USDA United States Department of Agriculture

Drought and Rangelands

Effects and Management Responses

A synopsis of presentations from the

Drought and Rangelands Webinar

June 2017

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Drought and Rangelands

Background

In June 2017, the USDA Forest Service hosted a webinar that explored drought issues related to rangelands. Scientists discussed how droughts and climatic changes affect vegetation, soils, livestock, and wildlife within rangeland communities. Presenters shared research from around the world, based on historical reconstructions, experiments, and observations from periods of drought. Tools and management response options were also presented.

This summary provides a synopsis of the various concepts, analyses, and recommendations presented during the webinar.

Drought

Droughts can result in reduced growth rates, defoliation, and increased stress on vegetation, with accompanying ecological, economic, and social effects in rangeland areas. Droughts may be caused by a reduction in precipitation or an increase in temperature. These "hot droughts" reduce the supply of water through increased evaporation and faster melting of snow and ice. During these droughts, plants increase their demand for water through increased evapotranspiration and longer growing seasons. (Udall & Overpeck, 2017).

These trends are expected to continue in the future, with higher temperatures, decreased snowpack and faster snowmelt, more extreme wet and dry years, and larger, more severe fires (Pachauri et al., 2014).

Droughts have been increasing in frequency and severity over the last 50 years in much of the United States (Figure 1) (Peters, Iverson, & Matthews, 2014). This trend is expected to continue in the future, particularly in the Central Plains and Southwest rangelands (Cook, Ault, & Smerdon, 2015).

Photo courtesy of Mike Pellant

According to the National Drought Mitigation Center, drought originates from an insufficiency of precipitation over an extended time period—usually more than a season—producing a water shortage for some activity, group, or environmental sector. Types of drought include:

- ***Meteorological* – degree of dryness in weather over a defined period of time;**
- ***Agricultural* – links meteorological drought with agricultural impacts;**
- ***Hydrological* – precipitation deficits, with emphasis on effects on the hydrological system (e.g., water storage and flux); and**
- ***Socio-economic* – demand for economic goods exceeds supply as a result of weather/climate-related shortfall in water supply (Wilhite & Glantz 1985).**

In terms of forested and rangeland ecosystems, *ecological drought* is an episodic deficiency in water availability that drives ecosystems beyond thresholds of vulnerability, affects ecosystem services, and triggers feedbacks in natural and human systems (Crausbay et al. 2017).

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

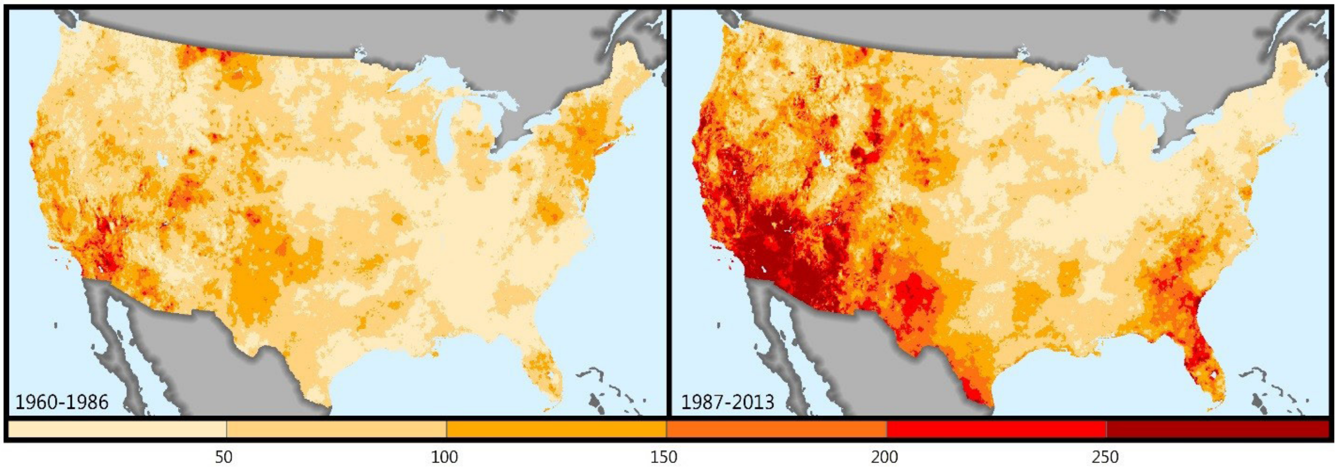

Figure 1 - Cumulative Drought Severity Index (meteorological drought) compared over two time periods (1960–1986 and 1987–2013) (Peters et al., 2014). [Click here] to learn more about this dataset and zoom in to your area of interest. For an annual comparison of relative moisture surplus and deficit from 2000–2016 (in 3-year increments), view a [time series webmap here].

There are currently over half a billion acres of rangelands in the conterminous United States (Figure 2), though the exact area depends upon how rangelands are defined (see Reeves and Mitchell (2011) for a comparison of different rangeland definitions).

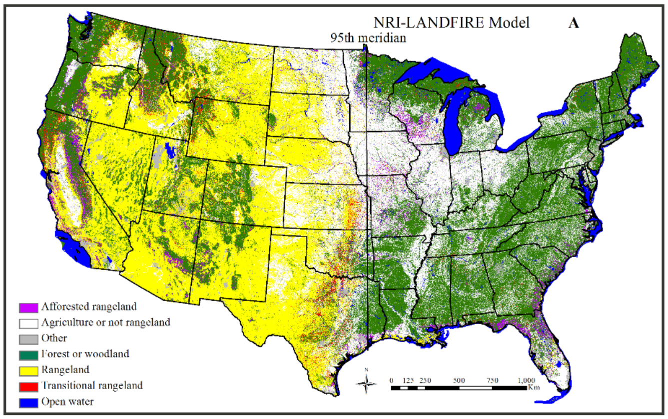

Figure 2 - Rangelands in the conterminous United States, based on the NRI-Landfire model, created by M. C. Reeves and Mitchell (2011). To learn more about this dataset, and zoom into your area of interest, see the interactive figure.

Definition of Rangelands

Land on which the indigenous vegetation (climax or natural potential) is predominantly grasses, grass-like plants, forbs, or shrubs and is managed as a natural ecosystem. If plants are introduced, they are managed similarly. Rangelands include natural grasslands, savannas, shrublands, many deserts, tundra, alpine communities, marshes, and wet meadows *(Bedell, 1998).*

Effects of Drought on Rangeland Soils

In the 1930s Dust Bowl, portions of the Midwest were transformed into a “moonscape, empty and hideous,” with no plants or wildlife to be seen (Egan, 2006). This is an extreme example of the effects of drought and poor soil management, but even moderate droughts can have profound ecological effects.

Some of the most profound effects of drought are on soils. As plant cover and water availability declines, soil temperatures increase and soil chemistry changes (Sanaullah, Rumpel, Charrier, & Chabbi, 2012). Soil acidification and salinization can occur, microbial activity can decline, organic matter in the soil can decrease, and soil runoff and erosion can increase. These changes can affect carbon and water storage: for any given soil type, the amount of water may double or triple, depending on how much carbon is in the soil (Saxton & Rawls, 2006).

These variables create feedback loops: as plant cover and water availability decline, this leads to changes in soil quality, which further reduce plant cover and water storage in the soil. These feedback loops worsen the effects of drought. In addition, drought may also lead to increased fire activity in some regions, which has further ecological consequences on the system (Westerling, Gershunov, & Cayan, 2003).

Figure 3 - A dust storm moving across the landscape, during the 1930s Dust Bowl. (Photo courtesy of the [Natural Resources Conservation Service](#).)

Effects of Drought on Rangeland Vegetation

Precipitation is a strong driver of ecosystem function and productivity. Research from the United States' Great Plains, African Serengeti, and Mongolian Plateau have all found that primary productivity increases steadily with increases in rainfall (Sala, Gherardi, Reichmann, Jobbagy, & Peters, 2012). Grasslands are highly dynamic, with frequent droughts (Xiaomao, Harrington, Ciampitti, & Knapp, 2016) and large annual differences in productivity (Figures 4 and 5) (M. Reeves, 2017; Xiao, Liu, & Stoy, 2016).

Drought can reduce vegetation productivity, but vegetation in turn can also affect droughts. For example, deep-rooted perennials store more soil organic carbon than annual grasses (such as the invasive cheatgrass, *Bromus tectorum*) (Rau et al., 2011). As cheatgrass spreads and reduces the storage of organic carbon by the soil, this reduces the soil's water-holding capacity, thus reducing the resilience of the system to drought.

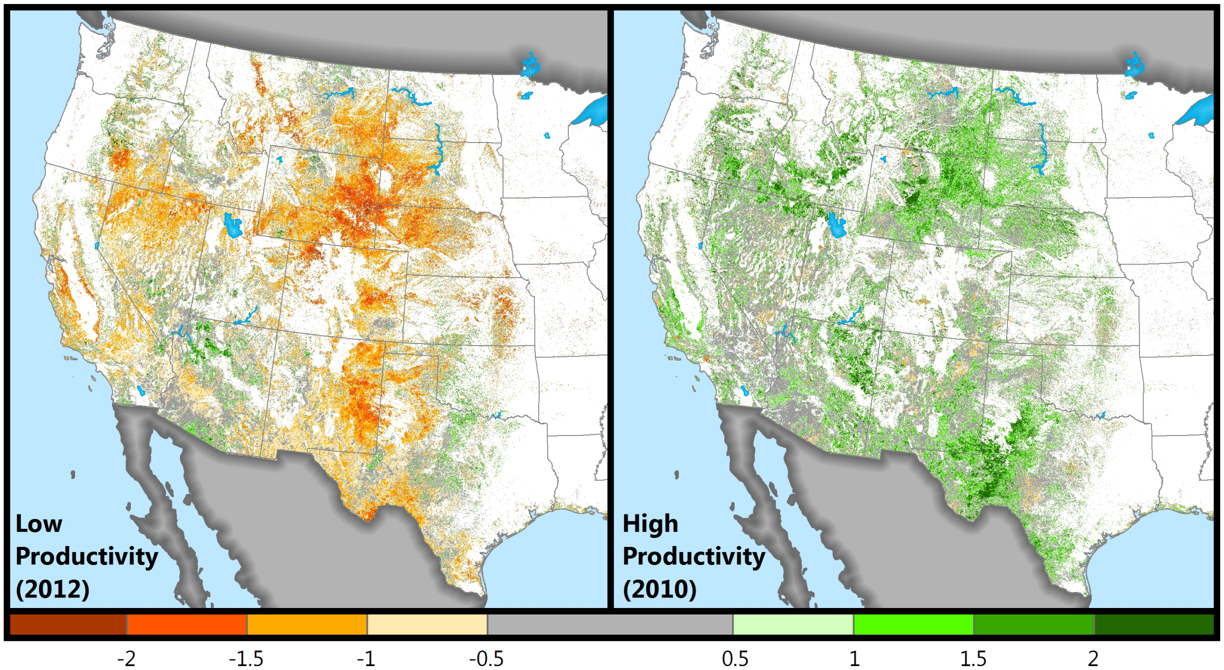

Figure 4 - Examples of low and high-productivity years, in the rangelands of the conterminous United States, expressed in standard deviations from the mean, based on 2000-2016 data (Reeves, 2017). Total estimated rangeland forage for the United States ranged from 467 to 611 million tons for 2012 and 2010, respectively. [Click for an interactive version](#) showing year by year changes in rangeland productivity.

Moreover, because cheatgrass spreads fire more readily than perennial grasses (Klemmedson & Smith, 1964) and fire can promote the spread of invasive species, this can act as a positive feedback loop for the spread of fire and invasive species (Abatzoglou & Kolden, 2011; Finch et al., 2016). By drying out fuels and increasing the stress on native vegetation, drought can drive this loop to further spread fire and invasive plants (Abatzoglou & Kolden, 2011).

Researchers find differential sensitivity to drought in different species, among both native and invasive plant species (Alpert, Bone, & Holzapfel, 2000; Cavaleri & Sack, 2010; Heberling & Fridley, 2013). While some plant species steadily decline in productivity as drought increases, others show rapid declines past some threshold (Reeves et al., in preparation). Some warm-climate plants are better adapted to drought and can respond quickly with rapid bursts of productivity when precipitation increases Reeves et al., in preparation) .

There is also variation by climatic region. Research by Smith (2017) found that arid rangelands were more sensitive to droughts than mesic rangelands, both in their productivity and in vegetation community responses to drought (see also Tielbörger et al. (2014). Additionally, sensitivity to drought varies over time. Arid regions are affected in the first year of a drought while plant communities in mesic regions are not strongly affected until the third year, with differences in recovery times as well (Smith, 2011).

Overall, drought indices only explained around 40 percent of the difference in productivity in some rangeland systems; the rest of the variation may be due to differences in soils, vegetation, topography, and other factors (Reeves et al., in preparation). While programs such as the United States Drought Monitor provide valuable information on drought intensity, they do not account for all the differences in local vegetation productivity. The greater sensitivity of arid rangelands to drought is also relevant in the face of continued climate change. As mesic systems become more arid, they may also become less resilient to year-to-year fluctuations in rainfall.

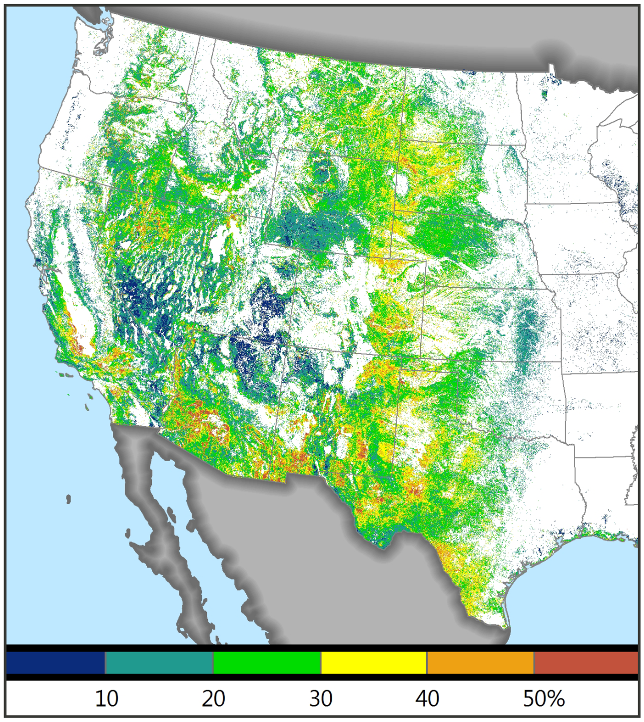

Figure 5 - Relative variability in rangeland productivity (standard deviation divided by the mean), based on 2000-2016 data (Reeves, 2017). For example, green in this map indicates areas that typically have 20-30 percent changes in productivity each year. Click for an interactive version.

Effects of Drought on Rangeland Livestock and Wildlife

Droughts affect not just rangeland plants and soils, but the entire ecological and social systems that depend on them. Lower plant productivity means fewer arthropods, which means fewer sage grouse (Gregg & Crawford, 2009; Guttery et al., 2013). This also means less forage and water available for ungulates and other herbivores, which can reduce their survival (Bender, Lomas, & Browning, 2007; Frank & McNaughton, 1992).

These effects extend to livestock production and to the local economies that depend on these animals. In 2013, following a major drought, the U.S. calf crop was the lowest since 1951, according to the National Agricultural Statistical Service (NASS) (2017), and major feedlots were forced to close. Several years later, cattle businesses were still recovering.

There are a wide variety of other social and economic benefits provided by rangelands that can be affected by drought, including carbon sequestration, enhancement to water quality and quantity, and recreation (Havstad et al., 2007).

Figure 6 - A dry riverbed in California during the 2009 drought. Droughts affect rangeland soils, plants, and wildlife. (Photo courtesy of the National Oceanic and Atmospheric Adminstration.)

Management Recommendations

Drought is complex. Managers should use an integrated and coordinated approach to manage rangeland vegetation, water, and soils, in order to maintain healthy rangeland communities before and after droughts. The timeframes for improving resilience to the effects of drought fall into three categories: pre-drought, during drought, and post-drought.

Pre-Drought

» Reduce and prevent incursions of invasive plants including cheatgrass, which can reduce the ability of native vegetation to resist the effects of drought and to recover after drought (Stewart & Hull, 1949).

» Maintain cover, vigor, and diversity of native perennial grasses, forbs, shrubs, and other desirable plants. Increased production increases litter, which aids soils moisture retention, adds to carbon accumulation, and decreases soil temperature (Bot & Benites, 2005). Increased density of perennials improves site resistance to infestation by weedy annuals. Plants that are more vigorous are likely to recover more quickly after drought and have better reproductive capacity to replace plants lost due to drought.

» Maintain adequate biological soil crust and plant litter to maintain cover and reduce erosion potential, especially wind erosion, during a drought (Bot & Benites, 2005; Munson, Belnap, & Okin, 2011).

» Follow appropriate grazing practices to maintain plant vigor and productivity. Vigorous plants have deeper root systems than plants that have been weakened by inappropriate management, and are better able to survive drought and recover more quickly after a drought (Ekanayake, O'Toole, Garrity, & Masajo, 1985). Appropriate livestock management supports herbage production and ensures litter cover is present in adequate quantities to maintain soil moisture, mediate soil temperatures, and support the nutrient cycle (Amiri, Ariapour, & Fadai, 2008; Van Poollen & Lacey, 1979). Good grazing management also limits soil compaction, maintaining moisture infiltration into the soil (Amiri et al., 2008). Improved grazing practices include conservative stocking rates, appropriate grazing seasons and utilization levels, good livestock distribution across management units, and use of the appropriate class of livestock (Krausman et al., 2009).

» Promote appropriate fire regimes. Fuels management and reduction of invasive species such as cheatgrass and buffelgrass (*Cenchrus ciliaris*) can reduce wildfires and help to maintain the resilience of native plant communities (Finch et al., 2016).

» Use resistance and resilience information based on widely available soils data in advance of drought events to perform risk assessments (Maestas, Campbell, Chambers, Pellant, & Miller, 2016) and develop contingency plans for when droughts occur.

Resistance and resilience concepts can be used as a framework for planning land management treatments and actions, and for responding to threats at multiple scales (Chambers et al., 2017; Chambers et al., 2016; Chambers et al., 2014).

» Design multi-site, multi-year drought studies to better understand drought recovery dynamics and the interactions between drought and grazing, and to coordinate research between different sites, for example through the Drought-Net program (Smith et al., 2016).

Figure 7 - In sagebrush steppe ecosystems in the Great Basin, plant communities that are in poor condition without adequate ground cover (left photo) are much more susceptible to accelerated erosion and increases in invasive plants (i.e. resilience is low). The sagebrush steppe community in the right photo is dominated by deep rooted perennial grasses and sagebrush. The high resilience of this plant community minimizes drought-induced erosion and the entry of invasive plants. (Photo courtesy of the Bureau of Land Management.)

During Drought

» Regularly assess resource conditions (water availability, vegetation vigor, soils, etc.).

» Coordinate and communicate with stakeholders on adaptation strategies and tactics.

» Adjust livestock use near permanent water sources to minimize impacts to soil, wildlife habitat, and other resources, and to meet wildlife needs.

» Improve distribution of livestock, moving or removing herds as needed and utilizing portable water troughs to improve livestock distribution and reduce the impacts on vegetation, soils, and permanent water supplies.

» Managers can develop expected use maps (Guenther, Guenther, & Redick, 2000) based on slope and distance to water to predict areas where livestock use could be concentrated during a drought and to identify underutilized areas where livestock could be moved if water sources were provided.

Post-Drought

» Root growth is an essential part of drought recovery, and may occur at different times than regrowth of above-ground biomass (Hagedorn et al., 2016). Allow sufficient time for full recovery above and below ground when making management decisions on the resumption of rangeland uses.

» Promote recovery of perennial plant cover, litter, and biological crusts after drought to reduce the potential for accelerated erosion and the spread of invasive species. The sooner recovery occurs after a drought, the less likely that increased soil erosion will occur and that invasive plants will spread.

» Monitoring is always important in rangeland management, but it is even more important before, during, and after droughts. Managers need to understand how the plants are responding to these conditions and adjust livestock management to meet long-term needs.

» Recovery after drought may take a long time. It is as important as planning prior to—and management during—drought.

Conclusion

The effects of droughts on rangelands have been increasing over recent decades and are expected to continue to increase in the future. These effects include not just drying vegetation, but also changes to soil chemistry, plant communities, wildlife, and to the social and economic systems that depend on these. In some cases, even minor or temporary changes in ecological conditions may lead to permanent shifts in rangeland communities. By taking action before, during, and after a drought, rangeland managers can improve the resistance and resilience of rangelands to droughts and other climatic changes.

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