepole pine, Engleman spruce, and subalpine fir since they rely on snowmelt late into the growing season. Although longer growing seasons are often associated with higher carbon sequestration, the reverse may be true in these species because of moisture limitations (Hu et al. 2010).

Drought impacts the natural regeneration of trees by reducing seed production, limiting seed germination, and increasing seedling mortality (Chmura et al. 2011). Between 1982 and 2013, conifer mortality increased from moisture stress in the Colorado Front Range (Smith et al. 2015).

Drought exacerbates the effect of other stressors including insects, diseases, and fire. Drought reduces tree vigor, making forests more susceptible to insects and pathogens (Weed et al. 2013). Insects and disease have killed drought-stressed trees across millions of acres in the western U.S. since the beginning of the 21st century.

In Colorado, between 2000 and 2016, mountain pine beetles have killed lodgepole pine (3.4 million acres); spruce beetle has killed Engelmann spruce and other species (1.7 million acres); and sudden aspen decline has killed or affected quaking aspen (1.2 million acres). See Figure 5.

*Figure 5 - Proportion of basal area projected to be lost between 2013 and 2027, for the host species of four disturbance agents.*




Increased temperatures may increase the frequency and magnitude of droughts, causing more fires and larger areas burned (Littell et al. 2016). Dense forests often contain elevated fuel loadings, which combined with drought, can increase the incidence of high-severity fire (Clark et al. 2016; Littell et al. 2016). During the 2002 drought in Colorado, more than 927,000 acres burned in wildfires.

Indirect effects of drought through insects and tree mortality can also change landscape patterns and species composition.

### *Forest Vegetation Management Response Options*

» Use ***planting*** to ensure adequate tree establishment and to sequester carbon. Focus on areas of large-scale mortality that are not regenerating naturally. Plant seedlings in suitable microsites and provide artificial shading.

» Select/favor ***drought-tolerant species*** and genotypes.

» ***Identify sites to protect special species***. Establish refugia for ponderosa pine by enhancing regeneration.

» ***Enhance opportunities for self-migration*** (e.g., establishing seedlings in more favorable sites more resistant to drought) by favoring seed production and dispersal in current habitat, and receptive seed beds in nearby emergent habitats. Promote existing female aspen near emergent areas to enhance seed production. Facilitate aspen establishment by favoring disturbances, especially fire, in newly suitable areas.

» ***Manage seed inventories*** to maintain genetic diversity while updating and maintaining seed procurement inventories to increase genetic diversity. Collect seeds from multiple trees of the same species in seed transfer zones. Plan to increase planting densities to compensate for potentially higher seedling mortality.

» ***Emphasize soil conservation*** techniques by reducing surface temperatures through slash or coarse woody debris, and retention of vegetation in sensitive locations. Avoid increasing soil bulk density by designing effective skid trail network. Maintain soil moisture by avoiding activities that reduce or remove soil organic matter.

» ***Reduce fuels.*** Use prescribed burning or managed wildfire to manage for diversity of age class and species.

» ***Collaborate with ski areas*** to access stands and maintain forest cover.

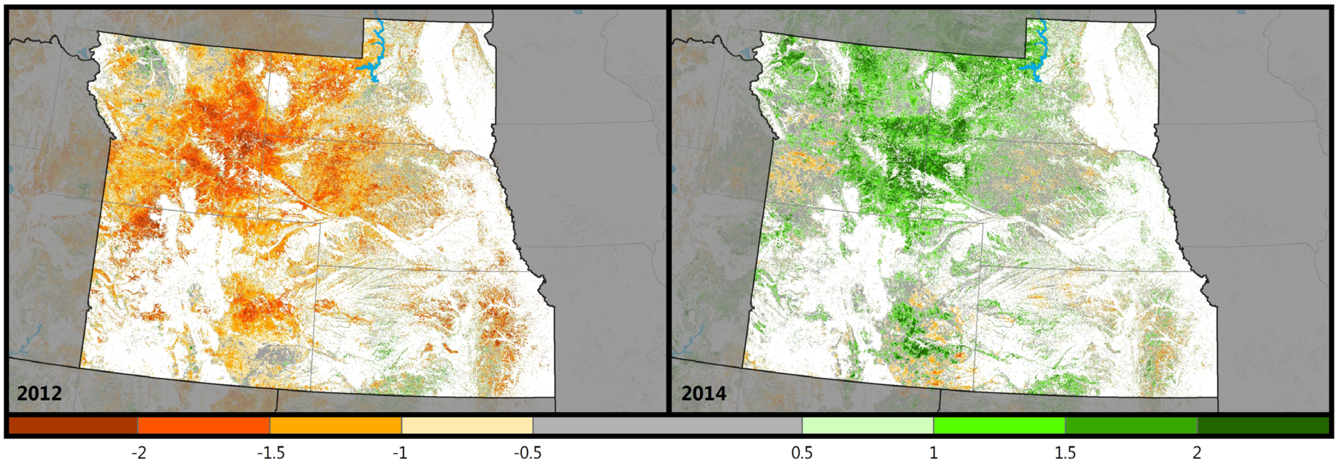
» ***Promote tree size and age diversity at the stand and landscape-levels*** to increase resilience to insect outbreaks, fire, and drought.

## Rangeland

For much of the Rocky Mountain Region, precipitation and forage production are highly variable within and among years. For example, the difference in forage production during a wet year versus a dry year is over 3 million tons, enough to support/feed approximately 192,000 cows in one year (see Figure 6).

This level of variability presents challenges for rangeland managers and grazing permittees to match forage production variability with annual animal management flexibility.

*Figure 6 - Examples of low and high-productivity years, expressed in standard deviations from the mean, based on 2000-2016 data. Total forage for Region 2 ranges from 111 to 161 million tons for 2012 and 2014, respectively. (Click for an interactive version.)*



Higher temperatures reduce soil moisture and plant cover, with the potential for increased soil erosion (Polley et al. 2013). In addition, vegetation productivity and regeneration are linked to annual precipitation and soil moisture levels (Haddad et al. 2002). For grassland species, very low soil water content can increase plant moisture stress reducing plant vigor and in some cases cause mortality (Poirier et al. 2012).

Drought may also increase the movement of invasive species into rangelands, favoring nonnative over native species (Finch et al. 2016).

### *Rangelands Management Response Options*

- Increase resilience by using ***grazing methods*** that alternate periods of stress (grazing) and rest (reduced grazing).
- ***Evaluate and adjust herd composition and numbers*** so stocking rates match forage production using drought monitoring tools such as the [Evaporative Demand Drought Index (EDDI)] or the [US Drought Portal.]
- ***Use livestock breeds adapted to local conditions*** (hot and fluctuating weather) or shift the type of livestock grazing that area.
- ***Develop market-based adaptation strategies*** including forage purchase, insurance-based risk management.
- Create ***community-scale social networks*** to pool resources and exchange technology, labor, equipment, forage, and ideas.

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- Increase watershed health and function by ***reintroducing American beaver*** into areas where they are not presently thriving as a means to retain more water in meadows and riparian areas.
- Use ***smart fencing*** (e.g., drift fences) and electric fences in order to rest areas after grazing.
- Employ ***targeted grazing methods*** (e.g., use livestock to eat weeds) after disturbance events like fire to restore vegetation cover.

## Recreation

Drought affects the ability of forests and grasslands to provide various types of recreation opportunities. These effects differ between winter and summer recreation opportunities activities mainly due to the dependence on snow for winter recreation and on warm weather and water for summer recreation activities (Thomas and Wilhelmi 2013).

Winter drought lowers snowfall reducing economic benefits in the winter recreation sector (e.g., skiing, snowmobiling). Likewise, winter drought can worsen water-dependent summer recreation activities such as rafting and fishing, but can create more opportunities for hiking and camping because of earlier snowmelt (Thomas and Wilhelmi 2013).

Other effects of drought on recreation include altered animal migration patterns for hunters and wildlife viewers; campground and forest closures from wildfire or insect and disease outbreaks; and aesthetic and scenic values from dry vegetation and dead trees.

The potential effects of drought on ski areas is an example of a socioeconomic effects of drought. In 2016, the Forest Service collected $45 million in ski area fee receipts, exceeding the amount received from all other fee categories (e.g., timber, grazing, mining, power generation).

In Colorado, the 26 ski areas on national forest lands were visited by13 million skiers and received $25 million in fee receipts. The ski industry in

Colorado is worth $3 billion in skier expenditures and $4.8 billion in direct and indirect economic output; supports 46,000 year-round equivalent jobs; and generates $1.88 billion in labor income (RRC Associates 2015).

Given the magnitude of this growing economic driver on Colorado's economy, the Forest Service and the ski industry have developed adaptation strategies by developing new technologies, policies, and resource management options.

Courtesy of the Denver Post

### *Ski Area Management Response Options*

- ***Invest in snowmaking infrastructure*** at ski areas to ensure a reliable skiing surface in the absence of reliable snowfall.
- ***Transition to four-season resorts*** by diversifying activities (e.g., mountain biking, hiking, zip lines, outdoor education) to maximize return on investment. Develop policies allowing for seasonal and year-round recreation activities at ski areas in accordance with the Ski Area Recreational Opportunity Enhancement Act of 2011.
- ***Manage user expectations*** by having flexible opening/closing dates.

### *Developed and Dispersed Recreation Management Response Options*

- ***Increase flexibility*** through permitting process (e.g., outfitters/guides, ski area open/close days, backcountry permits)
- ***Modify the location of recreation*** to reduce impacts in sensitive locations (e.g., riparian areas).
- ***Monitor wildlife and dispersed recreation*** use to ensure wildlife populations are not being adversely impacted by increased visitor use
- ***Institute permit systems*** to reduce impacts to natural resources from increased visitor use.
- Employ firewood collection, tree thinning, and fuel treatments to ***manage fire risk*** in high use areas.

## Aquatic Ecosystems and Terrestrial Wildlife

Increased drought frequency and severity have implications for stream temperature, aquatic systems, and terrestrial wildlife. A strong linear relationship exists between drought and the availability of groundwater (Bruce et al. 2015). Groundwater and surface water are an interconnected resource with an estimated 56 percent of streamflow in the Upper Colorado River Basin coming from groundwater discharge (Bruce et al. 2015; Miller et al. 2014).

Instream impacts from drought include lower plant productivity, reduced flow, shifts from perennial to ephemeral streams, loss of habitat, and reduced pond size, availability, and longevity.

For aquatic species, consequences include poor water quality, increased UV radiation exposure, altered development rates and phenology, and increased crowding, competition and disease transmission (Friggens et al. 2013). For the native cutthroat trout in Colorado, warmer stream temperatures limit habitat extent and fragment populations, and high temperatures can be lethal if they cross species thresholds.

Drought affects terrestrial wildlife by reducing riparian habitat and shade cover near stream beds. Additional effects include lower plant productivity; less forage and water; more crowding, competition, and disease transmission; disrupted food chains; increased invasive species; and increased conflicts with humans.

In mule deer, poor nutrition associated with drought-affected vegetation makes deer fawns more susceptible to parasites, diseases, and predation (Friggens et al. 2013).

Reduced function of riparian systems can affect a wide range of bird species that use them for foraging and nesting.

### *Aquatic Ecosystems and Terrestrial Wildlife Management Response Options*

- ***Reduce gullying and reconnect channels*** to maintain functionality of riparian areas.
- ***Use stream temperature models*** (e.g., NORWEST Stream Temperature Database) to guide future management actions for cutthroat trout conservation work. Based on these models, the Grand Mesa, Uncompahgre, and Gunnison NF discovered lower elevation streams will become too warm for cutthroat trout but areas of the Cimarrons—which is currently too cold—will become more suitable with projected warming.
- Before droughts occur, ***raise groundwater levels*** by reconnecting channels with floodplains.
- ***Coordinate with range managers*** to better manage riparian areas, focusing on how cattle move across the landscape.
- ***Reintroduce fire*** through prescribed fire in forest plans.
- Focus on ***aspen enhancement*** efforts to reduce fire risk and benefit wildlife.
- Use ***Forest Plan Revisions*** as opportunities to encourage riparian vegetation treatments across the landscape to restore desired functions and processes.
- ***Build and maintain constructive relationships*** among state agencies and other organizations, and engage in collective problem solving to manage a wide range of hydrologic conditions.
- ***Manage beaver*** activity to increase water storage.

## Literature Cited

Averyt, K; Cody, K; Gordon, E; Klein, R; Lukas, J; Smith, J; William, T; Udall, B; Vogel, J et al. 2011. Colorado climate preparedness project: Final report. The Western Water Assessment for the State of Colorado, 38.

Bruce, B.W.; Clow, D.W.; Maupin, M.A.; Miller, M.P.; Senay, G.B.; et al. 2015, U.S. Geological Survey National Water Census—Colorado iver Basin Geographic Focus Area Study: U.S. Geological Survey Fact Sheet 2015–3080.

Chmura, D; Anderson, P; Howe, G; Harrington, C; Halofsky, J; Peterson, D; et al. Forest responses to climate change in the northwestern United States: Ecophysical foundations for adaptive management. Forest Ecology and Management, (April 2011) 261, 1121-1142.

Clark, J; Iverson, L; Woodall, C; Allen, C; Bell, D; Bragg, D; et al. (2016). The impacts of increasing drought on forest dynamics, structure, and biodiversity in the United States. Global Change Biology 22, 2329–2352.

Crausbay, R. et al. 2017. Bulletin of the American Meteorological Society. Preliminary online version.
Doesken, N; Kleist, J; McKee, T. A history of drought in Colorado. Lessons learned and what lies ahead. Colorado Water Resources Research Institute, (Feb 2000) 9.

Finch, D; Pendleton, R; Reeves, M; Ott, J; Kilkenny, F; et al. Rangeland Drought: Effects, Restoration, and Adaptation. Effects of Drought on Forests and Rangelands in the United States: A Comprehensive Science Synthesis. Forest Service GTR WO-93b, (Jan 2016) 155-194.

Friggens, M; Finch, D; Bagne, K; Coe, S; Hawksworth, D. Vulnerability of species to climate change in the Southwest: terrestrial species of the Middle Rio Grande. Forest Service Gen. Tech. Rep. RMRS-GTR-306 (July 2013).

Haddad, N.M; Tilman. D; Knops, J.M. Long-term oscillations in grassland productivity induced by drought. Ecology Letters, (2002)5: 110-120.

Hu, J; Moore, D; Burns, S; Monsons, R. Longer growing seasons lead to less carbon sequestration by a subalpine forest. Global Change Biology, (2010) 16, 771-783.

Littell, J. S.; Peterson, D. L.; Riley, K. L.; Liu, Y.; Luce, C. H. (2016). A review of the relationships between drought and forest fire in the United States. Global change biology, 22(7), 2353-2369.

Lukas, J; Barsuali, J; Doesken, N; Rangwala, I; Wolter, K. Climate change in Colorado. A synthesis to support water resources management and adaptation. University of Colorado (2014).

Miller, M. P.; Susong, D.D; Shope, C. L.; Heilweil, V. M.; and Stolp, B. J. Continuous estimation of baseflow in snowmelt-dominated streams and rivers in the Upper Colorado River Basin: A chemical hydrograph separation approach. Water Resources. Research, (2014) 50, 6986–6999.

Park Williams, A; Allen, Craig D; Macalady, Alison K; Griffin, Daniel; Woodhouse, Connie A; et al. Temperatures as a potent driver of regional forest drought stress and tree mortality. Nature Climate Change, (Mar 2013): 292-297.

Poirier, M; Durand, J.L; Volaire, F. Persistence and Production of perennial grasses under water deficits and extreme temperatures: importance of intraspecific vs. interspecific variability. Global Change Biology, (2012) 18: 3632-3646.

Polley, H.W.; Briske, D.D.; Morgan, J.A. [and others}. 2013. Climate change and North American rangelands: trends, projections, and implications. Rangeland Ecology & Management, (2013)66: 493-511.

RRC Associates, prepared for Colorado Ski Country USA/Vail Resorts, July 2015. Economic Impact of Skiing in Colorado

Smith, J; Paritsis, J; Veblen, T; Chapman, T. Permanent forest plots show accelerating tree mortality in subalpine forests of the Colorado Front Range from 1982 to 2013. Forest Ecology and Management, (April 2015)341, 8-17.

Thomas, D.S.K.; Wilhelmi, O.V.; Finnessey, T.N.; et al. A comprehensive framework for tourism and recreation drought vulnerability reduction. Environmental Research Letters, (2013).

Weed A; Ayres M; Hicke J. 2013. Consequences of climate change for biotic disturbances in North American forests. Ecological Monographs 83: 441–470.

Wilhite, D.A. and Glantz, M.H. 1985. Understanding the drought phenomenon: The role of definitions. Water International 10(3):111–120.

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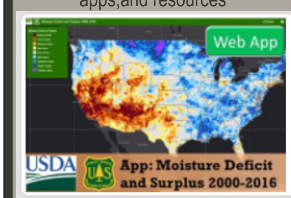
Gallery of drought maps, apps,and resources




http://arcg.is/2uTALWW

## Map Data Sources

***Figure 5:*** (Data source: Krist, F., Ellenwood, J., Woods, M., McMahan, A., Cowardin, J., Ryerson, D., Sapio, F., Zweifler, M., Romero, S. (2014). 2013-2027 National insect and disease forest risk assessment. United States Department of Agriculture, Forest Service, Forest Health Technology Enterprise Team. https://www.fs.fed.us/foresthealth/technology/pdfs/2012_RiskMap_Report_web.pdf.)

***Figure 6:*** Reeves, Matthew C. 2017. MODIS-based annual production estimates from 2000-2015 for rangelands in USFS grazing allotments in Region 5. Fort Collins, CO: Forest Service Research Data Archive. https://doi.org/10.2737/RDS-2017-0004