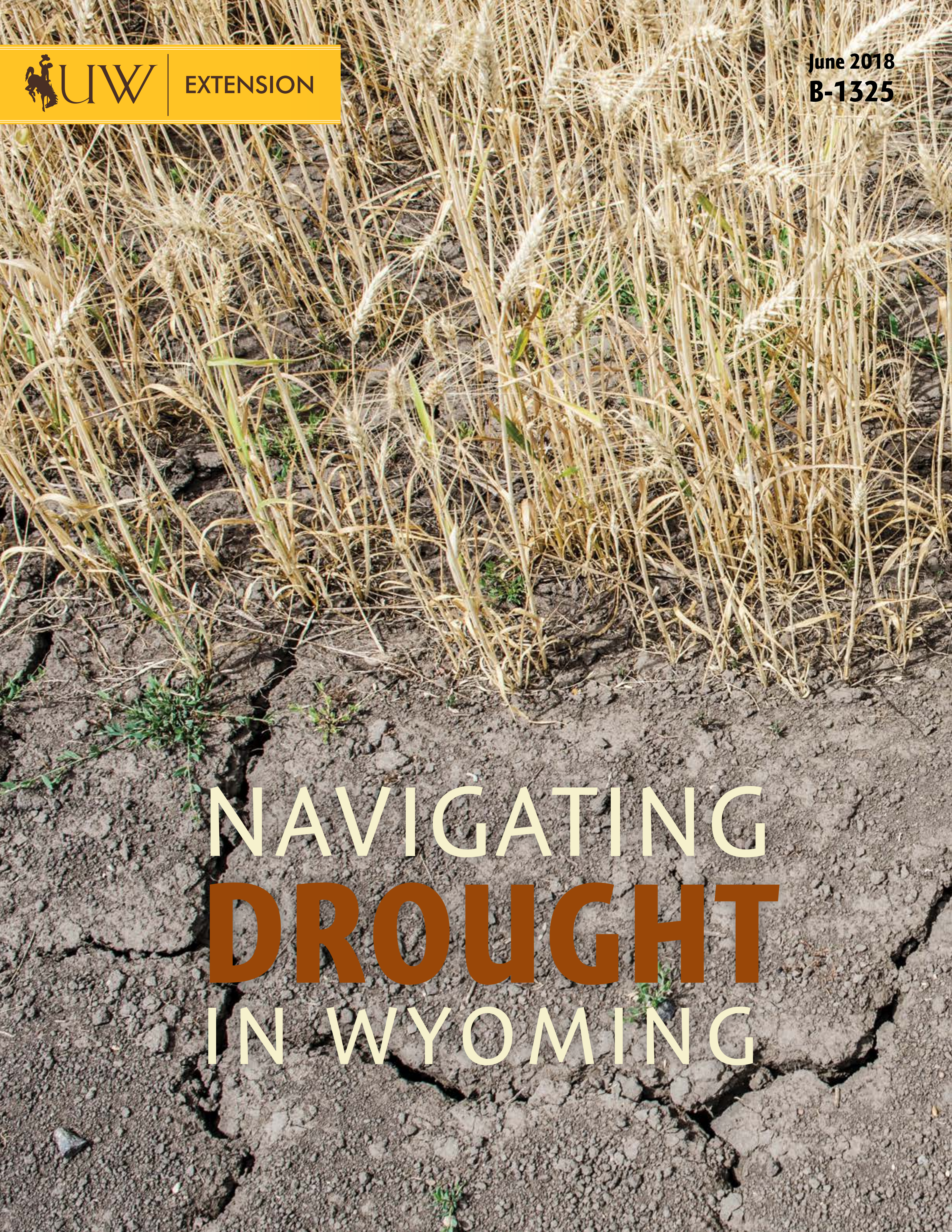
UW EXTENSION
June 2018
B-1325



NAVIGATING DROUGHT IN WYOMING

NAVIGATING DROUGHT IN WYOMING

Brian Sebade, ed.

Thank you Windy Kelley, Kristi Hansen, Ginger Paige, and Jenny Thompson for your diligent review and feedback for this publication.

Navigating Drought in Wyoming is a peer-reviewed publication.

Original available at: www.wyoextension.org/publications/pubs/b1295.pdf

Suggested acknowledgment: Sebade, Brian, ed. Navigating Drought in Wyoming. B-1325. 2018.

UW Extension county offices and contact information
bit.ly/wyomingoffices

Like University of Wyoming Extension on Facebook

Follow us on Twitter
@UWyoExtension

Follow us on Pinterest
Search University of Wyoming Extension

View us on YouTube
www.youtube.com/user/UWyoExtension

Issued in furtherance of extension work, acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture. Glen Whipple, director, University of Wyoming Extension, University of Wyoming, Laramie, Wyoming 82071.

Table of Contents

PRIOR TO DROUGHT

The climate of Wyoming 3

Just like precipitation, measuring moisture takes many forms 6

Economic models show drought effects on cattle producers over 35-year horizon; suggest herd diversification helps minimize impact 9

Preparing for drought on rangelands minimizes more than lost income 12

Five sources of risk loom over drought 15

Have a plan prior to drought for pasture management 19

Strategies to save water when irrigating 22

Drought Risk Atlas (DRA) 27

U.S. Drought Monitor (USDM) 29

Drought issues for small parcel landowners 32

DURING DROUGHT

Understanding how drought affects rangeland plants offers strategies to combat moisture shortage 37

Managing cropland during drought 39

I didn't anticipate a drought; things are tough; what do I do now? 41

Not just agriculture – drought collides with state's wonderful recreation 44

AFTER THE DROUGHT

Rangeland management AFTER precipitation near more-normal 47

Agronomic challenges post-drought 50

Drought recovery for livestock operations 53

When can we expect the next drought? How will drought in the 21st century be different? 55

NAVIGATING **DROUGHT** IN WYOMING

Navigating Drought in Wyoming was developed to help the agriculture community identify, prepare, and negotiate drought impacts.

Even though this publication is agriculture-focused, we attempt to show the different types of drought perspectives that affect everyone in the state.

“Drought” has various definitions, perspectives, and implications depending on how insufficient moisture affects each person or agricultural operation. The term “drought” is discussed and outlined with specific ramifications and impacts in a paper by Thurow, Thomas and Taylor, Charles, “Viewpoint: The Role of Drought in Range Management.” *Journal of Range Management*, vol. 52, no.5, September 1999, pp. 413-419. Please refer to this paper for more detail on the issues outlined in the next four paragraphs.

As Thurow and Taylor point out (413&414), there are four perspectives: 1) meteorological 2) agricultural 3) hydrologic 4) socio-economic.

1. **Meteorological drought** occurs when the expected or desired precipitation value is less than “normal.” “Normal” generally refers to a 30-year average, which may be skewed in some cases and may not actually represent what you should expect. Most drought definitions have some sort of metrological component. A meteorological drought perspective varies greatly depending on geographical location (think a desert compared to a rainforest).
2. An **agricultural perspective** usually involves a decrease in precipitation that limits plant growth in rangeland and cropping systems. Sometimes this can be very difficult to correctly define and identify. The timing and amount of precipitation greatly affects plant growth. Receiving all of the normal precipitation for an area, but during the wrong time for plant growth, may lead to an agricultural drought. This climate pattern might not be considered a meteorological drought because the expected precipitation was received. Other climatic factors such as wind, temperature, and humidity have large implications for agricultural droughts.

“Viewpoint: The Role of Drought in Range Management”
Journal of Range Management

3. **Hydrological drought** perspectives are closely tied to water storage. Water storage might be underground such as an aquifer or on the Earth’s surface as water in ponds, lakes, reservoirs, or snowpack. Hydroelectricity, irrigation water, municipalities, recreation users, and water for livestock consumption are all affected by hydrological drought. People who use irrigation water in rural agriculture settings and people who live within urban municipalities will feel similar effects of decreased surface or underground water resources.
4. **Socio-economic drought** perspectives are tied more closely to people’s behavior and choices. These perspectives might be a loss of income, decreased options for making decisions, water use restrictions, or loss of revenue sources. Socio-economic factors tend to affect different groups of people due to drought issues.

The bottom line is to be prepared no matter what is chosen as a drought definition or perspective. It is not a matter of if, but when, Wyoming will experience the next drought.

There are additional resources listed with each article for questions you might have. Do not hesitate to discuss drought issues with your local University of Wyoming Extension office.

PRIOR TO DROUGHT

The climate of Wyoming

Tony Bergantino

Numerous micro-climates characterize Wyoming.

Wyoming's basin and range topography cause temperature and precipitation patterns to vary markedly across short distances. Wyoming has a minimum elevation of 3,099 feet in the northeast where the Belle Fourche River leaves the state, and the highest elevation being Gannett Peak in the Wind River Range standing at 13,809 feet. This leaves an elevation range for Wyoming of over 10,000 feet and contributes greatly to varying climates found within the state.

So, as one part of the state experiences drought conditions, others are experiencing above-average precipitation levels.

The state's official coldest temperature was -63°F on February 9, 1933, at the Moran station

Temperature

Wyoming is known for having a relatively cool climate given the high elevation of much of the state. The state's warmer temperatures are in its lower regions with the official all-time highest temperature of 114 on July 12, 1900, in Basin in the Big Horn Basin. This is one of the warmest spots in Wyoming with an average maximum temperature for July of about 92°F.

The state's official coldest temperature was -63°F on February 9, 1933, at the Moran station on the east side of Jackson Lake. The average January minimum temperature for Moran is a little below 1°F, making it one of the colder locations in the state.

The rest of Wyoming falls within this 177° temperature range. The mean maximum July temperature is between 85 and 95°F for most of the state but with temperatures dropping about 5.5°F for each 1,000 feet of elevation gained, these July maximum temperatures can be relatively cool at higher elevations.

Burgess Junction in the northern Bighorns (at about 8,000 feet) has an average July maximum temperature of only 70°F. Nighttime temperatures are usually cool throughout the state with mean minimum July temperatures 50 to 60°F. Locations in the mountains and high-elevation valleys have average minimum temperatures in July that are in the 30 to 40°F range, and it is not rare for some of those lows to drop below freezing.

Wyoming is also known for its deep cold spells. These usually happen when cold arctic air slides southward down along the continental divide. These cold waves are often

Water and climate data for the state of Wyoming
http://www.wrds.uwyo.edu/

preceded by widespread snowfall; the wide, white blanket reflects the sun's energy back into space in the clear skies that follow.

Air temperatures in the -25 to -35°F range or less are common during these events, and any spot in Wyoming can be expected to experience at least one of these spells every winter.

Precipitation

Wyoming's varied topography and elevation results in very different precipitation around the state. While precipitation is typically higher in the mountains than in the lower plains, elevation itself is only one contributor. The surrounding topography plays a big factor.

In the northeastern plains (4,000 to 5,000 feet) the average annual precipitation ranges from 11 to 15 inches. But for the southwest part of the state (for example Sweetwater County and eastern Lincoln and Uinta counties with elevations from 6,500 to 7,500 feet), the average annual precipitation is even less at 6 to 10 inches. In general, the average annual precipitation for Wyoming from 1901 to 2000 is 15.94 inches, while it has decreased to 15.38 inches for the 2001-2016 period.

The average annual precipitation for Wyoming from 1901 to 2000 is 15.94 inches, while it has decreased to 15.38 inches for the 2001-2016 period.

The average annual precipitation in Wyoming, across such varied elevation and topography, is not necessarily very helpful, especially when one looks at the range of inter-annual precipitation amounts. The lowest average annual precipitation total for the state was 10.96 inches in 2012 while the highest amount was 20.40 inches in 1927.

One reason for this difference is because the southwest region of Wyoming is a high plateau nearly surrounded by mountains, whereas the northeastern part of the state is open plains with only a few areas of higher elevation. The Bighorn Basin is an even more drastic example since it is almost completely mountains that block most of the moist air that flows from the west or the east. The average annual precipitation there is also about 6 to 10 inches per year.

Precipitation timing throughout the year varies, too. Lower elevation sites typically see the highest monthly precipitation totals in May or June, while mid-elevation locations see their maximum precipitation amounts from March to May, and the high-elevation "snow-dominated" sites usually have their maximum precipitation amounts from November to January.

Drought

Wyoming is a semiarid state, so how do we know when we are experiencing a drought? Drought is often defined as a lack of sufficient precipitation over an extended period of time and has different thresholds based upon location and activity.

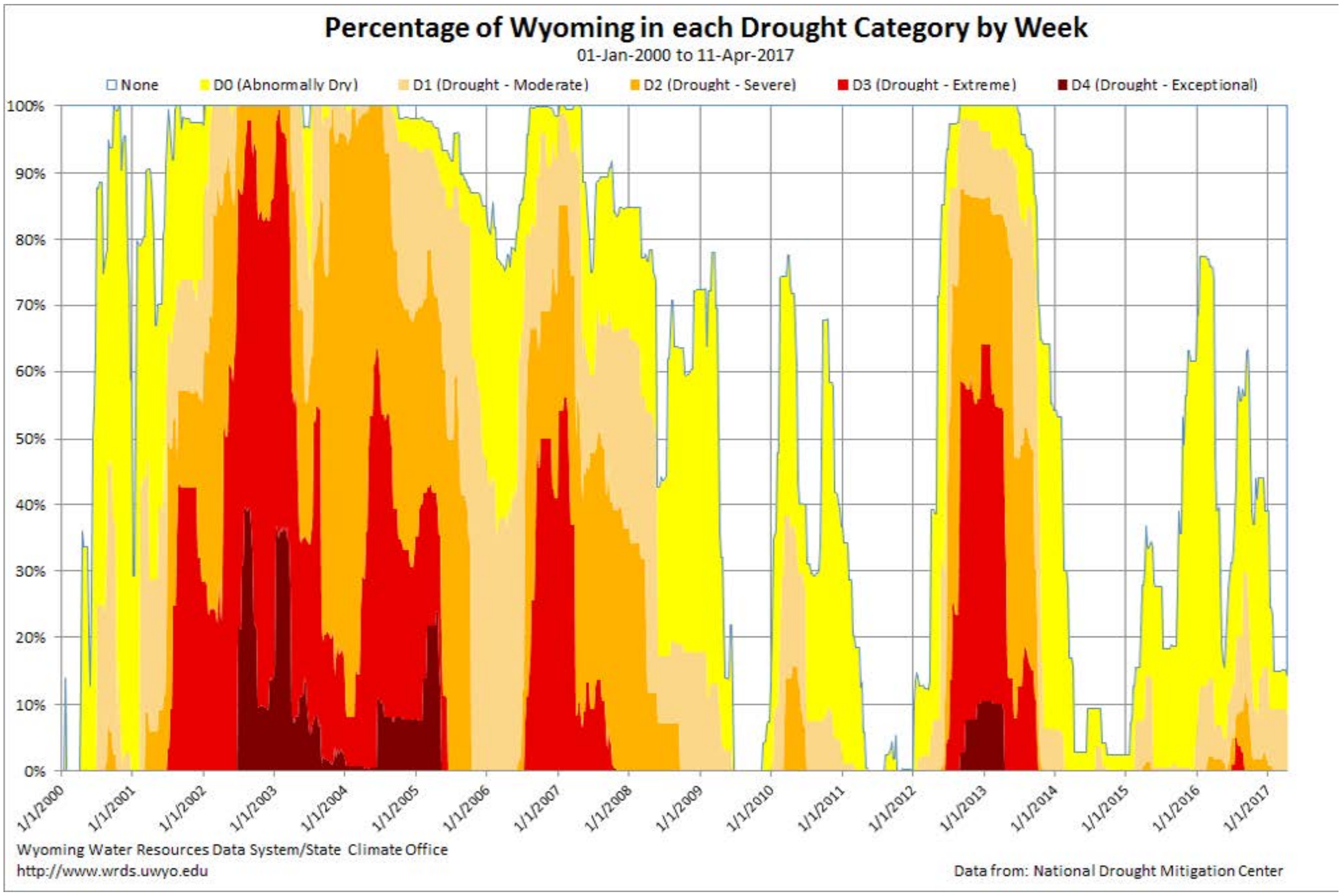
Given this definition, there could always be a drought of some fashion in any part of Wyoming.

The National Drought Mitigation Center (NDMC) uses five categories of drought ranking in increasing intensity from D0 (Abnormally Dry) to D4 (Exceptional Drought). Operationally, an area begins to go into drought when the average amount of precipitation over a particular period (for example 30-day, 60-day, 90-day) is 75 percent of what is "normal" over that same length of time. This serves simply as guidance and must be coupled with actual conditions on the ground. The actual threshold might be higher than 75 percent if the area has experienced high evapotranspiration resulting from situations such as increased wind or higher temperatures.

Conversely, the 75 percent threshold may be too high if there is excessive cloudiness and/or lower than normal winds. Drought is also tied to impacts, which is why other parameters are considered such as crop status, water shortages (further complicated by water rights), or river and reservoir levels.

Maps showing areas and intensities of drought are released by the NDMC every Thursday since 2000. A chart showing the percentage of each drought category by week from January 4, 2000, to present is shown page 5.

Conditions have been Abnormally Dry or worse for almost the entire length of the time period in at least one area of the state with brief exceptions in late 2009 and mid-2011.



Since impacts are an important factor in what level of drought an area is experiencing, the Drought Impact Reporter found at http://droughtreporter.unl.edu/submitreport/ was created. This reporter was created to allow anyone to submit a report about conditions in their area. Wyoming covers a large area, and many areas are "data poor." Precipitation can be very variable depending upon location. For that reason, the Community Collaborative Rain, Hail, and Snow network (CoCoRaHS http://cocorahs.org) was established whereby anyone can set up a standard 4-inch rain gauge at their location and report. These reports add to the knowledge of what is happening at a spot and are a valuable part of the data used by authors of the weekly drought maps.

Wyoming's climate varies considerably over distance and elevation. We continue to learn more and more as instruments to collect parameters such as temperature, precipitation, and wind speed and direction are established in new places around the state.

Tony Bergantino is deputy director of the Wyoming State Climate Office. He can be contacted at antonius@uwyo.edu.

Just like precipitation, measuring moisture takes many forms

Tony Bergantino

Community Collaborative Rain, Hail and Snow Network
https://cocorahs.org/

Put out a rain gauge and observe what is in it.

Sounds easy, doesn't it? Sure, but there are many other factors involved.

I'll describe two classes of instruments used by the general population and explain why only one of these is used by "citizen scientists" in the Community Collaborative Rain, Hail, and Snow network (CoCoRaHS) program. Each type of gauge has advantages and disadvantages.

Automated Precipitation Gauges

Home weather stations are the first set of instruments. They automatically record various parameters ranging from temperature and precipitation to those that collect wind speed and direction, humidity, solar radiation, and other data types.

An advantage of an automatic station is that, if an observer is away for a few days, the station will record daily totals rather than accumulating the precipitation in the gauge and forcing the observer to assign the total to a range of dates. Automatic gauges do fairly well for slow and steady rainfalls but tend to fall behind during intense rains.

The reason is in how precipitation is measured. The gauge usually consists of a funnel on top of a cylinder. The funnel has a small hole in the bottom that allows precipitation to drip through. Below the opening is a see-saw device that has a collection space on each side of the balance. The drips are collected in the catch box until the amount of liquid equals a certain weight, usually 0.01 inch-worth. When that happens, the weight is enough to tip the see-saw down, dump out the water, and raise the other side of the device so subsequent drops are collected on the other side.

Once the other side has a weight of water equal to 0.01 inch, that side tips and the process repeats. Electrical contacts are made when each side of the see-saw tips, which signals to the device's program a tip has occurred. The amount of precipitation collected is incremented by 0.01 inch each time a tip is counted.

The tipper often cannot keep up with the amount of water coming through the funnel during heavy rain and, subsequently, under-reports the amount of precipitation.

During winter months, precipitation in Wyoming usually falls as snow, which has to be turned into water so it can drip onto the see-saw. This happens one of two ways. In the first, a heater foil is wrapped around the inside of the funnel. This melts the snow as it falls, converting it to liquid so it can be measured. The disadvantage of this heater is it usually requires more power than the solar panels can provide, so it needs to be plugged into conventional power. If the snow is not heated sufficiently, melting cannot occur. Conversely, if the foil provides too much heat, some of the liquid may be lost to vaporization.

Allowing the snow to melt naturally after a storm is the other process. This can sometimes result in the amount of precipitation being reported for the wrong day(s) and, again, some of the total may be lost to evaporation.

Manual Precipitation Gauges

Manual rain gauges take many forms and can be any marked vessel used to collect precipitation. The markings tell how much is in the gauge. These gauges are considered "manual" because an observer has to physically read the gauge and report the amount.

Manual gauges range from the amber-colored, little square-mouthed ones you either stick in the ground or nail to a fence post, all the way up to large-mouth cylinders, either 4 or 8 inches in diameter, that allow the observer to read amounts to the nearest hundredth of an inch.

The obvious disadvantage of manual precipitation gauges is they require a person to physically read the gauge each day, ideally at a set time. Observation times are generally in the morning or evening, since most people are sleeping at midnight. While the automatic gauge can report amounts for full "midnight-to-midnight" days, the person using a manual gauge usually reports for a "day" that starts and ends at 7 a.m. or 6 p.m. or whatever time the observer has set.

The higher-end gauges consist of two cylinders, a smaller one inside a larger one that may be 4 or 8 inches in diameter. The outer cylinder has a collector funnel that directs precipitation into the smaller cylinder. By concentrating the precipitation from a larger area into a smaller diameter, precipitation can be measured to much finer amounts, for example, to the nearest 0.01 inch. The funnel and inner cylinder are removed during the winter, and snow is captured in the large cylinder.

What snow has accumulated in the large cylinder must first be melted and then poured into the inner measuring cylinder. This can be through natural melting with the automatic gauge or the observer can speed up the process by pouring in a known amount of warm water to melt the snow.

Letting the snow melt naturally indoors means the observer has a second gauge he can place outside, or he risks not collecting any precipitation that may fall while the gauge of snow is inside melting. The disadvantage of speeding up the melt process with water is the observer has to remember to subtract the amount of water used to speed up the melt. Fortunately, this is not hard.

Another method is to simply weigh the gauge full of snow. The observer will have obtained the weight of an empty gauge as well as the weight of an inch of water and use those variables to calculate the amount of water in the gauge while it is still in "snow form." This method can be very accurate, although a scale capable of weighing to the nearest tenth of a gram is required.

Core Snow Samples

Observers frequently take a core sample of new snow and use that for the precipitation amount. This is often done in situations in which the amount of snow in the gauge is not representative of the amount that actually fell. Wind, notorious for stirring up fallen and falling snow, is often a factor.

Two types of core samples can be taken. One is of just new snow, and the second is of all snow on the ground. Both are important hydrologically. While the core of new snow will be used to determine the amount of newly fallen precipitation, the total snow core determines how much water is available in an area if all the snow melted. This is useful for reservoir operators, streamflow forecasting, and flood warnings.

Observers taking snow cores will want to designate a place from which to collect a new snow core. After the core is taken, the area is cleared of snow so the only snow there will be that which has fallen since the last time a core was taken. The total snow core can be taken from an undisturbed area, which will have both new and old snow present.

To take a snow core (whether new or total snow), the large cylinder of the gauge is turned upside down and pressed through the snow until it reaches ground. The observer then slides a flat object like a spatula underneath the mouth of the gauge to keep the snow inside, turns the gauge right-side-up, and takes it inside to measure. The liquid equivalent of the snow can be found by any of the methods above (warm water melting, natural melting, or weighing).

Putting manual and automated gauges in the best spot to obtain the most accurate amounts is important. Things to consider are where the nearest tree is, direction of the prevailing wind, and locating it far enough from buildings. While the CoCoRaHS Network makes use of only manual gauges, siting information found in the training materials at http://cocorahs.org apply to manual and automated gauges.

CoCoRaHS

CoCoRaHS is a nationwide program in which volunteers can do precisely what has been described above and have their observations recorded along with those from thousands of others across the country. CoCoRaHS tries to obtain the densest network of observers as possible because precipitation amounts can vary greatly over short distances.

CoCoRaHS uses the manual precipitation gauge rather than an automated one for several reasons. Number one is so instruments are consistent across the network. The second reason is the cost of automated gauges would be too much for many potential observers. The 4-inch standard rain gauge used costs $25 to $35 depending upon where purchased; automated gauges start on the low end at about $50 and can exceed $1,000, which would prohibit many potential observers from participating. Consistency would be lost across the network given the price differences.

The problems associated with collecting snow in an automated gauge are another factor as adding heaters adds cost. The advantages of the manual gauge outweigh the disadvantages, and many more observers can be set up with the 4-inch manual gauge dollar for dollar.

Sign up here http://cocorahs.org if interested in becoming part of the CoCoRaHS network or contact Tony Bergantino at Antonius@uwyo.edu.

Just what *is* Precipitation?

So, now that we've discussed how precipitation is collected, let's look a bit at **what** is collected.

Most will say rain and snow are forms of precipitation. They may have some misconceptions about what to report when it snows and some will report the snow depth as the precipitation amount.

But, what about dew? Eventually an observer will see droplets of dew on the inside of his or her gauge and, in some areas, those droplets may add up to a measurable amount, and the temptation will be to report it as precipitation. Dew (and frost) is not precipitation but is, rather, *condensation*. While the amounts may be measureable, they are not reported as precipitation.

CoCoRaHS observers and others who measure precipitation regularly will eventually hear the term **Water Year** and wonder what it means.

A **Water Year** spans October 1-September 30 of the following year. The first of October was established as the date for the beginning of the **Water Year** because it is a good break signifying the start of a new snow season. In the western United States, new snow accumulates to form a snowpack, which will then melt in the spring replenishing streamflows.

The streamflows during the spring and summer are greatly influenced by the snowpack that begins to form in the latter part of the previous year, so it was decided to create a **Water Year** based upon when snow begins to accumulate. The high evaporation rates, which characterize the summer months, lessen and soil moisture often begins to accumulate, which will be used by vegetation in the following spring and summer.

As a headwaters state, precipitation is important to Wyoming no matter how collected. Its frozen flakes accumulate in winter to form a solid reservoir of water released in the spring to fill rivers for recreation and irrigation. Its cool drops in the summer water gardens and fields.

Too much at once can cause disaster from flooding or dangerous snow loads, while too little can be equally disastrous to crops and livestock.

Please consider helping us by taking a few minutes each day to report how much precipitation fell in your part of Wyoming.

Antony Bergantino is deputy director of the Wyoming State Climate Office. He can be contacted at antonius@uwyo.edu.

Economic models show drought effects on cattle producers over 35-year horizon; suggest herd diversification helps minimize impact

John Ritten
Christopher Bastian
Steven Paisley

Department of Agricultural and Applied Economics
University of Wyoming

"Considerations for Preparing a Drought Management Plan for Livestock Producers"
bit.ly/wyodroughtplan

Drought can dramatically reduce profits and equity for livestock producers.

Figure 1 on page 10 shows how profits over a 35-year horizon compare across 100 different price cycle scenarios when **average** weather is assumed in all years versus **actual** historical weather patterns for an average ranch in southeastern Wyoming.

Overall profits were reduced by 45 percent over the 35-year horizon, due primarily to herd fluctuations that must occur to try to match forage supply with demand. Additionally, animal performance is also likely to decline resulting in lower weaning weights and less revenue, although this has a lesser negative impact on profitability than reduced herd sizes.

Recent research has shown Wyoming producers' response to drought is varied. The most common strategies are generally reactive and not proactive, although some proactive drought management strategies show promise. Reducing herd size or purchasing supplemental feed as forage supplies decline are two common strategies.

Reactive Strategies

Increased culling is often the easiest way to decrease forage needs. By reducing herd size, a producer may be able to survive drought with minimal cost increases; however, this strategy can be risky. If a large enough area is affected by drought, the increased numbers of cows sold can depress prices, creating less revenue than expected. Producers also have fewer calves to market until herd rebuilding occurs.

This decrease in revenues can dramatically affect ranch equity if the drought is long-term. When drought abates, the lag from when heifers are retained to rebuild the herd until they calve can be costly. Ranches may take longer to recover financially than anticipated if this retention and lack of revenues occurs when prices are higher due to lower cattle supplies in the region.

Acquiring supplemental feed to offset some of the reduced forage supply is another common drought response. This strategy obviously increases short-term costs but does have the advantages of keeping herd numbers higher through the drought.

Previous work has shown this strategy is not any more profitable during a drought than liquidation but does provide the advantage of selling more calves immediately after the drought. Figure 2 shows how this strategy performs compared to simply liquidating breeding stock during a two-year drought as well as the three years immediately following the drought.

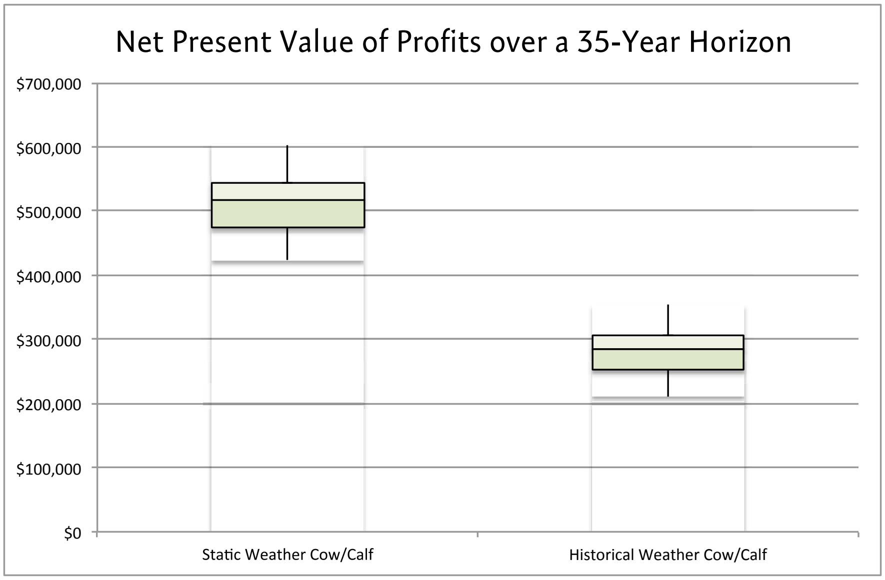


Figure 1. Comparison of Profitability over 35 years and 100 different price cycles when using average and actual weather.

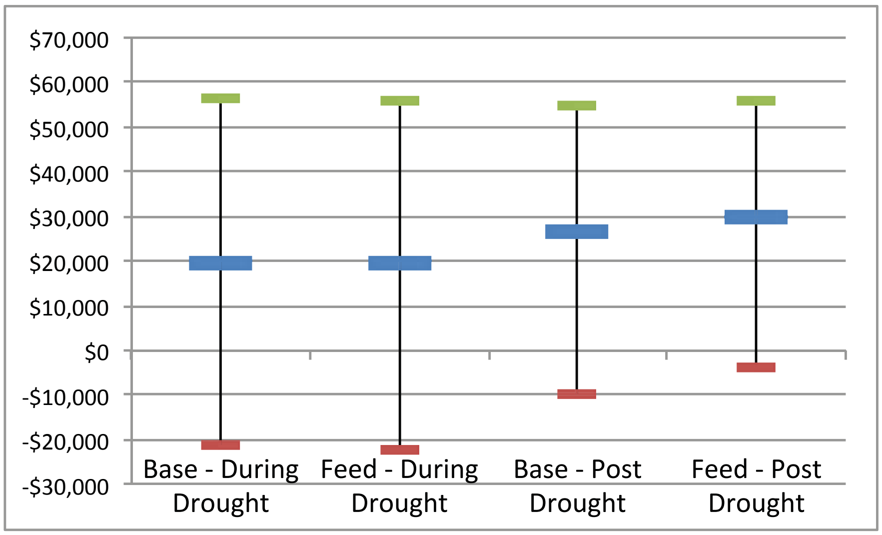


Figure 2. Comparison of liquidation alone (Base) and Supplemental Feeding as strategies to get through a drought in Central Wyoming. Green Bars show the maximum outcome, red bars show the minimum, and blue bars show the average.

This strategy is generally only profitable if cattle prices are expected to increase as drought eases. The longer the drought exists, the more costly this strategy is and requiring continued feed purchases until the drought subsides.

A less-common practice is to sell calves in the summer to reduce nutritional requirements of the herd. This strategy can reduce feed requirements and related costs but can result in selling less calf pounds at potentially higher prices per pound. This option of early weaning can be profitable, but usually requires ranches calve early enough in the season to have as much calf weight gain as possible by July or August. This strategy also is more likely to be profitable in short droughts rather than longer, multi-year droughts.

Proactive Strategy

Diversifying the herd is one strategy that shows promise to minimize drought impacts. A yearling enterprise added to a ranch by retaining steer calves in the fall adds flexibility while maintaining constant breeding stock numbers.

In favorable weather years, steers are retained over winter and used to consume extra forage. These animals can be sold early in the grazing season if spring precipitation is lower than expected. If the situation does not improve over the course of the year, steer calves are sold in the fall, and no additional culling is necessary. This process is continued until precipitation improves. This strategy provides flexibility in herd numbers without the need to sell significant numbers of breeding stock and causing the production lag associated with heifer retention.

Figures 3 and 4 show how the four strategies (early weaning, retaining steers, supplemental or summer feeding, and herd reduction) compare over a two-year and five-year drought respectively. While early weaning can be profitable in some scenarios, retaining steers has a much more certain outcome. This strategy has a comparative advantage the longer the drought lasts.

Have a Drought Plan

Having a plan on paper prior to a drought is important regardless of the strategy.

- This drought plan should include actions and triggers tied to dates and events (minimum rainfall amount by May 15, for example) that determine when these actions occur. Reevaluating the strategy as the drought unfolds is also important.

- A drought plan should account for short-term and long-term droughts, and the response to these events will likely evolve as a drought lengthens. The plan should lay out these potential contingency actions.
- Be sure to account for any long-term impacts, such as range degradation, that may result if management actions are not altered as droughts become more severe.

Drought plans are an important ranching tool. Drought has been, and will continue to be, a regular occurrence in Wyoming, but prior planning and being proactive rather than reactive could improve ranch profitability and survivability over the long-term.

Ritten can be reached at (307) 766-3373 or at john.ritten@uwyo.edu.

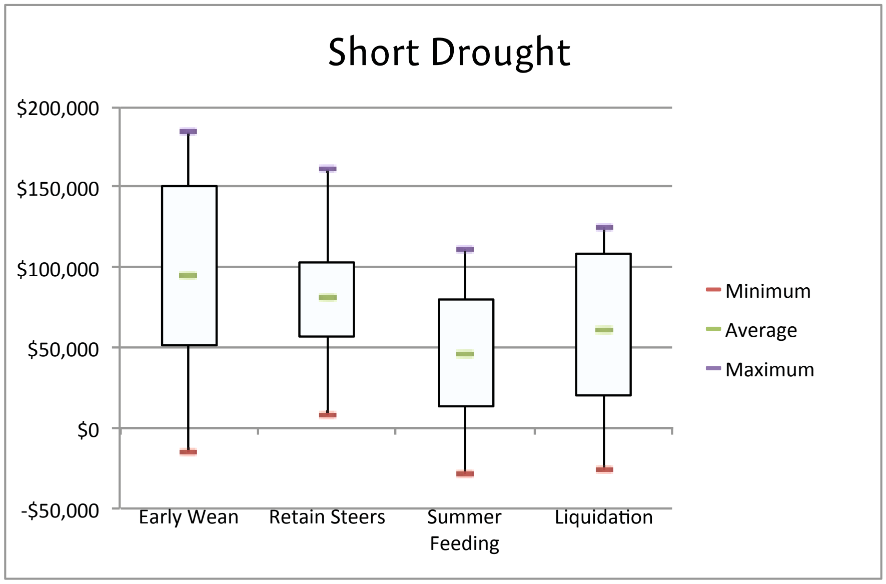


Figure 3. Comparison of Strategies during a 2-year drought.

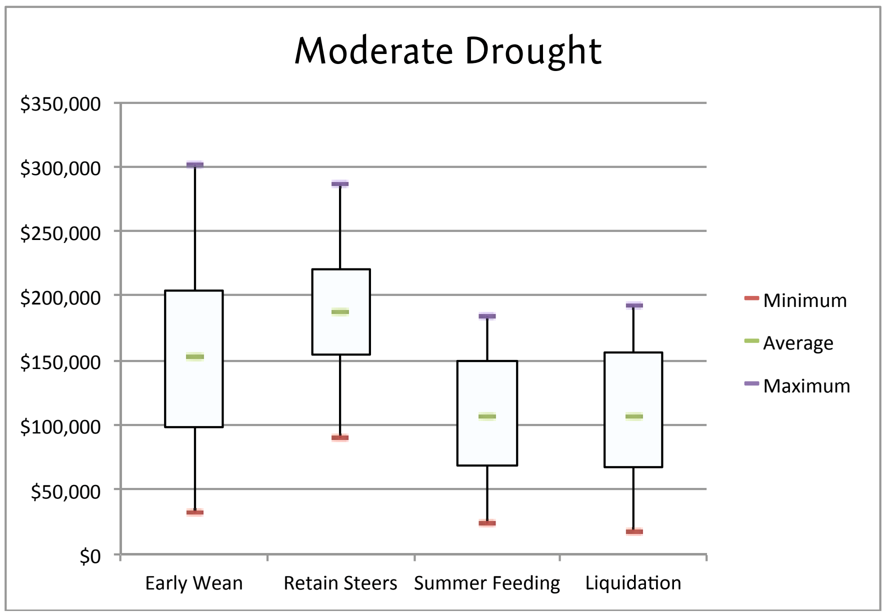


Figure 4. Comparison of Strategies during a 5-year drought

Additional Resources

All of the publications below can be viewed or downloaded by going to www.uwyo.edu/uwe and typing the bulletin number into the search field.

Two Common Drought Management Strategies and some Considerations for Wyoming Cattle Producers, B-1218, June 2011, University of Wyoming Cooperative Extension Service, available at: http://www.wyoextension.org/agpubs/pubs/B1218.pdf

Comparison of Alternative Cattle Management Strategies Under Long-Term Drought, B-1219, August 2011, University of Wyoming Cooperative Extension Service, available at: http://www.wyoextension.org/agpubs/pubs/B1219.pdf

Considerations for Preparing a Drought Management Plan for Livestock Producers, B-1220, June 2011, University of Wyoming Cooperative Extension Service, available at: www.wyoextension.org/agpubs/pubs/B1220.pdf

Price or Weather – Which Signal Should Livestock Producers Follow?, B-1221, August 2011, University of Wyoming Cooperative Extension Service, available at: http://www.wyoextension.org/agpubs/pubs/B1221.pdf

Multiple Impacts – Multiple Strategies. How Wyoming Cattle Producers Are Surviving a Prolonged Drought, B-1178, April 2007, University of Wyoming Cooperative Extension Service, available at: http://www.wyomingextension.org/agpubs/pubs/ B1178.pdf.

Managing Your Ranch During Drought: Implications from Long- and Short-Run Analyses, B-1205, University of Wyoming Cooperative Extension Service, available at: http://www.wyomingextension.org/agpubs/pubs/B1205.pdf.

Preparing for drought on rangelands minimizes more than lost income

Ashley Garrelts
Mae Smith
Glenn Owings
Dan Tekiela
Blaine Horn,
University of Wyoming Extension

Drought is inevitable, a common occurrence everywhere.

Rangeland managers and livestock producers need to be aware of how rangeland reacts and how to be prepared. This article addresses steps to reduce the vulnerability to drought's effects, including how to develop a drought plan. Being prepared minimizes damage to rangelands, saves managers and producers money, and makes the range more sustainable.

Drought affects rangeland differently depending on when drought occurs and the plants present. Effective drought plans are based on the growth cycle of certain plants on your rangeland. In Wyoming, there are two types of grasses – warm season and cool season.

Critical dates for drought decisions
bit.ly/criticaldecisiondates

"Recognizing and Responding to Drought on Rangelands"
bit.ly/wyodroughtresponse

Warm-season, Cool-season

Warm-season grasses are more common in the warmer areas of the state, such as the Big Horn Basin, the eastern half of the state, and lower elevations. These grasses begin growth when soil temperatures reach 60-65 degrees Fahrenheit and have optimum growth when air temperatures are consistently at 70-90 degrees Fahrenheit. Common examples include blue grama, little bluestem, prairie sandreed, and alkali sacaton. Growth is affected when drought occurs June-August.

Cool-season grasses are more common and can be found across the state. They provide most of the feed for grazing. Cool-season grasses begin growth when soil temperatures reach 40-45 degrees Fahrenheit and have optimum growth when air temperatures are consistently 65-80 degrees Fahrenheit. Common examples include bluegrasses, fescues, needle grasses, and wheatgrasses. Growth is affected when drought occurs in April-June because their growth is earlier in the season than warm-season grasses.

Precipitation Timing Determines Forage

Cool-season grass growth directly correlates to the amount of precipitation received in April, May, and June. Monitoring precipitation and soil moisture during these months, especially April and May, is the key to developing a drought plan. Soil moisture drives the start of plant growth once optimum temperatures are reached.

If soil moisture is inadequate, plant growth will be delayed, stunted, or nonexistent depending on future moisture events. Depending on the exact location, precipitation in May is more important than April, and in other areas, April is more important.

Example Drought Management Plan for Cool-Season Grass Dominated Pastures

Trigger Date	What to look at	Conditions	Management Decision
April 1	• Late summer early fall precipitation • Soil moisture • Current & forecasted precipitation • Current & forecasted temperatures	Normal to above normal precipitation	None
		Dry	Continued monitoring
		Exceptionally dry and warm	Be prepared to reduce stocking rates 10-20% through culling if conditions do not change
May 1	• Current & forecasted precipitation • Temperature forecasts	Normal to above normal precipitation	None
		Dry	Reduce stocking rates
		Exceptionally dry and warm	Further reduce numbers and/or find alternate feed for livestock either through purchased feeds or leased pasture
June 1	• Current & forecasted precipitation • Current and forecasted temperatures	Normal to above normal precipitation	None
		Dry	Find alternate feed for livestock through either purchased feeds or leased pastures or reduced stocking rates
		Exceptionally dry and warm	Find alternative feed for livestock through either purchased feeds or leased pastures Consider timing for early weaning

May

Begin implementing your drought plan by early May, and definitely by the middle of the month, if April moisture is below average. If conditions are dry in April and May, no amount of June precipitation will result in near-average rangeland forage production unless warm-season grasses dominate the pastures.

June

During June, temperatures often rise to levels not conducive to cool-season grass growth, so grasses complete their growth cycle, even if there is adequate moisture for additional growth. If plants were defoliated prior to this warm period, they will remain at the height they were when temperatures warmed.

June moisture is more critical if a ranch has a higher proportion of warm-season grasses, and key dates will be later than a ranch with cool-season grasses. If spring moisture was not adequate, June 1 can be a key date to make management decisions. Livestock numbers will probably need to be cut and additional forage purchased or leased. June precipitation may keep land out of drought if you have pastures in the higher elevations of Wyoming that allow maintaining stocking levels.

Every rangeland operation needs a drought management plan. That plan should include trigger dates based on the information discussed above, and the management decisions that need to be made on those trigger dates. Management decisions are operation-specific but may include destocking, moving livestock, dry-lotting, and feeding purchased feeds, early weaning, etc.

Forage Stockpiling, Flexible Stocking

Forage stockpiling and flexible stocking are other management practices that can help ranchers when responding to drought. Both practices require planning and forethought before drought occurs.

Close communication during drought with land management agency personnel may allow producers to know in advance any changes in their Animal Unit Months.

Stockpiling forage is the practice of accumulating forage growth used later in the season or at a time when forage production is lacking, such as during a drought. Grasses and other plants are not exposed to grazing during the growing season so mature plants can then be grazed when needed either in the dormant season or during the next spring or summer.

Producers will have a stockpiled feed source for their livestock if drought conditions occur.

Flexible stocking is having a base herd of breeding livestock and adding short-term livestock such as yearlings during times of increased precipitation and forage production. The number of animals in the base herd of breeding livestock is determined by matching animal forage demand to the forage available during a drought situation. This helps mitigate the risk of frequent destocking of the breeding herd during years of below-average forage production.

During times of above-average forage production, producers can purchase or lease short-term livestock to take advantage of the extra forage resource. Or this forage can be stockpiled and used later in the season or during times of drought as discussed above.

You might also want to include some type of risk management package, such as insurance. The USDA Risk Management Agency offers a number of insurance programs to cover different types of drought-related risks. These programs are discussed in the *Drought Risk Article*.

If Holding Grazing Permits

If you hold or lease grazing permits on federal land, drought may affect how the managing agency administers your allotment. Be in close contact with agency range staff members so you know ahead of time if the district or field office intends to temporarily cut Animal Unit Months. They will often send drought letters with a final decision in late spring, but early communication may allow you to be part of the management discussion for your allotment or area. There may be movement strategies that reduce or eliminate the need to cut permitted livestock numbers.

Planning for drought is critical to ensure healthy rangelands and livestock as well as sustainability. All operations need a drought management plan that includes trigger dates and management decisions. By having a plan in place, you will be able to more easily make critical management decisions, which may save time, money, and stress. Take some time to sit down with all those involved in your operation and put a drought plan down on paper. Make those critical decisions now.

University of Wyoming Extension educators **Glenn Owings** is based in Sublette County and can be reached at (307) 367-4380 or at gowings@uwyo.edu, and **Blaine Horn** is based in Johnson County and can be contacted at (307) 684-7522 or bhorn@uwyo.edu. Extension invasive plant specialist **Dan Tekiela** is an assistant professor in the Department of Plant Sciences and can be reached at (307) 766-3113 or dtekiela@uwyo.edu.

Five sources of risk loom over drought

John Hewlett,
University of Wyoming Extension

Risk is generally understood to mean future events with uncertain outcomes.

Not all uncertainty is created equal. Risk is a case where the uncertainty matters; if the outcomes did not matter, then there would be no risk. Risk does not always imply a negative or bad outcome. Uncertain future events may result in good, bad, or neutral outcomes.

The sources of risk to agricultural businesses are described as five distinct sources: market risk, production risk, institutional risk, human risk, and financial risk.

Marketing or **price risk** includes the prices of inputs or outputs that change after a manager commits to a plan of action.

Production risk might be best described as uncontrollable events such as weather, pests, or disease that make yields, quality, or outputs unpredictable.

Institutional or **legal risk** includes government or other institutional rules, regulations, and policies that influence profitability through changes in costs or returns.

Human risk arises from the character, health, or behavior of the people involved in the business. **Financial risk** is the extra risk attached to borrowing outside capital to make the business function.

Risk Management

Risk management can be thought of as one or more strategies created to reduce the consequences of negative outcomes or increasing the likelihood of positive outcomes. Several different risk controls might be considered for a particular situation. Risk management strategies vary by source of risk and level of protection already in place. In general, there are several options for managing risk to a more acceptable level.

- **Avoid the Risk** – is accomplished where a manager makes an active decision to not engage in a particular practice or activity due to the level of risk involved.
- **Reduce the Risk** – can be accomplished by making negative outcomes less likely or by reducing the consequences should they occur.
- **Transferring the Risk** – can be done through insurance policies, by contracting, or through other types of agreements with a third party willing to share in the negative consequences in return for a premium paid in advance.
- **Increase Capacity to Bear the Risk** – can be developed by increasing the capacity to bear the negative consequences by holding resources in reserve or from keeping management options open, allowing for flexibility in the face of bad outcomes.

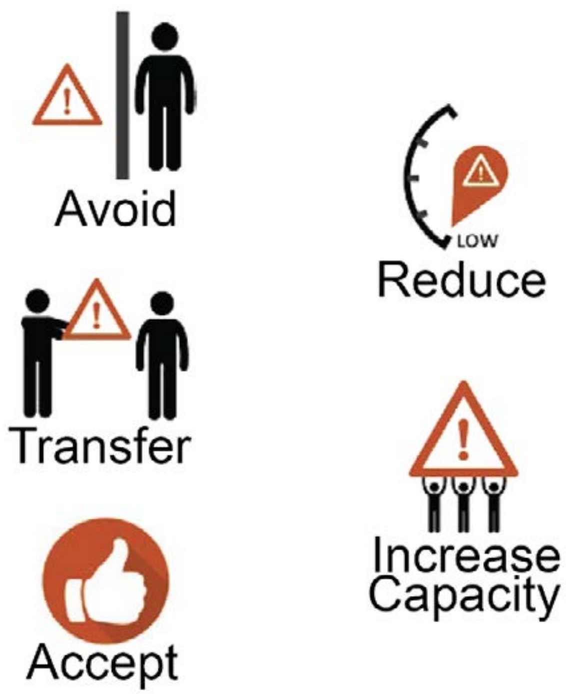


Figure 1. Alternative Risk Management Strategies

- **Accept the Risk** – some risks are too costly to control or the negative consequences may be too small to bother with managing. Management may choose to simply accept the risk as a cost of doing business with the idea the business will cover the entire cost should a negative event occur. This is sometimes referred to as self-insuring.

Risk Controls

Risk controls represent a broad category of tools and approaches for managing risk. These controls are the specific means by which the strategies outlined above are carried out. For example, the use of sheds to protect newborn livestock from inclement weather, cultivating a row crop to remove weeds, vaccinating against potential disease, or applying fertilizer to provide the nutrients a crop needs in an appropriate balance are all forms of risk management. These practices or risk controls are intended to reduce production risk.

Agricultural business managers use risk controls in nearly every dimension of management. The controls selected vary by source of risk, timing of consequences, magnitude of the threat, likelihood of occurrence, etc.

Production agriculture is inherently uncertain, and success rides on a mix of uncontrollable variables, such as weather, falling prices, and rising input costs. That is why a comprehensive risk management strategy is imperative. One or more programs developed under the Federal Crop Insurance or Disaster Assistance programs is a key component of that strategy for most crop and livestock producers. Options let producers insure levels of revenue against losses ranging from individual crops, livestock and pasture, to whole farm revenue.

Price Risk

Livestock producers can protect against declines in market prices with Livestock Risk Protection insurance (LRP). LRP policies are available for feeder and fed cattle, lamb, and swine in Wyoming. A producer selects the coverage period, from 13 to 52 weeks, and coverage of 70 to 100 percent of the expected ending price.

Prices are determined by a Chicago Mercantile Exchange-based index for the period selected; it is important to note the actual cash price received by a producer is not determined by the ending index for the policy. An indemnity is paid on the difference if the ending index falls below the contract price. Limitations specific to each type of policy include age, weights, and number of total head insured.

Livestock Gross Margin (LGM) insurance takes LRP price insurance a step further by allowing producers to protect against declines in gross margin due to increases in feed costs or falling livestock prices. LGM is available for fed cattle, dairy, and swine. LGM policies use a complex formula to determine actual revenue levels at the end of the insured period; indemnities are paid when the ending gross margin falls below the contracted revenue guarantee.

Forage Insurance

Rainfall index pasture, rangeland, forage insurance (RI-PRF) is available to Wyoming producers. This policy relies on National Oceanic and Atmospheric Administration (NOAA) rainfall index data as an index for pasture productivity on 17-by-17-mile grid areas. RI-PRF offers protection using the rainfall index for two-month intervals over a year. Coverage may be purchased for either native range on either private or public land or for hay land where forage is mechanically harvested at least once

Forage insurance options are available for protection against production declines due to drought.

a year. Producers can select a productivity factor of 60 to 150 percent of the county base value and coverage from 70 to 90 percent. Producers must choose more than one interval and a coverage level of at least 30 and no more than 70 percent on any one interval; intervals may not be consecutive. Indemnities are paid when the ending index drops below the coverage selected. Producers should note that actual rainfall received may not coincide with the grid index.

Forage insurance similar to an APH-based policy is available for producers of alfalfa and alfalfa-grass mixes harvested for hay. The coverage level available for this policy varies annually, as forage prices are adjusted yearly. Stand populations must meet minimum requirements, and coverage is available from 50 to 75 percent of the established yield at the determined price for an existing stand. Producers eligible for the Supplemental Coverage Option (SCO) can increase their coverage up to 86 percent, and buy-up under catastrophic (CAT) coverage is also available in most areas.

Non-insured Crop Disaster Assistance Program (NAP) coverage is available through the Farm Service Agency and provides protection to producers not otherwise covered by traditional crop insurance policies.

Under NAP, producers can insure yields at 50-percent coverage and 55 percent of the market price. Pasture or crops planted or maintained for grazing may be insured under NAP. Utilizing the NAP buy-up option may allow operators to increase coverage from 50 to 65 percent for eligible crops at 100 percent of the market price determined by FSA. Service fees are capped at $250 per crop and $750 per producer. Buy-up premiums are capped at $6,250. Although grazing policies are not eligible for buy-up coverage, producers may opt for concurrent enrollment with NAP and RI-PRF coverage.

Whole Farm Revenue Insurance

Whole Farm Revenue Protection (WFRP) insurance is designed to provide coverage for all commodities produced on a farm or ranch under a single policy. This coverage could be of particular benefit to specialty crop growers, specialty livestock producers, direct farm marketers, vegetable growers, and other farm operations that might not be covered under traditional crop insurance policies or other risk management instruments.

WFRP differs from other crop insurance in that it provides protection against declines in a farm's gross revenue due to an unavoidable natural cause; up to $8.5 million is insurable at various coverage levels with indemnifiable losses determined after the farm's fiscal year has ended.

WFRP provides coverage for all farm commodities except for timber products, livestock for show or sport, and pets. WFRP can provide replant coverage for annual crops, except those covered by another crop insurance policy, equal to the cost of replanting or a maximum of 20 percent of the expected revenue.

WFRP can be used in conjunction with other crop insurance policies; premiums and coverages are reduced depending on the protection offered by the other policies (CAT coverage makes a producer ineligible for WFRP).

Any participating farm can insure gross revenue up to $10 million at 85-percent coverage. Coverage levels decrease for insured revenue exceeding $10 million. To be insured at 80 or 85 percent coverage, farms must meet the diversity requirement of at least three different commodities grown or raised. To be counted, revenue for a commodity must represent at least 8.3 percent of the total revenue insured. Insured revenue is determined from a farm's five-year production history and IRS Schedule F tax returns. Indemnities are paid when actual gross revenue falls below the guarantee level.

Disaster Assistance Programs

Disaster assistance options are available through the Agricultural Act of 2014 to help protect producers of livestock, forage, trees, honeybees, and trees against adverse weather and other natural disasters. Producers should be aware of several important changes. Livestock and forage producers are no longer required to carry crop insurance or NAP coverage (Non-insured Crop Disaster Program) to be eligible for disaster payments. Producers are required to comply with conservation requirements on any eligible lands; this includes a conservation plan, complying with highly erodible and wetland requirements, and having an AD-1026 form on file (demonstrates compliance with these provisions). Program participation requires producers keep complete and accurate records. Records should include veterinary death-loss verification, pictures, weather records, grazing records/receipts, feed purchased, livestock headcounts, and contracts/leases, among other documents.

- **Livestock Indemnity Program (LIP)** - Pays producers for livestock deaths in excess of normal mortality due to extreme weather events or predator attacks. The program pays for 75 percent of the approved market value the day before the animal is lost. Notice of loss must be given within 30 days of occurrence. Producers must prove ownership and provide documentation (veterinary or otherwise) as to the loss of the animal(s).
- **Livestock Forage Loss Programs (LFP)** - Provides payments due to loss of grazing on native or improved pastures. A producer must be in a D2 or higher designated drought county via the U.S. Drought Monitor or have a fire/natural disaster designation. Payments for grazing losses due to drought or fire are based on rates determined by the Farm Service Agency (FSA) and can cover losses for up to 180 grazing days. Payments vary based on severity of the drought and are adjusted accordingly.
  Covered livestock are livestock that were owned, leased, purchased, or entered into a contract to purchase during the 60 calendar days before the beginning date of a qualifying drought or fire. Eligible livestock must be part of a commercial operation and not for recreational uses such as roping, and may include animals sold or otherwise disposed of because of qualifying drought conditions during the current year, or in some cases, prior years. They also cannot normally be in a feedlot situation when a drought event occurs.
- **The Emergency Assistance for Livestock, Honeybees, and Farm raised fish (ELAP)** - Pays producers for losses due to natural disasters not associated with drought or fire that are not covered by either LFP or LIP. Livestock losses, feed shortages, and losses associated with hauling water are covered. Livestock losses must be due to an approved event and cover up to 75 percent of the approved market value.

* For more information from the Risk Management Agency, see: http://www.rma.usda.gov

* For more information from the Farm Service Agency, see: http://www.fsa.usda.gov

* For more information on risk and risk management in agriculture, see: http://RightRisk.org.

John Hewlett is a ranch/farm management extension specialist in the University of Wyoming – Department of Agricultural and Applied Economics.

***RightRisk** helps decision-makers throughout the world discover innovative and effective risk management solutions. RightRisk.org*

Have a plan prior to drought for pasture management

Anowar Islam
Dennis Ashilenje

Soil management on Wyoming farms and ranches
bit.ly/wyosoilmanagement

Having a good management plan is critical to survive drought.

Drought forces forage and livestock producers to develop strategies to deal with reduced water supplies for plants and animals. This induces indirect economic and biological effects on animal production and availability of feed resources.

Strategies need to be developed to handle reduced forage resources. Some important drought management strategies include use of existing forage resources, livestock inventory, and alternative feeding programs.

Drought Trends in Wyoming

Drought manifests in four stages: below normal precipitation extending three months; depleted soil moisture to the level that adversely affects crop yield; reduced streamflow; and negative socioeconomic impacts.

The Palmer Drought Severity Index (PDSI) indicates prolonged and abnormal moisture deficiency, which is a popular measure of drought. Another measure is Crop Moisture Index (CMI), which determines weekly drought and its impacts on agriculture during growing season.

Both the PDSI and CMI are a combination of magnitude and duration. A value of -2 and -3 indicates moderate drouth, -3 to -4 indicates severe drought, and higher than -4 indicates extreme drought.

Wyoming experienced seven severe droughts during the last century, each extending three years. More recently, 2002 and 2012 had extreme drought across a large portion of the state spanning the whole year resulting in water shortages and serious crop yield reductions.

Preparing for drought involves social awareness of drought, prediction, and expected impacts. Forecast information sources include the National Drought Mitigation Center and National Centers for Environmental Information.

Increasing water retention is an important drought strategy. This can be achieved by:

- Establishing small, water retention reservoirs and structures that restrict water outflow from fields;
- Increasing soil water retention and its availability for plants;
- Using efficient irrigation technologies; and
- Using crop water use efficiency and soil moisture conservation to set production targets.

Crop Selection for Pastures and Hay Production

Species and cultivar choices should be made based on their drought tolerance along with immediate and long-term demand for pasture and hay. For immediate forage needs, consider species that establish easily through germination and generate biomass rapidly under limited soil moisture; however, most forage crops are perennial species targeted for feeding livestock for periods lasting beyond a year. Resilience of such crops against water stress and regeneration to the point of providing sufficient and quality biomass is paramount.

General recommendations have been given that identify species that tolerate low levels of soil moisture, particularly typical of large parts of Wyoming (Table 1).

Sandberg bluegrass, Indian ricegrass, streambank wheatgrass, and thickspike wheatgrass are native cool-season grasses that can tolerate precipitation to a minimum of 6 inches per year. Thickspike wheatgrass ranks highest in terms of ease of establishment. On the other hand, Sandberg bluegrass is difficult to establish. Some non-native grasses (tall fescue [Figure 1], crested wheatgrass) and semi-shrub (forage kochia) perform well in drought conditions (Table 1).

Among the native warm-season grasses, big bluestem and blue grama can grow with limited precipitation, with as little as 5 inches for blue grama (Table 1). Dictated by the kind of photosynthesis that flourishes as the season warms up, these two species may not produce enough forage for immediate use early to mid-year.

A narrow range of legumes exist that can tolerate extreme to moderate drought. Prominent ones are perennial alfalfa, yellow sweet clover, sainfoin, red clover, and white clover. Well-established alfalfa has roots deep enough to draw water from lower soil profiles; this crop can tolerate drought. On the other hand, annual winter peas and Laramie medics have good drought tolerance.

Despite the limited number of legume species that can thrive under drought, their mixture with grass is still a viable option to avert the ravaging effects of water stress. The mixed crops withstand drought by exploiting the advantage of more even soil surface cover, with more water retained in the soil. In addition, different species respond variably to drought, hence the crop stand remains more stable.

Table 1. Common drought-tolerant grass and legume species grown in Wyoming.

Species	Minimum precipitation (inches)
Grass	
Tall fescue	4.6
Blue grama	5
Sandberg bluegrass	6
Indian ricegrass	6
Streambank wheatgrass	6
Siberian wheatgrass	7
Thickspike wheatgrass	7
Crested wheatgrass	9
Big bluestem	9
Western wheatgrass	10
Switchgrass	-
Sideoats grama	-
Legume	
Yellow sweetclover	9
White sweetclover	9
Alfalfa	10
Semi-shrub	
Forage kochia	6

Crop management

Seeding

Seeding is critical in crop establishment. Under normal conditions, seeding should coincide with sufficient soil moisture for seed germination and seedling growth in late spring and/or late summer/early fall. However, when to seed is best guided by the anticipated duration of drought. Under circumstances where precipitation is limited, no-till planting can be a useful way of preserving soil moisture at levels that can promote seed germination and subsequent growth. In that case, soil disturbance should be kept to a minimum, for instance, by using herbicides for weed control.

Soil fertility and irrigation management

Applying water soluble fertilizers, specifically nitrogen, is a major challenge during drought. Plants cannot access this vital nutrient without sufficient water dissolv-

Figure 1. Performance of different cool-season grasses near Lingle under dryland conditions. Middle strip: tall fescue – shows a clear evidence of drought tolerance and of a weed-free green, healthy stand compared to other grasses heavily infested by invasive weeds (Photo: Anowar Islam, October 2015).

ing the fertilizer and infiltrating into the soil. Growing grasses mixed with nitrogen-fixing legumes serves as an important remedy, especially after two to three years.

Yield and Quality

Drought reduces overall forage yield and quality, particularly resulting in poor protein content, low digestibility, and escalated levels of anti-nutrient properties, such as high fiber. Stressed crops accumulate nitrates to toxic levels where nitrogen fertilizer application precedes drought. Tissue nitrate levels exceeding 0.25 percent is detrimental, whereas amounts greater than 0.5 percent can be toxic to livestock. Nitrogen fertilizer application is emphasized for grasses rather than legumes. Analyzing hay and pastures before feeding to livestock is important.

Forage mixtures with 30 percent legumes can help alleviate excessive uptake of nitrogen but for grass monocrops, nitrogen fertility programs need to be tied to crop development. When risks of poor crop quality are high, the alternative is to plan to graze the forages gradually following drought or mowing for hay early before the drought intensifies.

Plan to restore crop and soil health

Reseeding patches with a thin crop stand can rehabilitate forage fields. For cases where over 50 percent of the original grass crop stand is expected to be lost, sod seeding with legumes will gradually restore soil organic matter, surface cover, and contribute to a balanced ration of proteins and carbohydrates.

Weed control

A rapid succession of weeds in the transition from dry soils to suboptimal soil moisture after drought may favor weeds more than crops. A prudent choice of herbicides that effectively eliminate weeds but do minimal injury to crops can help create suitable conditions for reseeding, unlike tillage.

Many forage crops and pastures may be seriously affected in the event of drought, especially if the drought lasts for more than one growing season. Planning to select the right species, fertility and irrigation management, weed control, and rehabilitative seeding at the right time will help crops recover.

Anowar Islam is the University of Wyoming Extension forage specialist and an associate professor in the Department of Plant Sciences, and **Dennis Ashilenje** is a graduate assistant. Islam can be reached at (307) 766-4151 or at mislam@uwyo.edu.

Strategies to save water when irrigating

Vivek Sharma

Irrigated agriculture is crucial to Wyoming's economy, with the state's 1.5 million acres, representing an annual income of about $1.8 billion.

Many production areas in recent years have experienced water shortages. Changes in climate variables and their significant implications on available irrigation water and crop yields further complicate crop productivity vs. water quantity vs. quality dynamics and interrelationships.

On-farm irrigation efficiency can be improved by irrigation scheduling, adopting deficit irrigation management practices, conservation tillage, and installing more efficient irrigation systems.

Producers and their advisers, as well as state and federal water resources agencies, are challenged to practice conservation methods and use water resources more efficiently while meeting crop water requirements to maintain high productivity and protect environmental services.

Strategic water management requires application of the right amount of water at the right time and at the right location. Even when abundant, use just enough water for a crop to thrive. For example, excessive irrigation not only raises fertilizer and irrigation pumping costs but can also generate additional nitrate, nitrites, and other chemical leaching. These contaminants contribute to the total daily load of chemicals carried by aquifers. By subjecting soil and plant canopies to frequent and prolonged wet conditions, excessive irrigation can decrease harvestable yield due to greater occurrences and severity of disease, anaerobic soil conditions, nutrient deficiencies, work fields in a timely manner and also contribute to the contamination of aquifer.

On the opposite extreme, inadequate soil water limits transpiration and photosynthesis and, in turn, hinders crop growth and reduces yield. Producers can use smart water management approaches to reduce on-farm water use without decreasing productivity. On-farm irrigation efficiency can be improved by irrigation scheduling, adopting deficit irrigation management practices, conservation tillage, and installing more efficient irrigation systems.

Irrigation Scheduling

Irrigation scheduling is a practical tool for preventing over-application of water while optimizing crop growth. When to start and stop irrigating each season and how much water to apply are two of the most important decisions an irrigator has to make. This can be done by estimating crop water use of different crops (evapotranspiration), timely monitoring of the moisture content of the soil, and by taking plant-based measurements for irrigation scheduling (canopy temperature, etc.).

Evapotranspiration (ET) Monitoring

Evapotranspiration (ET_c) based irrigation scheduling uses weather data with plant characteristics (crop coefficients), irrigation systems characteristics (application rate and efficiency), and site specific conditions (soil type, slope, etc.) to schedule irrigation.

ET_c losses are replaced in the plant root zone to meet crop water requirements. Crop water requirements are determined from a balance of water input and output in the plant root zone. Water inputs include effective rainfall (rainfall amounts that contributes to crop water requirement; P) and net irrigation (the amount of water required for optimum growth; I). Water output includes ETc, runoff (R), and deep percolation (D). All the parameters are summarized in what is referred as the root zone soil water balance as:

$$I = ET_c - P - \Delta S + D + R$$

Where ΔS is the change in water storage.

ET_c is defined as the combined loss of water from land surface to atmosphere in the form of water vapor by (1) evaporation from the soil surface, water bodies, and water droplets in leaves and (2) transpiration from the plant leaves. The seasonal and daily ET_c vary with crop type and climatic conditions during the growing season such as air temperature, rainfall, humidity, solar radiation, and wind speed.

ETc is estimated as the product of reference ET (ETo) and a crop coefficient (Kc). Weather stations often collect weather and ET_c data. More information on reference and crop evapotranspiration and crop coefficients is available in University of Wyoming Extension Bulletin B-1293, *Evapotranspiration: Basics, Terminology and its Importance.*

Producers can also use ETc tables from the Wyoming National Resources Conservation Service (NRCS) for different crops to improve decision making for irrigation scheduling. Knowing the water holding capacity of soils (Table 1) is also important. For example, sandy soil will not hold as much water as loam soil; irrigation must be more frequent with less water per irrigation.

Table 1: Available Water Holding Capacity by Texture [Source: USDA-NRCS Irrigation guide]

Soil texture	Inches of Water Available per Foot of Soil
Coarse Sand	0.1 – 0.4
Fine Sand	0.6 – 0.8
Loamy Sand	0.7 – 1.0
Sandy Loam	1.3 – 1.6
Loam	1.9 – 2.2
Silt Loam	2.3 – 2.5
Clay	1.7 – 1.9

Soil Moisture Monitoring

Keep the soil within a target moisture range by irrigating to replenish the plant water used. Soil moisture sensors help producers accurately determine soil water quantity and quality to better decide the timing and depth of irrigation applications and reduce excessive or insufficient irrigation.

Some of these sensors and methods used for irrigation management include appearance and feel, neutron gauges, capacitance probes, time domain reflectometer, tensiometer, and electrical resistance sensors.

Understand how the sensor works when selecting a soil water sensor for an intended use. Different sensors will not necessarily respond the same to influences. Physical characteristics can vary with sensors such as sensor spacing, response time, sensing volume, and operational range and frequency. The University of Wyoming conducts training sessions and workshops on the use and operation of soil moisture sensors.

A wide range of commercial soil moisture sensors are available with varying principles to monitor the soil moisture. When selecting the sensors, consider the advantages and disadvantages of each. Cost, product support, convenience, soil and crop type, and sensor accuracy should factor into your decision making.

The effectiveness of each soil moisture monitoring system is dependent on proper sensor placement in the

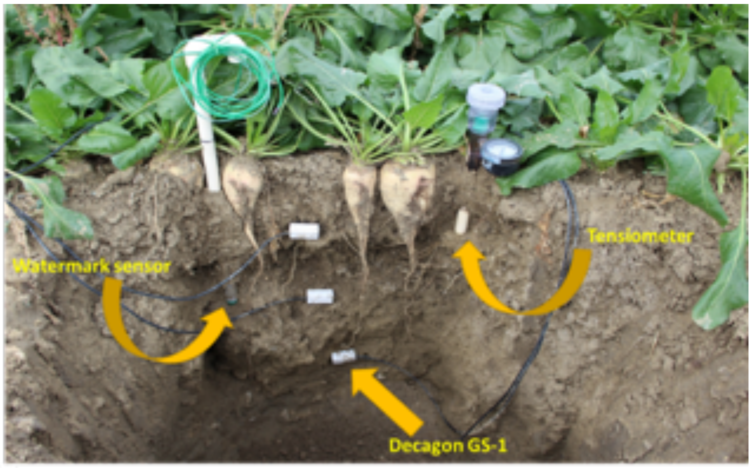


Figure 1: Soil Moisture Monitoring for irrigation scheduling using different soil moisture sensors installed at different depths in a sugarbeet field at Powell Research and Extension Center, Powell.

crop root zone. Install sensors in a location that represents the overall field. Avoid sensor installation where there is a big gap between the plants or near the edge of the field (Figure 1). If there is significant variation of different soil types, install multiple sensors at several locations. Also, note that sensors must have good contact with the soil and be installed at different depths depending on the crop type. For example, install four soil moisture sensors (at 1-foot deep, 2 feet deep, 3 feet deep, and finally 4 feet deep) for sugarbeets; however, for drybeans or barley, sensors at each foot down to 3 feet is sufficient to monitor soil moisture for the whole soil profile that contains roots.

Deficit Irrigation Management

Limited/deficit irrigation applies some level of water stress during drought-sensitive growth stages of a crop, or only a portion of the total crop water requirement is applied either evenly or unevenly during the growing season without significant yield reduction. Deficit irrigation generally works well with deep-rooted systems such as corn, sugarbeet, alfalfa, etc., as they can extract soil moisture from a greater depth, so they continue growth without irrigation as long as water is available at deeper layers.

Efficient Irrigation Systems

Efficiency is highly dependent on an irrigation system's design, regular maintenance, and operating conditions. For example, surface irrigation systems (the most dominant irrigation method in Wyoming) are inherently inefficient because of excessive application and soil erosion. Producers can use surge irrigation, which applies water intermittently by cycling irrigation water between both sides of a surge valve, to save money with surface irrigation (Figure 2). The alternate wetting and resting time for each surge slows the intake rate of the wet furrow and produces a smoother and hydraulically improved surface. This method can save water and reduce nitrogen loss through leaching.

Another approach is to irrigate alternate rows. This practice works well on crops less sensitive to moisture stress. If the irrigation system produces runoff, tail water reuse systems capture water at the lowest end of the field. Reuse of runoff water works best with soils that

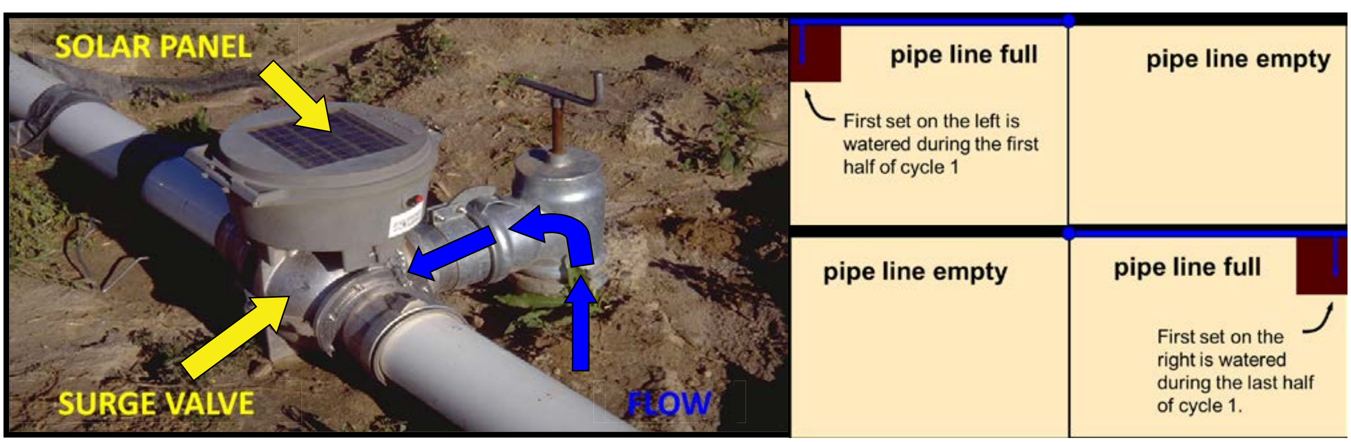


Figure 2. Component of surge irrigation systems. Water is pulsed on and off in planned time periods using surge valves, which direct the water to one side of the valve at one time.

Figure 3. (a) GPS mounted variable rate sprinkler irrigation system and (b) sub-surface drip irrigation system at Powell Research and Extension Center can apply less water than furrow flood irrigation systems while meeting the crop water needs.

have high water holding capacities. Reuse of runoff water is not recommended in areas where the soil contains a high concentration of salt (can exacerbate salinization of soils).

Switching from surface irrigation to more efficient irrigation systems such as sprinkler and drip irrigation allows managing water more efficiently and application to the depths needed (Figure 3). These systems often increase crop yields. Under sprinkler irrigation systems, producers can use Low Energy Precision Application (LEPA) and Low Elevation Spray Application (LESA) to distribute water directly to the furrow at very low pressure (6-10 psi). This will help avoid disease problems in some crops caused by foliage staying wet too long.

Drip irrigation can save a lot of water, in many cases more than half of the amount used for furrow irrigation. Drip irrigation applies small amounts of water frequently to the soil area surrounding plant roots through flexible tubing with attached emitters. Subsurface drip irrigation (SDI) delivers water underground directly to roots. Since water is applied directly to individual plant roots, SDI minimizes or eliminates evaporation, provides a uniform application of water to all crop plants, and applies chemicals more efficiently.

Table 2: Application Efficiency of Different Irrigation Systems.

Irrigation Systems	Application Efficiency (%)
Drip irrigation	95 – 98%
LEPA irrigation	90 – 95%
LESA irrigation	85 – 90%
Traditional center pivot irrigation systems	75 – 85%
Furrow irrigation with surge valve	50 – 70%
Furrow irrigation with open ditch	40 – 60%

Adoption of Conservation Tillage

Crop residue management and conservation tillage (such as no-till, strip till, minimum tillage) helps preserve soil moisture by leaving residue from previous crops on the soil surface, decreasing wind and water erosion and runoff (Figure 4). In no-till management, the crop stubble layer can reduce evaporation in the soil profile by one-half compared to bare soil, especially early in the crop season when more soil is exposed to direct sunlight.

In the long-term, the practice may improve soil physical properties by adding organic matter to the soil and enhancing soil health. Keeping crop residue even across the field is essential for spreading nutrients uni-

Figure 4. Sugarbeet production under strip tillage helps to conserve soil water and reduces surface evaporation.

formly and shielding new plants from adverse weather conditions. Conservation tillage can also reduce water pollution caused by runoff and can enrich the soil with organic matter.

For more information or questions, contact University of Wyoming Extension irrigation specialist **Vivek Sharma** at vsharma@uwyo.edu.

Resources:

United State Department of Agriculture (USDA)- Natural Resources Conservation Service (NRCS) Irrigation Guide. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs144p2_033068.pdf

Sharma, V., J. Heitholt and M. A. Islam. 2016. *Evapotranspiration: Basic, terminology and its Importance.* University of Wyoming, Extension Bulletin B-1293.

Drought Risk Atlas (DRA)

Windy Kelley

An online tool that enables users to access climatological data from drought indices, such as the Palmer Drought Severity Index (PDSI), to better visualize and understand the risk of drought for an area of interest. Data are available at weekly, monthly, and annual timeframes.

Questions I can answer in the DRA:

When was the last time a drought like this happened?

How long do droughts like this typically last?

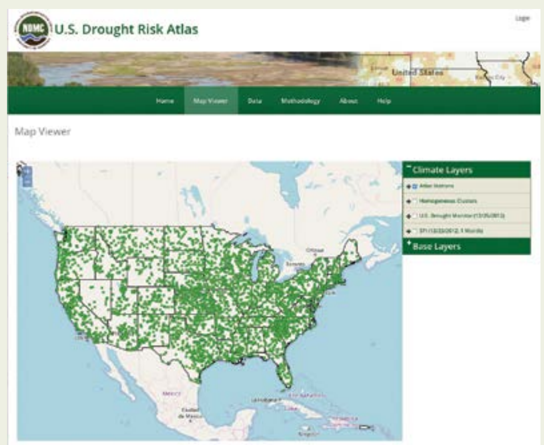
How often does a drought this severe occur?

How much area did the last drought cover?

How does this drought compare to historical droughts? Magnitude? Frequency? Duration?

Who could use the DRA?

- Agricultural producers
- Natural resource managers
- Municipalities
- Community economic development
- Water planners
- Emergency managers
- Researchers
- Public health and mental health professionals
- Media
- Policy makers
- Anyone who wants to prepare for DROUGHT!



Where do the DRA data come from?

The data come from the most comprehensive, long-term climate stations throughout the nation! What does this mean?

In brief:

Data from more than 3,000 stations with at least 40 years of data in 139 unique climate regimes!

Now that is impressive!

Where do I find the DRA and how do I use it?

Go to http://droughtatlas.unl.edu/ and start exploring!

What ... there's no station near me!? Now what?

The DRA team has you in mind. You will be able to view climatologically similar stations.

Who is behind the DRA?

The U.S. Drought Mitigation Center

And, partners:

National Oceanic and Atmospheric Administration

Climate Program Office

USDA

Risk Management Agency

High Plains Regional Climate Center

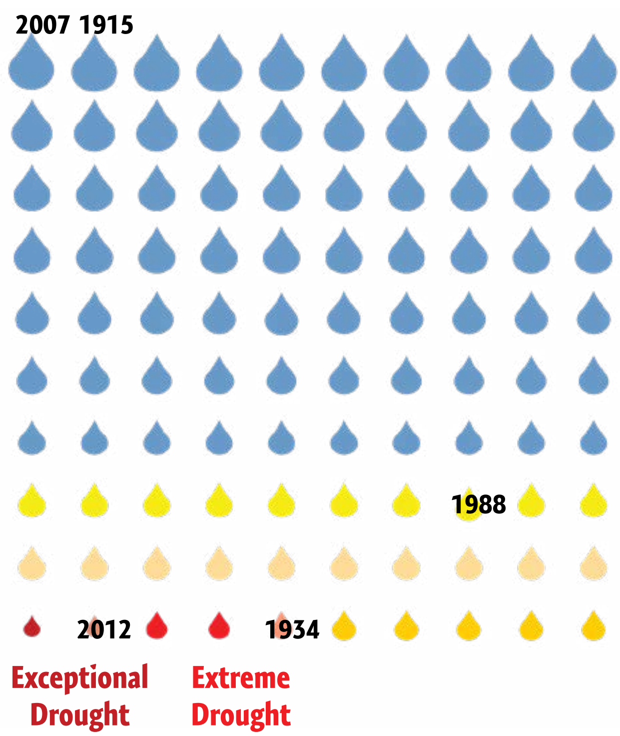
American Association of State Climatologists

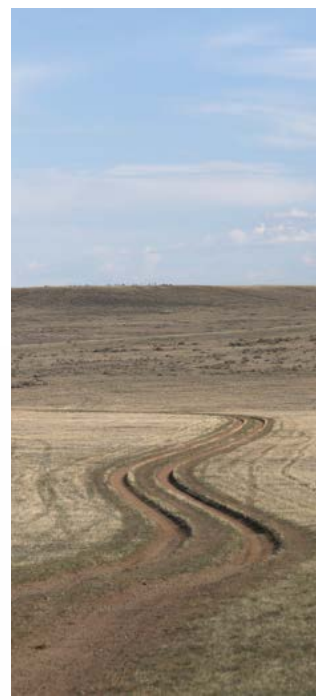
U.S. Drought Monitor (USDM)

Windy Kelley

The USDM map is released weekly for the entire U.S. capturing drought conditions. Area drought conditions are depicted by one of five colors or classifications associated with a percentile based on historical drought information. Drought duration is suggested by an 'S' (short) or an 'L' (Long). Generally, short-term drought developed within the past six months and long-term drought has continued for longer than six months.

			Percentile
	D0	Abnormally Dry	21 - 30
	D1	Moderate Drought	11 - 20
	D2	Severe Drought	6 - 10
	D3	Extreme Drought	3 - 5
	D4	Exceptional Drought	1 - 2

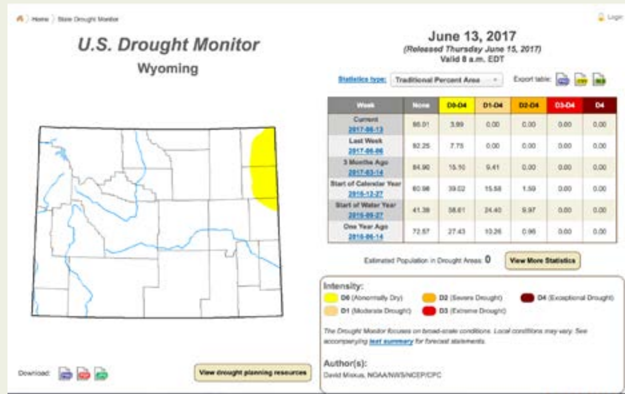




Become a citizen scientist with the Community, Collaborative, Rain, Hail, & Snow (CoCoRaHS) Network. Volunteers collect and report precipitation or lack, and other current conditions. Learn more at http://cocorahs.org

Who could use the USDM? And how?

- U.S. Department of Agriculture → trigger disaster declarations and eligibility for low-interest loans and the Farm Service Agency's Livestock Forage Program
- Internal Revenue → ranch-related tax determinations due to forced livestock sales as a result of drought
- States → trigger drought response actions
- Media → communicate drought information
- Individuals → manage their drought risk



Who determines the drought areas and intensity? And how?

Several authors take turns creating the map each week. They develop the map by analyzing multiple drought indices and indicators such as:

- Rainfall
- Soil moisture
- Streamflow
- Crop conditions
- Wildfire conditions
- Reservoir levels
- And MANY, MANY MORE!

The authors also work with a network of 350 observers throughout the nation who provide on-the-ground observations and ground truth the USDM.

Other sources of information include citizen scientists, media, government agencies, and scientific publications.

Is there a role for me?

YES! We need your observations! Regular, on-the-ground observations paired with photos, when available, are best. There are three primary ways to submit observations:

- Become a citizen scientist with the Community, Collaborative, Rain, Hail, & Snow (CoCoRaHS) Network. Volunteers collect and report precipitation or lack, and other current conditions. Learn more at http://cocorahs.org
- Contribute to a national archive of drought-related information, including impacts by submitting a report to the Drought Impact Reporter, which accepts photos! Visit http://droughtreporter.unl.edu to report not just drought, but current local conditions.
- Contact Wyoming's State Climatologist based in the Water Resources Data System and Wyoming State Climate Office at the University of Wyoming.

The USDM authors reference data and information provided in CoCoRaHS, the Drought Impact Reporter, and to state climatologists to verify and ground truth the map.

What type of impacts should I report?

You do not have to report **impacts** per se. You can report current conditions as they are. In other words, you don't have to wait to experience a **major** impact. Impacts or sector-related impacts to consider include:

- Plants and wildlife
- Agriculture
- Water supply and quality
- Recreation and tourism
- Society and public health
- Business and industry
- Relief, response, and restrictions (for example, lawn watering restrictions)

So, where do I find the USDM?

The USDM is made available by a number of partnering agencies and organizations, but it lives at the National Drought Mitigation Center's website at http://droughtmonitor.unl.edu.

Who is behind the USDM?

- U.S. Drought Mitigation Center
- USDA
- National Drought Mitigation Center
- Department of Commerce
- National Oceanic and Atmospheric Adminstration

Drought issues for small-parcel landowners

Your land and livestock health in drought

Scott Cotton

Your land, animals, property value, and stress levels will benefit from any time invested in preparation pre-drought and timely action when drought strikes.

Planning for drought and monitoring its affects when it arrives can help reduce damage. Expect reduced plant growth, less water for animals (through the plants they eat), and changes in water tables and water usage.

Several things happen to native and desirable plant communities during drought. These plants attempt to survive by reducing growth demands, shrinking roots, and, if possible, generating seed earlier than usual. Often this results in plants with reduced leaf area, reduced stability, and reduced moisture content. In addition, many species generate fewer growth points for the following year (growth points are the areas for plant growth each year).

All of these changes can generate issues for landowners. Plants that produce less leaf area dramatically reduce available forage for grazing animals and wildlife. This can drop pasture production in many areas of Wyoming from 1,800 pounds of forage per acre down to as low as 500 pounds per acre. You may not have enough land to produce enough forage to feed your livestock during drought. You may need to purchase additional feed for livestock.

Due to the decreased forage and decreased water content of that forage, livestock may not be getting as much water from their food as they did pre-drought. You may need to provide more water. Plants used for grazing can become less palatable, less digestible, and less nutritious during drought. The soil temperature and evaporation rate increases during drought (since there is not as much leaf area shading the ground). This can compound the effect of drought on your land.

The effects of drought can last into the future, even when the drought is over. Drought may cause more bare soil in pastures. This creates an opening for undesirable plants such as weeds to start growing. When plant species set fewer growth points than normal for the next growing season, there will be reduced growth even if suitable moisture is present the following year.

Animals including pets, livestock, and wildlife are all impacted by drought. On smaller land parcels, these creatures have fewer options to seek alternative water than on larger landscapes where ponds and streams may exist. Grazing animals lose a portion of their moisture intake when plants are impacted by drought requiring you to provide more water. You will need to make sure any water tanks and other sources are reliably

Planning for drought when creating new landscapes, such as selecting drought tolerant species, can be time well-invested.

providing an adequate amount of water to see animals through drought as they will be drinking more water.

Since drought conditions usually coincide with increased heat periods, the requirements for water delivery to livestock and pets can more than double. Often wildlife will sense the available water and compete with livestock for the water source you provide. This can be problematic if you are struggling just to meet the needs of your animals.

Tips to see livestock through drought:

- Make sure livestock have suitable water and dry matter intake each day.
- Do not overgraze forage resources – in fact, leave them taller than normal to provide protection and reduce potential soil erosion.
- Provide shade and wind blocks for animals.
- Place shades over water tanks to reduce evaporation.
- If you have enough land leave one segment of pasture ungrazed except in drought periods.
- Identify sources to purchase feed prior to a drought (this may be a significant distance away).
- Try to identify alternative grazing locations that could be leased while yours recovers from drought.
- Keep a sharp eye out for unknown plants and weeds that may be toxic. Livestock are more likely to consume toxic plants when other forage is not available. Pay close attention to what animals are actually eating since they may try unsafe plants in desperation.
- Do not buy or utilize "alternative" feed types without getting research-based information from the local University of Wyoming Extension office.
- If you do not have the means to get additional resources, consider working with neighbors collaboratively to lease new ground or bring in larger shipments of purchased feeds.

Landscapes and Drought

Maintaining established landscape plantings can demand significant amounts of water and labor. Drought

Grazing animals lose a portion of their moisture intake when plants are affected by drought and will require more water.

can also significantly affect ornamental plants. Planning for drought when planning out a new landscape, and/or planning changes for existing landscapes to make them more "drought tolerant," can be time well-invested.

Drought tips for landscapes:

- Establish plants that are "drought tolerant" and require lower amounts of water (including your turf choices).
- Water plants less often but more deeply than normal at times of day when evaporation is at a minimum such as early morning and late evening.
- Consider using drip irrigation on trees, shrubs, and other plants. Also consider using mulch (if you don't already) to reduce water loss from the soil.
- Erect windbreaks and partial sunshades around trees and shrubs that provide shade for part of the day so the amount of moisture loss from these plants is reduced.
- Control weeds so the plants you want won't have to compete for water.
- Erect snow fences to capture snow so it may melt in spring and drain into areas populated by desirable plants. Be sure they won't also drop snow onto places you don't want it, like your driveway.
- Consider buying a tank to haul water from a known quality water source to plants.
- Once the drought begins to lessen, carefully re-evaluate your ground and keep weeds controlled (they will start sprouting when moisture arrives).

Water Supply and Drought

During droughts, water supplies diminish in most cases - whether a municipal source, a local water distribution system, or a private well. If the drought encompasses more than one county, many watersheds will have reduced water levels resulting in restrictions on water use, irrigation, and other effects. Water yields from homeowner associations' water distribution systems will may also be reduced or restricted.

Many small landowners operate from private wells. In many western states, these are limited to 15 gallons per minute by decree. Many areas have wells with low flow rates requiring pumping to a cistern or tank to meet home, livestock, and horticulture needs. One of the most common rude awakenings for small landowners is when the flow rate of private wells diminishes during droughts.

Private wells are drilled and cased so that after a water table is found, the well casing is extended well below the water level and the pump is suspended at least 20-50 feet into the water. When the pump runs, pushing water into a delivery system, the water table in the soil surrounding the well is drawn down into a "cone of depression." Normally, the depression is shallow enough to allow the water to have a steady flow and recharge within minutes when the pumps stops. During drought periods, the "cone of depression" gets deeper and significantly wider, and the "recharge" or recovery rate of the entire well system gets dramatically longer.

The water table recharge in almost all types of wells comes from water infiltrating downward into local and regional underground water holding referred to as aquifers. The water for these aquifers sometimes comes from the local area, while others may have recharge zones hundreds of miles away. In all cases when a shortage of precipitation and/or runoff is substandard, all wells in the area of draw where the wells pull up the water will have less water to respond to use in a normal timely manner.

In short, many wells do not produce as much water after drought and affects a landscape. This reduced water source further aggravates difficulty in meeting the needs of humans, animals, and plants.

- If private wells continue to provide less water than required, they can be deepened by a well-driller or can be re-drilled at another site. Check with the State Engineers Office on guidelines for both of these actions. Average drilling costs can be expensive, so plan ahead.
- During drought periods, the well service companies will be in high demand, and you may face a waiting period. The least expensive period for well work tends to be mid-fall.

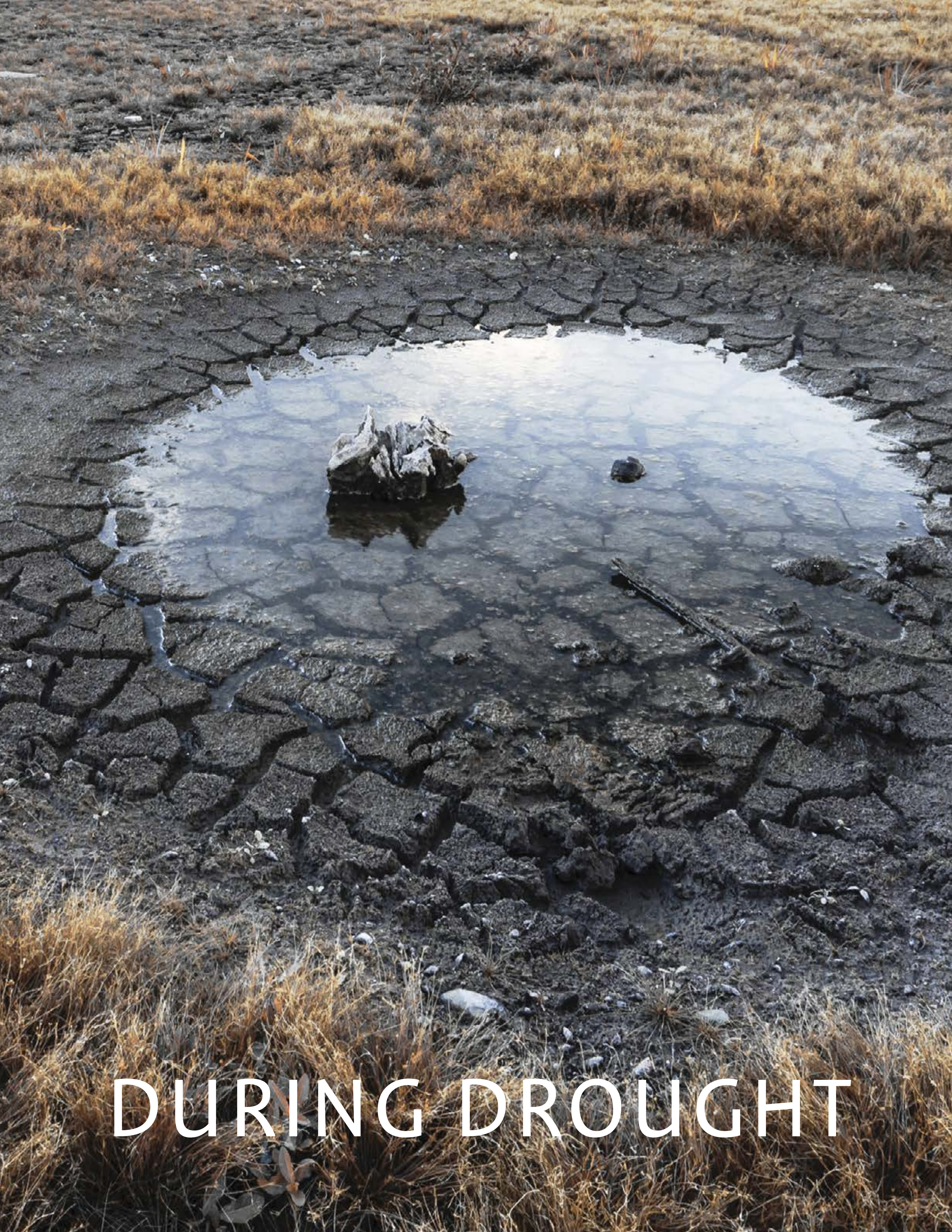
Last Tips for Drought Preparation and Timely Actions

Drought impacts can be mitigated by implementing several steps:

- Plan on having drought and create a plan that outlines your response,
- Do some research about how frequently drought conditions occur in your vicinity,
- Pay close attention to climatic conditions and adjust rapidly,
- Plant drought tolerant trees, shrubs, and grasses,
- Identify and recognize plant species you have in your pastures during non-drought periods so you can recognize changes,
- Identify resources for additional feed and water before drought arrives,
- Monitor water demands of livestock and their body condition throughout drought,
- Adjust grazing pressure so you always have one additional pasture or paddock to use during drought,
- Monitor the water table in your well, conditions of your water supply system, and total consumption. Consider reducing water use by running fewer loads of laundry, watering lawns less frequently, and not washing cars as often.

If you think about drought and plan accordingly, you will be way ahead when drought inevitably arrives. Your land, animals, property value, and stress levels will benefit from any time invested in preparation pre-drought and timely action when drought strikes.

Scott Cotton is a University of Wyoming Extension educator based in Natrona County and also serving Converse and Niobrara counties. He can be reached at (307) 235-9400 or scotton1@uwyo.edu.



DURING DROUGHT

Understanding how drought affects rangeland plants offers strategies to combat moisture shortage

Ashley Garrelts
Mae Smith
Glenn Owings
Daniel Tekiela
Blaine Horn

bit.ly/effectsandsolutions
Drought on Rangelands: Effects and Solutions

bit.ly/wyodroughtresources
Drought, Barnyards and Backyards resources

Drought affects growing plants, grazing animals, and humans that depend on the land. Management of rangeland before, during, and after drought is critical.

Recent research has improved understanding of how drought influences rangeland plants and suggests strategies to overcome the effects.

In desperate times, producers may be tempted to get what they can out of rangeland to preserve herds. Just remember, the drought may last more than one season, and the effects of one or two years of overgrazing can lead to many more years of soil erosion, decreased plant production, and weed infestations after the drought.

Shock to a Plant's System

Drought influences plants at the cellular level, affecting all biochemical and physiological processes used to make food and survive. Cell division slows, enzyme levels decline, and chlorophyll formation may cease when plants are water stressed. Transpiration and photosynthesis are also depressed, which subsequently slows shoot and leaf growth. The plant may not expend valuable resources for reproduction, so seed heads do not develop. In extreme cases, there are a reduced number of plant basal buds, which results in fewer shoots produced the following year. The plant will eventually die if this occurs over a period of years.

Plants have above and below ground components – shoots and roots. They must be able to support both through photosynthesis, transpiration, and respiration. During drought, a robust root system is important for the plant to extract what little soil moisture is present. When soil moisture is limited, shoot growth is reduced and plants have a harder time making their own food. There is less energy to support healthy, growing roots and shoots. Prolonged drought can be very damaging to the plant's ability to survive.

Grazing Effects on Plant Growth, Soil Moisture

Understanding how livestock grazing affects plant growth and soil moisture is key to making proper management decisions. Rangeland that has a diversity of plant species, optimum plant cover, and plants with robust root systems, has greater infiltration of moisture into the soil compared to rangeland that has been overgrazed or is in poor condition.

Rangeland in poor condition typically has less plant cover, more soil compaction, and less productive plant species. This can intensify drought effects like runoff and decreased soil moisture. Leaving standing forage and plant litter on the soil surface lessens these effects.

Grazing can also affect plant health. Proper grazing can increase and maintain plant health, while improper and overgrazing can lead to a decline in plant health. Most grazing livestock select the tastiest plants first. If livestock are in a pasture for long periods, they will graze the same desirable plants repeatedly, not allowing for plant recovery between grazing. They will also select grasses and forbs that are in the vegetative stage first.

Grasses grazed during the elongation phase (when plants start to send up seed heads) typically produce less forage in subsequent years. Grazing in one pasture for long time periods or grazing during the elongation phase year after year can lead to decreased forage production, less desirable plant species, and increased bare ground.

How Much to Graze?

Determining what constitutes an appropriate level of grazing for drought conditions is an art and a science. Research has shown how certain plants respond to drought and grazing pressure, but each management scenario and suite of species presents a unique challenge.

Range managers typically refer to standards of how much forage can be removed by dry weight while maintaining landscape health and plant resilience. These can be adjusted depending on things like drought conditions, period of rest, and results of monitoring. Understanding the capabilities of your soil to produce certain forage grasses and implementing a monitoring plan is a good place to start.

If rangelands are grazed during drought, managers must be careful to consider both above and below ground plant health. Stocking rates should be adjusted accordingly to ensure plants are not overgrazed, and enough residual plant material is left to maintain photosynthesis, root health, and soil cover.

Even if stocking rates are reduced, rotating livestock during grazing so plants are allowed time to recover is important. In addition, allowing grazing when plants are least susceptible to defoliation, prior to stem elongation or late in the season after plants have gone dormant, is an option that can help reduce the detrimental grazing effects during drought.

Grazing 50 Percent

A plant community can overcome drought if good grazing management is practiced by not allowing livestock to remove too much plant material; no more than 50 percent of aboveground growth. However, if overgrazing occurs and plants are weakened through excessive loss of leaves, weedy species can benefit from the reduction in these desirable plants and even increase *during* drought conditions.

The severity and timing of the drought will determine what type of grazing, if any, can occur on a particular rangeland.

- If drought is severe, plant growth is greatly limited, leaving little useable grazable forage. Completely removing livestock from the rangeland may be warranted.
- If drought occurs early in the growing season but is not severe, plant growth may be adequate for some controlled grazing.
- If drought occurs late in the growing season, grazing plants may not be affected, but soil moisture and subsequent growing season moisture and plant growth should be monitored.

Monitoring and having a plan in place for when anticipated or current forage production decreases is the best activities you can do before, during, and after drought.

Production and management strategies to maintain plant health during a drought include destocking pastures, early weaning of young livestock, stockpiling forage, purchasing harvested feeds, and leasing pastures elsewhere.

Which plan you choose will greatly depend on the type of operation, drought severity, previous management, and rangeland health.

More information on drought planning and management strategies can be found by searching for "drought" on the University of Wyoming Extension publications webpage http://www.wyoextension.org/publications/ or by speaking with your local University of Wyoming Extension educator.

Extension educators **Glenn Owings** based in Sublette County can be reached at (307) 367-4380 or at gowings@uwyo.edu, and **Blaine Horn** based in Johnson County at (307) 684-7522 or bhorn@uwyo.edu. Extension invasive plant specialist **Dan Tekiela** is an assistant professor in the Department of Plant Sciences and can be contacted at (307) 766-3113 or dtekiela@uwyo.edu.

Managing cropland during drought

Preparation, using sustainable practices that build soil and crop resiliency most valuable tools in crop drought management

Carrie Eberle

Drought can affect a crop in many ways. Timing can impact germination, stand establishment, yield potential, nutrient availability, and other factors.

Different crops have different tolerances to drought conditions and different critical periods where lack of adequate water is the most detrimental to yield.

Preparation and using sustainable practices that help build soil and crop resiliency are the most valuable tools in crop drought management.

But once in the middle of a drought, there are still steps to help manage drought-affected crops.

Drought during flowering and seed filling can often be the most detrimental to seed crop yield. For non-seed crops like alfalfa and sugarbeets, drought stress early can be more critical than later in the season. If crops are under irrigation, managing irrigation by watering crops at critical stages will give the most return on investment and ensure water is going where most needed.

Using No-Till to Minimize Extreme Weather Impacts
bit.ly/wyonotill

Under more severe drought, consider only irrigating crops that are under ideal field conditions, where there is good water infiltration to reduce runoff waste, high organic matter to hold water, and high crop residue to prevent evaporation.

Different crops have different water use requirements. We typically think of crops like sunflower and winter grain crops as more drought tolerant. This is in large part due to their ability to access water deeper in the soil profile than other crops. So while these crops may perform better during drought, they also will leave your soil drier and slow drought recovery. Knowing how much water your crop uses will help identify its impact on soil moisture in drought situations.

Crop management in drought
bit.ly/unlcropwatch

Weed Control

Weed management becomes increasingly more difficult and important as weeds compete for precious water. Keeping fields weed-free will help ensure your limited water goes to crops. There are a few different considerations for weed control during drought.

First, pre-emergent herbicides need to be incorporated into soil (by rain or irrigation) as soon after application as possible for activation. Save money and do not apply these during a drought if there is no irrigation for incorporation.

Second, weeds growing under drought conditions typically will have a thicker, waxy

cuticle covering their leaves than normal, to help conserve moisture. This thick cuticle makes foliar herbicides less efficient. Using surfactants and higher application rates (within label limits) can counteract the effect; however, crops also become more susceptible to herbicide damage under drought conditions, so careful management of herbicides is needed.

Third, herbicide carryover can increase under drought. Moisture is one of the factors affecting the breakdown of chemical herbicides in the soil. Under drought, residual herbicide effects can last longer than what is on the label. Rotation care needs to be considered.

Tillage can be used for weed control but is best avoided during drought due to increased water loss through evaporation. Tillage exposes more soil surface to the air, increases water evaporation, and reduces surface residues, which protect soil water from evaporation. If you must, use implements like sweeps and rod weeders that minimally disturb the soil surface and retain higher residue than more aggressive tillage operations.

Nitrates and Feed

Nitrate accumulation is a major issue with drought-stressed crops. This is especially problematic in animal feed, such as silage corn. Extra care is needed when harvesting corn for silage. High nitrates can be toxic to animals making it imperative to analyze silage for nitrate concentration and blend appropriately with other feed to keep nitrate levels within acceptable ranges. Cutting silage corn higher, 10-12 inches, can also help reduce nitrates in feed. This method will also leave taller stubble to help catch snow. For more information on nitrates in forages, see Chapter 6: Nitrate and Nitrites of UW Bulletin B-1183 (bit.ly/nitratesforages).

The decision to harvest a crop for hay/silage or grain can also impact the following year's crop, especially if the drought is expected to continue. Cutting a crop for feed leaves little stubble and residue on the soil surface, which leaves the soils even more susceptible to evaporation, further reducing soil moisture. Depending on your situation, harvesting a crop for grain may provide more economic value than just the grain but also in water saving for the next season's crop. If you need to cut the crop for feed, consider leaving one-third to one-half of the crop standing to help catch snow, retain residue, and prevent evaporation.

Before adjusting your crop use plan, be sure to work with your approved insurance provider to ensure you manage and record drought effects appropriately so the opportunity for any claims is not lost.

Carrie Eberle is the University of Wyoming Extension agronomy and cropping systems specialist. She can be reached at (307) 837-2000 or at carrie.eberle@uwyo.edu.

Resources

Cropwatch.unl.edu/crop-management-drought

Colorado State University Extension. *Crop Water Use and Growth Stages*. Fact Sheet No. 4.715.

University of Wyoming Extension. *Crop selection for supplemental and emergency forage*. Bulletin B-1122.1

Water Management for Sugarbeet and Dry Bean. UNL.

Drought Management on Cropland Fields. USDA ARS

I didn’t anticipate a drought; things are tough; what do I do now?

John Hewlett

Figure 1. Risk comes from the uncertainty. Outcomes can be positive, negative, or neutral. The fact that we don’t know is what makes it challenging.

Drought isn’t the only challenge that can catch agricultural operations managers by surprise.

But when it looms heavy on the horizon, decision makers should carefully evaluate their strategies:

- Forage management,
- Livestock management,
- Cropping; and perhaps most importantly,
- Risk management.

These strategies often must be readjusted mid-stride in response to changing conditions. Many times the choices, adjustments, and refinements must be made with little or no time to consider or evaluate, let alone collect more information that might help make the best option clearer.

For those who have yet to cut their teeth managing such trials offered by the school of hard knocks, evaluating the management alternatives and making meaningful comparisons, let alone considering the possible risks involved, can be overwhelming.

Evaluating Possible Reponses

One of the first steps is considering how the business defines success for any selected strategy. Some managers are content to simply survive the current operating year. Others look for not just survival but success in the face of the current challenge across multiple years of operation. Still others take a more long-term or strategic view and consider how success over the next year can position the business for success in subsequent years or across the entire operation.

These last two approaches imply management has developed strategic goals. These types of goals can serve as a useful yardstick for measuring progress year-by-year. Success is not so clear without them.

Where management is focused on the performance of an individual resource (forage, livestock, financial) or enterprise, evaluating the success of one strategy or another is difficult. For example, a number of management strategies can increase calf weaning weights. Higher weaning weights clearly result in higher revenues and that may look like success; however, higher revenues do not necessarily result in higher net incomes. If higher costs are incurred in reaching those higher weaning weights, then net incomes may be even lower than when following an alternative, lower-cost approach. A similar case can be made for most crops. The question a manager must answer is, “How do we define success for this resource or enterprise?”

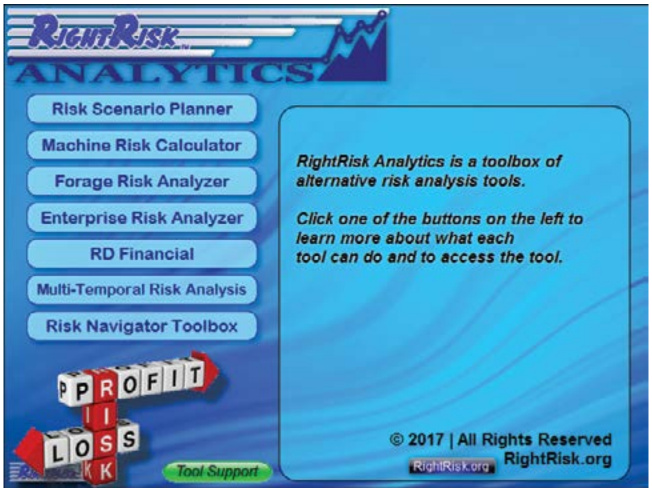


Figure 2 RightRisk Analytics Toolbox available at RightRisk.org

Comparing management strategies is difficult without a clear understanding of what success looks like for a particular resource area or for a specific enterprise. Most comparisons consider resources used versus benefits gained or the financial tradeoffs; however, other measures are also available. Which measure of performance is most appropriate for the situation at hand depends on management's perspective on risk and the strategies selected for managing risk across the business as a whole.

Compare Available Strategies

Comparing the available alternative strategies is the next step to selecting a response. These comparisons can be based on changes to estimated net income, measures of income variability (risk), value at risk, likelihood measures, and many others. Recognizing that the various responses can be measured in qualitative and quantitative terms is important. Comparing strategies is one of the biggest challenges any business manager faces, whether or not drought is on the horizon.

RightRisk has developed a Risk Analytics site loaded with budgeting and risk analytics tools to assist users to compare management alternatives. These tools help managers properly account for the risk within the management decisions they face. The Risk Scenario Planner Tool (RSP) specifically helps producers take into account a wide range of values when considering a change or decision. The RSP tool can help a producer quantify the risk associated with a particular decision or management change and provides results showing a probability distribution based on the variables entered. The tool contains a user guide to help start the process, as well as several crop and livestock examples to demonstrate how the tool works.

Using the RSP tool can help managers evaluate the benefits and costs associated with various drought responses. The tool allows users to consider the range of possible outcomes from strategies for buying and feeding hay, selling calves early, or supplementing cows where the results vary by changes in weaning weights, cost of gain, or expected price received.

Bell Livestock*

Bell Livestock has an extensive forage base of 8,670 acres of owned rangeland, 1,200 acres of hay meadows (irrigated and dryland), and 13,800 acres of public land leases. The Bells run 300 cow-calf pairs and retain ownership of their steer calves. Rainfall in recent years has been unusually good in Carbon County where the Bells are headquartered. The threat of drought in southern Wyoming, however, was starting to weigh on the Bells, especially as livestock prices seemed to be declining. They really couldn't afford many revenue reductions given higher input prices. The Bells had previously relied on Non-insured Crop Disaster Assistance (NAP) coverage to protect their operation from forage loss, but they recently heard about a program called Pasture, Rangeland, Forage (RI-PRF) insurance based on a rainfall index. The Bells are seriously considering whether this product might offer the protection for which they are looking.

The Bells investigated the information available from the Risk Management Agency (RMA) website covering RI-PRF, including the online Decision Support Tools; however, they were still unclear whether this type of insurance would work for them.

They were able to evaluate the product further using the Risk Scenario Planning tool. Entering the relevant information for their ranch from 1948 forward using data supplied by the RMA Decision Support Tool, the Bells learned from the RSP analysis that (Figure 3):

- About one-third of the time they could expect to receive an indemnity payment greater than zero ($0)

** Bell Livestock is a case study example created to demonstrate RightRisk tools and their applications. No identification with actual persons (living or deceased), places, or agricultural operation is intended nor should be inferred.*

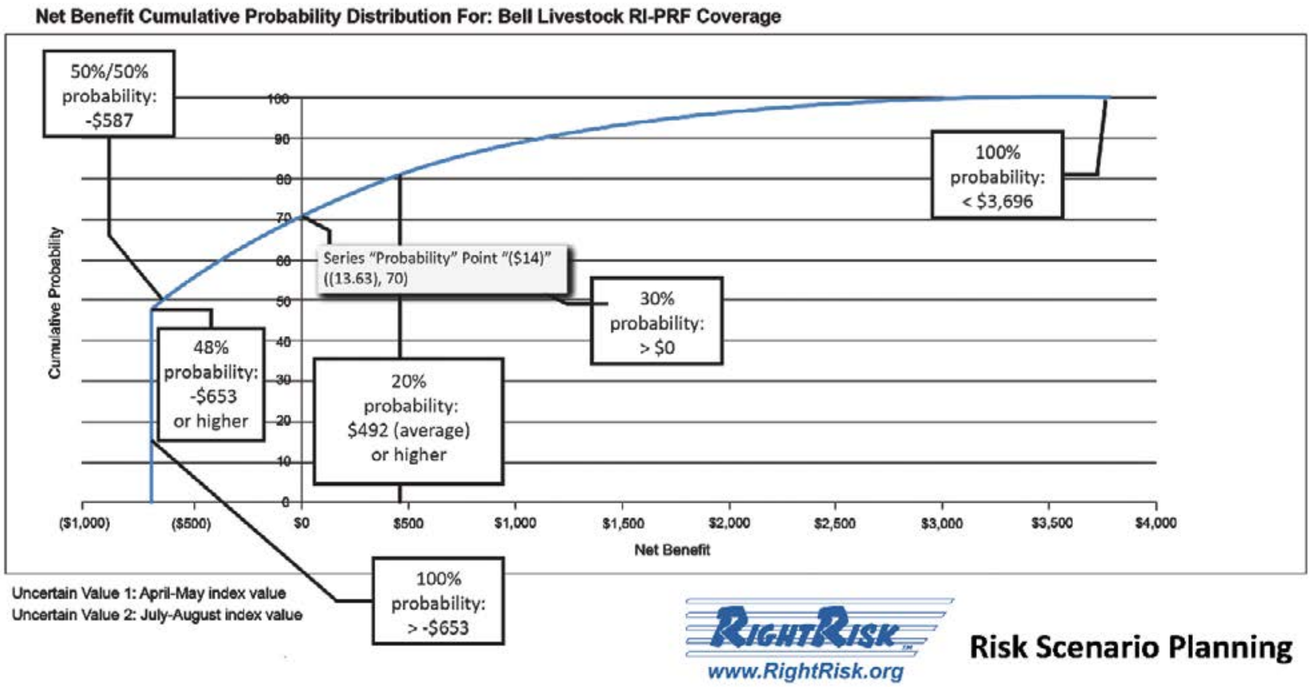


Figure 3. Risk Scenario Planning Tool Probability Distribution Describing the Dollar-Value of Possible Outcomes and Their Probabilities for Bell Livestock RI-PRF Coverage

for one example area of the ranch (Grid Id: 25291);

- Indemnity payments would likely not ever be higher than $3,696;
- The average return from the estimated indemnity payments was estimated at $636; they should expect payments at or above the average 21 percent of the time;
- About two-thirds of the time the Bells should expect their annual cost would equal the cost of the premium ($857/year) and no higher; and
- The RI-PRF policy would pay an indemnity of some amount about 48 percent of the time, softening the blow of reduced forage due to covered causes.

The Bells understand other combinations of coverage and on other grids may yield different results. Further RSP analysis may help better identify coverage levels and times of the year at greater risk for forage loss, higher payments, or better protection.

For more information about Bell Livestock and the analysis they completed, see the Risk Scenario Planning course at RightRisk.org > Courses > Risk Scenario Planning > Topics > Bell Livestock.

Summary

Production agriculture is inherently uncertain, and success rides on a mix of uncontrollable variables, such as weather, falling prices, and rising input costs. For these reasons and others, a comprehensive risk management strategy is imperative.

Perhaps just as important are tools and techniques for evaluating management alternatives and possible outcomes as those strategies are carried out. The risk analytics tools, online courses, and other resources available from RightRisk are free any time of day or night at RightRisk.org.

For more information from the Risk Management Agency, see http://www.rma.usda.gov For more information from the Farm Service Agency, see http://www.fsa.usda.gov For more information from RightRisk on risk and risk management in agriculture, see http://RightRisk.org.

John Hewlett is the ranch/farm management extension specialist in the University of Wyoming – Department of Agricultural and Applied Economics

RightRisk helps decision-makers throughout the world discover innovative and effective risk management solutions. RightRisk.org

Not just agriculture – drought collides with state's wonderful recreation

Glenn Owings

Drought can affect your daily routine and way of life whether relying on water resources to take care of lawns, grow crops, produce livestock, or recreate.

Many Wyoming residents enjoy living here because of the fantastic recreational opportunities. These opportunities also drive economics in the state, attracting visitors from across the world. In 2016, visitors to Wyoming spent $3.2 billion (generating $170 million in tax revenue) and supported the 31,500 tourism-based jobs local communities rely upon.

Drought can significantly affect recreation in Wyoming in aquatic and terrestrial environments. It also affects people who enjoy recreating in the state for sport and fun and individuals and businesses that rely on income from recreation activities.

Aquatic Environments

Consistent water levels and cool water temperatures are important for recreational water use in much of the state. Many sport and non-sport fish rely on cold water temperatures to survive. Drought reduces water depth in reservoirs and lakes during hot times of the year. Rising air temperatures in the spring and summer cause snow to melt at high elevations. With decreased amounts of cold water from snow melt, water temperatures rise, and streams and rivers can be reduced to a trickle. Some waterways may become too low to safely navigate.

Recreationists need to be aware of water quality for health reasons, and quality can decrease when water levels are low during drought years. *Escherichia coli* (*E. coli*) and other pathogen levels can rise in these water bodies. With less water in the system, bacteria are more likely to be stirred up and represent a higher percentage of solids suspended in the water column. Drought-affected water bodies tend to have less water moving through them (more stagnant). This can increase pathogen growth. Levels above the state and EPA recommended "colony forming units" of *E. coli* may result in closures of recreational water bodies due to unsafe conditions.

Anglers are often concerned during drought years because cold water trout fisheries become far less productive. Think of stream water depth as the layers of a cake. When there is sufficient streamflow, fish can find a depth and location that balances feeding and temperature regulation needs. As the water warms, temperatures in upper layers become more homogeneous, causing fish to seek even deeper areas. A fisherman may be paying for a guided trip to watch a trout rise to take his fly, but survival instincts keep fish from venturing off of the bottom of a deep hole.

Simply through observation, a person can often tell which streams or stream reaches might be most susceptible to drought. Research has shown that, even more than shade from vegetation, stream shape influences water temperature dynamics. Wide, shallow streams and rivers are more susceptible to heating (more of the water is spread out on the surface of the stream where the sun can heat it more easily). Narrow, deep stream channels have a higher volume-to-surface area ratio, which causes them to remain cooler longer.

Many boaters and fisherman recreate on reservoirs, and prolonged drought reduces reservoir storage. Managers may wish to release more water into downstream systems, but might not be able to due to low water stores. This affects fishing and boating opportunities on the reservoir itself and river systems lower in elevation. Just like moving water, lakes and reservoirs become warmer when low. Algae and invasive microorganisms often thrive in this environment.

Terrestrial

Land-based recreation is affected just as drought affects aquatic leisure activities. One example is the far-reaching impact of wildfire, which is directly linked to dry summer conditions. Hiking, mountain biking, trail running, hunting, and other outdoor activities may be banned in areas in and around active wildfires.

Drought can also affect wildlife viewing and hunting opportunities through the availability of forage. Wildlife viewers, tourists, and hunters come to Wyoming to experience our abundant wildlife resources. We know most wildlife species like deer, elk, and antelope have periods of nutritional deficit and abundance. Since females have a disproportionately strong influence on population growth or reduction, their ability to find nutritious forage at key times is very important. The abundance of that feed is directly related to the timing and amount of rain and snow that falls. Precipitation also influences leader growth on shrubs, which are a key big game food source at certain times of year.

Energy demands peak as deer, elk, and other ungulates give birth and begin producing milk for their young. During this time, usually May and June, they rely heavily on nutrient-dense, fresh spring growth. As the summer progresses and fawns and calves begin foraging, all age classes must rebuild fat stores to survive the winter and be ready to give birth again the following spring. In severe drought conditions, lower pregnancy and birth rates can arise due to insufficient energy stores.

Drought intrudes not only into production agriculture but how we recreate.

Although drought has many negative effects for those interested in wildlife-based recreation, there are some positive effects. In winter and spring drought conditions, survival of young and weaker wildlife can be higher due to less stress caused by soaking cold rains and snowstorms – lower snow levels often mean less time spent pawing for dried grasses and forbs beneath the snow. Less snow means risky driving conditions are minimized during winter travel, and wildlife are less likely to concentrate around roads and buildings.

However you choose to recreate in Wyoming, understanding some of the impacts of drought on recreation may help you plan your next trip. Watching precipitation and water flow charts to see how conditions are looking compared to average can help you understand what to expect.

Call local natural resource professionals if interested in their assessments of drought conditions or effects for the current year. Refer to the remainder of this publication and contact your local University of Wyoming Extension office to learn more about how drought can alter the landscape and how people use it.

Glen Owings is a UW Extension rangeland educator and can be reached at (307) 367-4380 or at gowings@uwyo.edu.


AFTER THE DROUGHT

Rangeland management AFTER precipitation near more-normal

Ashley Garrelts
Mae Smith
Glenn Owings
Daniel Tekiela
Blaine Horn,
University of
Wyoming Extension

Drought to a rangeland manager is typically any period of deficit moisture that affects plant growth and health.

Some droughts can last one year, others may last 10 years or more. A period of below-normal rainfall does not necessarily result in drought conditions; it depends on the timing of that precipitation deficit.

An increase in precipitation over time will provide some drought relief, but the amount of relief can vary greatly. Think of one single rain event as a single dosage of medicine – it may alleviate the symptoms of illness, but it typically will take a prolonged dosage of medication to cure the illness.

Severity, Length, Rangeland Condition

How one responds to drought will depend on the severity, length, and the rangeland condition prior to drought.

Rangeland plants evolved under variable precipitation and have been surviving droughts for millions of years.

Rangeland condition describes the current status of rangeland vegetation as compared to a reference community. Typically, rangeland condition is measured as a percent of climax vegetation or the vegetation species composition that has reached a steady state through ecological succession – in other words, the species that have been best adapted to survive the average conditions (soil type, climate, etc.) of the site.

Plant health prior to drought is one of the greatest factors in determining impacts of drought on rangeland function and recovery time. Rangelands in fair to poor condition are more adversely affected, and recovery is slower than rangeland in good to excellent condition.

Table 1: Range condition classes used by the Quantitative Climax Method (global rangelands.org)

Range Condition Class	Percent of Climax
Excellent	76-100
Good	51-75
Fair	26-50
Poor	0-25

Plant response after drought
bit.ly/plantresponse

Grass growth stages and grazing impacts
bit.ly/wyograssgrowth

Rangeland in good health heading into a drought recovers faster once the drought breaks.

Healthy rangelands in good to excellent condition typically have a higher diversity of plants including native perennial grasses, forbs, and even shrubs depending on the range site, and few, if any, undesirable species. Diverse plant communities often vary in their active period of growth and rooting depths, increasing the opportunity for plant communities to survive drought. Higher classes of range condition lessens soil erosion potential, which improves the ability of rangelands to retain soil moisture.

Robust Pre-drought Health Boosts Recovery

Individual plant health is as important as the plant community. When drought conditions have abated, plants that went into drought healthy are better able to use available nutrients once growing conditions improve. Their root systems, while diminished, are healthier than those in poor condition prior to drought. They are able to respond quickly to an increase in soil moisture.

Individual plant health and plant community condition before and after drought should be foremost as you determine actions following drought. Before grazing, determine how much forage is available and how the timing of grazing will affect grasses. It may take a couple of years before you are able to graze at what is considered full capacity. If drought was minor and/or rangeland was in good condition prior to drought, some light, initial grazing and weed control may be all that is needed to maintain that robust plant community.

A more active weed control program may be needed if rangeland was in poor condition and/or the drought was severe. Weedy species can establish in degraded landscapes due to drought far better and quicker than the native plant community. Weedy species that were suppressed when the plant community was healthy may still exist in the seedbank and may take advantage of the poor conditions to establish and outcompete desirable vegetation. Being able to identify weedy species and actively monitoring range after drought is a crucial first step to reestablishing healthy vegetation.

If weeds are left to spread, the time and cost to seed desirable vegetation will likely be greatly increased.

To Seed or not to Seed

Once weeds are under control, or as part of a weed control plan, you may decide rangeland seeding is needed. Goals for seeding rangeland are as diverse as the ranchers and rangelands. Weed competition, increased plant diversity, improved forage quality, increased structural diversity for wildlife, soil stabilization, and reclamation are just a few examples. Reseeding information and considerations can be found at the University of Wyoming Extension website by using the key word "reclamation" under the publications section.

Establish goals before seeding – you must know where you want to go before you can get there.

- Select seeds of plant species well-suited to the site and your goals. Knowing soil type and annual precipitation, as well as pasture use, is a must for selecting seeds.
- Certified seed should be used whenever possible. This means seeds are pure in genetics, uniform in cultivar identity, and run less risk of weed contamination. Read the label; all packaged seeds sold

commercially are required to have one by state and federal law.

- Dormant seeding of rangeland grasses is most successful when seeds are sown in late fall or winter when soil temperatures remain too low for germination. Seeding during this time allows those seeds to make the most of winter and spring moisture when soil temperatures are warm enough for germination in the spring.
- Late-summer seeding is not recommended unless supplemental moisture is available from stored soil moisture or irrigation.
- The seedbed should be firm and moist, free from weeds and large debris if possible. Good soil-to-seed contact is necessary for successful establishment. Seeds can dry out or be consumed by birds and rodents if sitting on top of dead plant material; however, do not remove all the dead plant material. There should be a moderate amount of mulch or soil surface or plant residue to protect from erosion and maintain nutrient cycling.

There are two methods for seeding – broadcast and drilled. Broadcast seeding is easier, especially on rough terrain but usually has lower success. To improve success, consider dragging something like a harrow over the site to roughen the soil surface. This provides opportunities for seeds to make contact with the soil.

Using a drill increases success because of better seed-to-soil contact, and they are designed to work around small obstacles such as rocks. Calculating the correct seeding rate is important. Rates depend on purity of the seed source, germination rate, and seed size.

Contact your local University of Wyoming Extension office for more information about rangeland management after drought. They have the necessary resources and will be able to help assess your rangeland health.

University of Wyoming Extension educators **Glenn Owings** is based in Sublette County and can be reached at (307) 367-4380 or at gowings@uwyo.edu, and **Blaine Horn** is based in Johnson County and can be contacted at (307) 684-7522 or bhorn@uwyo.edu. Extension invasive plant specialist **Dan Tekiela** is an assistant professor in the Department of Plant Sciences and can be reached at (307) 766-3113 or dtekiela@uwyo.edu.

PROACTIVE, NOT REACTIVE

Drought is sure to return, so a proactive approach is important for long-term success.

- Proper management of rangelands after drought is key to maintaining healthy and robust plant communities.
- Grazing practices that promote plant health and soil stability are especially important as plants rebound from a period of tough environmental conditions.
- Management practices will vary greatly depending on severity and length of drought and health of plant communities prior to drought.
- Assessing the health of rangeland, the quantity and quality of forage available, and extended weather forecasts are needed to determine those management actions.

Agronomic challenges post-drought

Challenges, considerations and strategies for addressing post-drought concerns

Caleb Carter

Seeing rain return and temperatures moderate is always a relief whether the drought lasts one growing season or several years. With this come visions of yield improvements and a return to more normal agronomic practices.

But despite this optimism, there are still challenges coming out of drought. These include carryover effects of the drought and include potential increases in pest and disease issues, herbicide carryover, weed management challenges, and soil fertility concerns. Thinking more long-term, diversification and sustainable practices may help ease drought effects.

Increased Pest and Disease Issues

Weather patterns can have a big effect on diseases and pests, and stressed plants can be more susceptible to both.

Being cold-blooded, many insects respond to hot, dry conditions by speeding up their life cycle process. This can lead to more insects, and set up producers' fields for a higher infestation the following year. Regular and early scouting is crucial to staying ahead of insect populations, especially following drought conditions, depending upon how they overwinter.

Many diseases can also increase with drought conditions. Many pests and diseases can overwinter in crop residue or in the soil, and cause more damage the following year, even when drought conditions may have abated.

Herbicide Carryover

Herbicide carryover is another concern with a decrease in moisture following a drought year, especially in Wyoming's arid, low organic matter soils. The rotational restrictions listed on the label may not be accurate under hot, dry conditions – herbicides might persist longer than anticipated and potentially cause issues with subsequent crop rotations.

Factors that can affect herbicide carryover include:

1. Chemical half-life
2. Rate of herbicide application
3. Application date
4. Soil characteristics (texture, organic matter, pH)

An aggressive weed plan following drought can help prevent weeds from shading out crops and decreasing yields.

5. Rainfall or irrigations (total amount and distribution throughout year)
6. Sensitivity of rotational crop
7. Growing conditions following planting next spring

Maintaining regular irrigation can alleviate much of this concern. But when irrigation water is limited or in dryland production, herbicide carryover following drought can be a big concern.

Looking at the list, the crop planted is the only factor a producer has control over after the fact. Carefully choose a crop that will not be affected by potential, unanticipated herbicide carryover. Be sure to not only look at replant restrictions on the label, but also the fine print in the footnotes. This is very important in helping make an informed decision.

While soil tests for herbicides exist, they can be expensive. Another option is to perform a bioassay. Collect representative soil samples from around the field in early spring. Place the collected soil about half to 1-inch deep and plant 50 seeds of the intended crop. Moisten the soil and observe for two weeks or more, as the plants germinate and grow, for any injury.

This strategy has proven useful, but time-consuming, if done properly. It should not be a substitute to closely studying the herbicide labels. Be sure to sample areas across the field, targeting specifically suspect areas such as end rows, low organic matter, boom overlap, etc. The results should be compared to seeds grown in unaffected soil. If test results show injury or inhibited growth, then select an alternate crop.

Weed Management Challenges

Weed management is always a challenge in agricultural production; drought conditions exacerbate the problem. Stressed crops are less competitive, and stressed weeds are more difficult to kill. Hot, dry conditions reduce plant growth and may induce dormancy, reducing pesticide efficacy on weeds. Weeds that do grow often have less competition, from crops as well as other weeds.

Producers may also be reluctant to follow through on weed control during drought, when yields are down, along with the anticipated revenue. All this can dramatically increase weed seed in the soil seed bank, and in turn can lead to a flush of weeds the following year, especially with increases in precipitation.

An aggressive weed management plan should be in place following drought to help prevent weeds from shading out crops and decreasing yield potential. Burndown herbicides and pre-emergent applications can be very effective prior to planting crops. But special consideration should be taken when controlling weeds in crops that overwinter such as wheat, alfalfa, and pastures.

To give these crops a leg up coming out of winter dormancy following drought, producers should plan to hit the first flush of weeds when they are about 3 to 4 inches tall and again with a follow-up application later in the summer if necessary.

Effects on Soil Fertility

Drought also greatly affects nutrient movement in the soil. The stress on crops from drought can decrease the amount of nutrient uptake by the plants. A crop failure, after fertilizer has already been applied, can also leave excess nutrients in the soil.

In irrigated fields, mineralization of soil nitrogen from organic matter such as manures and crop residue by microbes can increase as soil temperatures rise, and soils remain moist. In the case of sprinkler irrigated fields, applications are typically an inch or less per application, and little leaching of soil nitrates will occur.

In the case of furrow irrigation, irrigation amounts are usually much larger, and much of the soil nitrate will leach below the root zone. But variability can exist, with more leaching occurring in the upper third of the field versus farther from the irrigation source. Testing soil nutrient levels following drought can be very important in determining what residual nutrients are available for the following year.

Stay Vigilant!

Even coming out of drought conditions, there are still challenges and concerns to address. Get out in the fields and scout for any carryover in pest and disease issues, read pesticide labels carefully for replant restrictions, keep weeds in check, and test the soil to best prepare for the new growing season.

Keeping these important steps in mind early and planning for them will help you be successful coming out of a drought.

Caleb Carter is a University of Wyoming Extension educator based in Goshen County and serving southeast Wyoming. Contact him at (307) 532-2436 or at ccarte13@uwyo.edu and see his blog at www.uwyoextension.org/highplainscropsite.

Drought recovery for livestock operations

Chance Marshall

Drought recovery for livestock producers is a gradual process.

A drought recovery plan is important. Livestock producers will need to determine how they will allow the land to recover from the dry spell while readjusting animal inventory to normal stocking rates. By having an action plan already in place, "weathering the storm" will be easier. Or, in this case, the lack of storms.

Following a period of prolonged drought often means overgrazed areas and/or lagging forage regrowth. Much like forming a drought management plan, a livestock producer should assess the damage to their pasture resources and livestock and then consider ways to rebuild their inventory while allowing adequate time for pasture recovery.

A livestock producer should assess the damage to their pasture resources and livestock and then consider ways to rebuild their inventory while allowing adequate time for pasture recovery.

Restoring plant vigor, especially to those species preferred and beneficial to livestock, is a primary concern. This will likely mean implementing non-use periods during the growing season to re-establish root growth and overall plant health. Pastures may never produce like they used to without adequate recovery time.

Prioritize pastures by potential to recover quickly and allow additional time for slower recovering pastures. Pastures that have been overgrazed, newly established, or contain poor soils with little irrigation potential will take longer to recover.

- If prolonged pasture rest is not an option, delay turnout a couple of weeks or increase rotation frequency to restore plant vigor.

How to take a hay sample and the importance of nitrate testing
bit.ly/haysample

Laboratories can determine nitrate levels from core samples taken by producers.

- Target-grazing early-maturing grass species (cheatgrass, crested wheatgrass, etc.) and non-toxic weeds early in the growing season combined with other forms of weed control will also help plant recovery.

Plant recovery will make possible regaining lost condition and performance in cows and/or make restocking. Beef producers can restock cattle inventory by retaining replacement heifers, purchasing bred heifers, purchasing bred cows, or a mixture of these options.

Remember that the 2-3 year-old females are not as likely to be productive in the short-term when considering replacement female options. Purchasing mature and fleshy cows may be the fastest way to restock yet also requires more upfront costs. Retaining more heifers may be a more economically attractive option, but expansion back to pre-drought inventory will be slower.

Monitor before feeding the nutrient quality of some forages harvested during drought. With some forages (cereal forages and legumes), nitrate accumulation is possible, and ruminants are susceptible to poisoning. Forages such as oat hay are known to accumulate nitrates during drought due to plant stress. Nitrates consumed by a ruminant are converted to nitrites, which impair oxygen transport from blood circulation. Many laboratories can perform a simple nitrate test on a hay sample that will indicate nitrate accumulation in the hay. In many circumstances, high nitrate hay can still be fed as long as it is properly diluted with low nitrate hay.

Chance Marshall is a University of Wyoming Extension educator based in Fremont County and also serving northwest Wyoming. He can be reached at (307) 332-2363 or at cmarsha1@uwyo.edu.

When can we expect the next drought? How will drought in the 21st century be different?

Jeff Lukas
Andrea Ray

Whether you have a cow-calf operation near Cody, raise sheep outside of Casper, grow wheat in Goshen County, or trying to keep your plantings healthy in Cheyenne, you'd like to know when the next drought will come.

And if you struggled through the severe and persistent drought conditions from 2000 to 2007, and then again in 2012 and 2013, you might be wondering if the very nature of drought is changing in Wyoming.

We've seen a clear warming trend amid the year-to-year variability in Wyoming in recent decades. The average annual temperature statewide has gone up about 2 degrees F since the 1970s.

By "next drought" we're talking about something more than a garden-variety dry period of a few or several months that affect some parts of Wyoming in most years. We're referring to a severe and persistent statewide drought, lasting at least two years, and reaching a Palmer Drought Severity Index (PDSI) below -4, or "extreme drought."

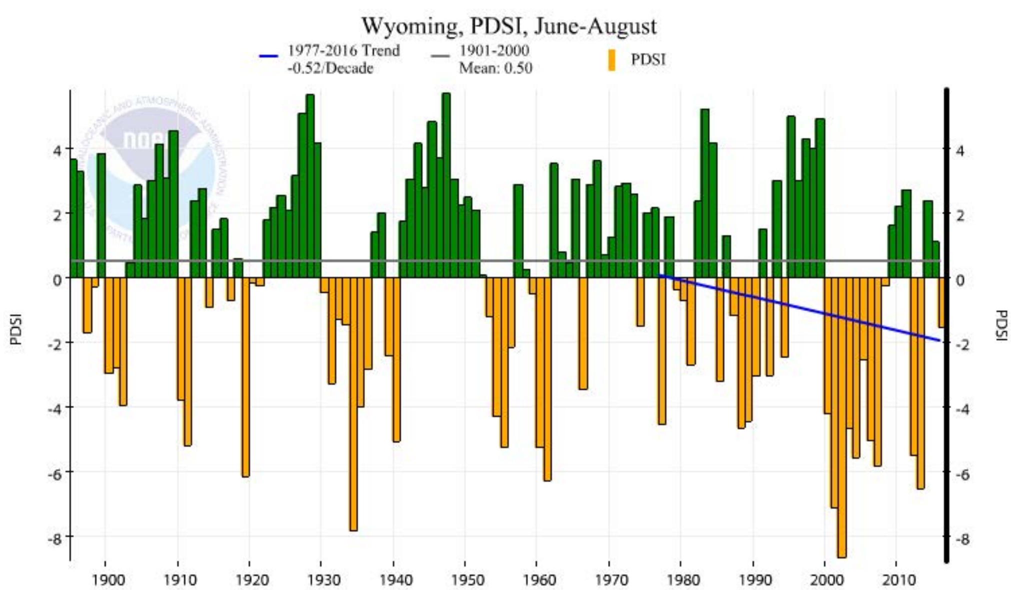


Figure 1: Wyoming Statewide Palmer Drought Severity Index (PDSI) for the June-August period from 1895-2016. PDSI captures the impact of drought on soil moisture by reflecting the contributions of precipitation and temperature. PDSI values below -2 are classified as moderate drought, below -3 as severe drought, and below -4 as extreme drought. There is a strong trend toward increasing drought severity over the past 40 years (blue line). (Source: NOAA NCEI; https://www.ncdc.noaa.gov/cag/)

U.S. Drought Monitor – Wyoming
bit.ly/wyodroughtmonitor

Ten to 15-year Cycles

There has been a severe and persistent statewide drought about every 10-15 years based on the instrumental record of drought in Wyoming since 1895 – although the gap between droughts has been as long as 25 years and as short as three (Figure 1). Unfortunately, there is no consistent cycle that would predict the next drought based on timing alone.

Can we anticipate the next drought based on other indications?

We often hear about **El Niño** and **La Niña** as having some bearing on wet and dry conditions. This is true on a West-wide basis.

El Niño, the warm phase of a 2- to 7-year oscillation ("ENSO") in the tropical Pacific Ocean, tends to lead to a split in the westerly storm tracks coming off the Pacific during fall, winter, and spring. The northern branch goes into Canada, so the Pacific Northwest down into northwestern Wyoming is generally drier than usual. The southern branch goes into the Southwest, so that parts of California, Arizona, and New Mexico, are wetter than usual.

During **La Niña**, the cold phase, the westerly storm track is not split and is often enhanced compared to normal conditions, so the Pacific Northwest is typically wetter than normal, and the Southwest is drier than normal.

Overall, El Niño and La Niña have relatively weak effects in Wyoming compared to other parts of the West. The strongest signal is in the northern third of Wyoming, which has tended to be wetter than normal during **La Niña** events, and – less consistently – drier than normal during **El Niño** events.

But while past severe droughts in Wyoming have initiated and persisted during El Niño events, they've also started during La Niña events and ENSO-neutral ("normal") conditions.

What we can say is that in northern Wyoming, especially the northwestern corner, an emerging or strengthening El Niño event is a caution flag that prompts us to watch for the upcoming fall-winter-spring turning out on the dry side.

The Pacific Decadal Oscillation (PDO) is similar to ENSO (2- to 7-year oscillation) but is centered in the northern Pacific and varies more slowly. Like ENSO, the PDO appears to have some relationship with cool-season precipitation in Wyoming – PDO may act as a long-term averaging of the effects of El Niño and La Niña. So it's not clear the phase of the PDO (cold/warm) gives us any more clues about the onset of drought in Wyoming than ENSO.

The bottom line is that **chance** is a major player in whether the storm tracks are in the right (or wrong) position to affect Wyoming, and when storm systems do arrive, whether they are big moisture producers or duds.

ENSO gives us some hint as to whether the odds are tipped to dry or wet conditions but not that much. The seasonal precipitation outlooks and seasonal drought outlooks issued by NOAA that depict a three-month period from one to several months have shown limited success in Wyoming and only during the cool season (November-March). The success is mainly based on that weak ENSO signal.

Future Wyoming Climates will be Warmer, Drier

While we don't know exactly – or even roughly – when the next drought will come, we can say the next severe drought of the 21st century will *feel* drier than if it had occurred during the 20th century. The reason is the climate of Wyoming is warming and will almost certainly get even warmer over the next several decades.

Drought years are typically warmer than average, in part because the same weather patterns associated with low precipitation (high pressure and sunny, cloudless skies) bring warmer temperatures, and in part because once soils dry out, the sun's energy can go into heating the ground and the air above, instead of into evaporating soil moisture.

We've seen a clear warming trend amid the year-to-year variability in Wyoming in recent decades. The average annual temperature statewide has gone up about 2 degrees F since the 1970s (Figure 2). The warmest calendar year on record in Wyoming was 2012, just beating out 1934 – both of these years, of course, were extremely dry, so the unusual warmth was to some degree expected.

But the third and fourth warmest years are 2015 and 2016, which had slightly-above-normal precipitation.

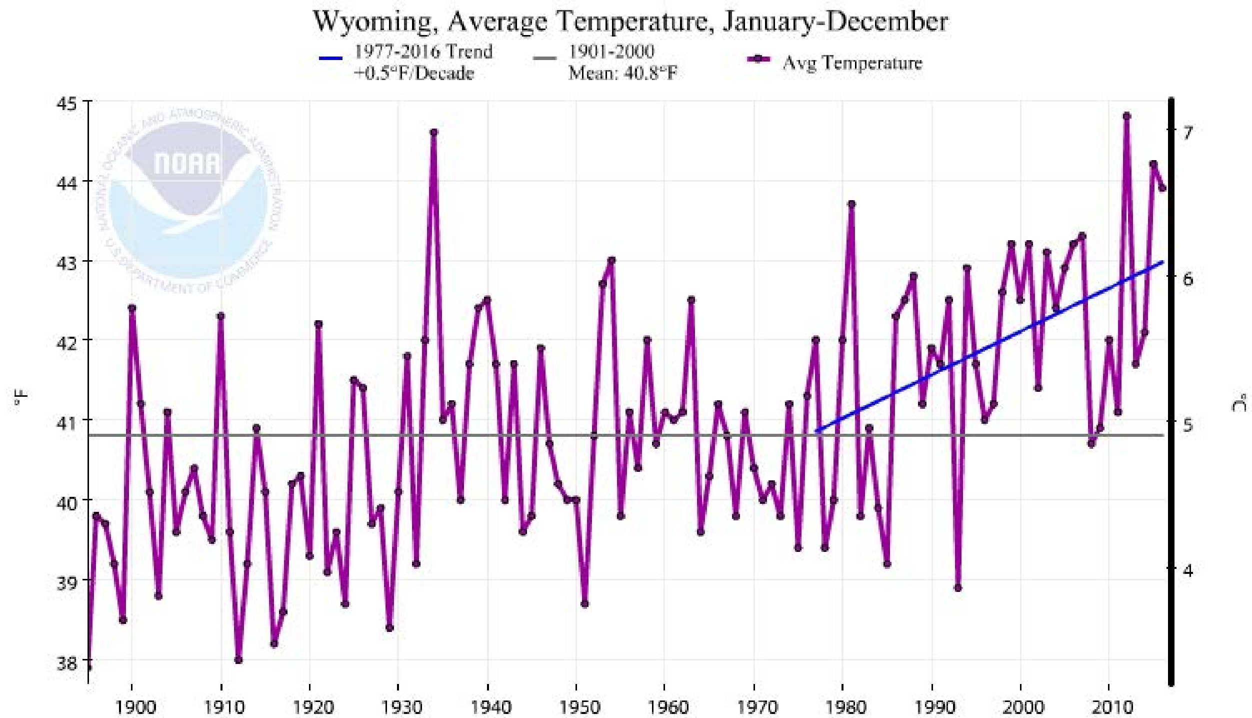


Figure 2: Wyoming statewide annual (January-December) average temperature, from 1895-2016. While there is substantial year-to-year variability, there has been a strong warming trend (blue line) over the past 40 years. The very warmest years tend also to be extremely dry years, like 1934, 1981, and 2012, but since the 1980s even some wetter than normal years, like 2015 and 2016, have been very warm. (Source: NOAA NCEI; https://www.ncdc.noaa.gov/cag/)

This tells us the recent warming trend is not just because Wyoming has had more than its share of dry years since 2000; the non-drought years are getting warmer, too.

A warmer atmosphere can hold more moisture, so it is also a thirstier atmosphere. We experience this each year with the seasonal cycle – evaporation rates are much higher in summer than in the other seasons. By the same token, if the annual average temperatures go up by 2 degrees F, then the evaporative demand of the atmosphere also increases – slightly but measurably.

When a dry year occurs in an overall warmer climate, it will *feel* even drier – to the soils, forest and range vegetation, crops, animals, and people. And so the indicators of drought severity, like spring snowpack, fuel moisture, summer soil moisture, and annual streamflow, will tend to be even lower than one would expect from past drought years.

The role of warmer temperatures in exacerbating drought is reflected in the Palmer Drought Severity Index shown in Figure 1. There is a strong downward trend, toward more negative PDSI values (= more drought) since 1977, even though the trend in water-year (October-September) statewide precipitation since 1977 is only slightly downward.

So it is the **warming temperatures**, not below-average precipitation, which is driving most of the recent downward trend in PDSI and contributed to those persistent drought conditions from 2000-2007 and again in 2012-2013.

Roughly speaking, in terms of the overall drying effect on the water cycle, a 1-degree F increase in temperature is like a 2-3 percent decrease in precipitation. The 2-degree warming in Wyoming in the last 30 to 40 years is equivalent to about a 5-percent reduction in precipitation. For comparison, in an extremely dry year like 2012, annual precipitation is about 75 percent of normal, or a 25-percent reduction. So the effect of recent warming on drought is not that large compared to the natural year-to-year variability in precipitation – yet.

We say "yet" because the weight of scientific evi-

Projected Summer Soil Moisture through 2100, Wyoming Statewide

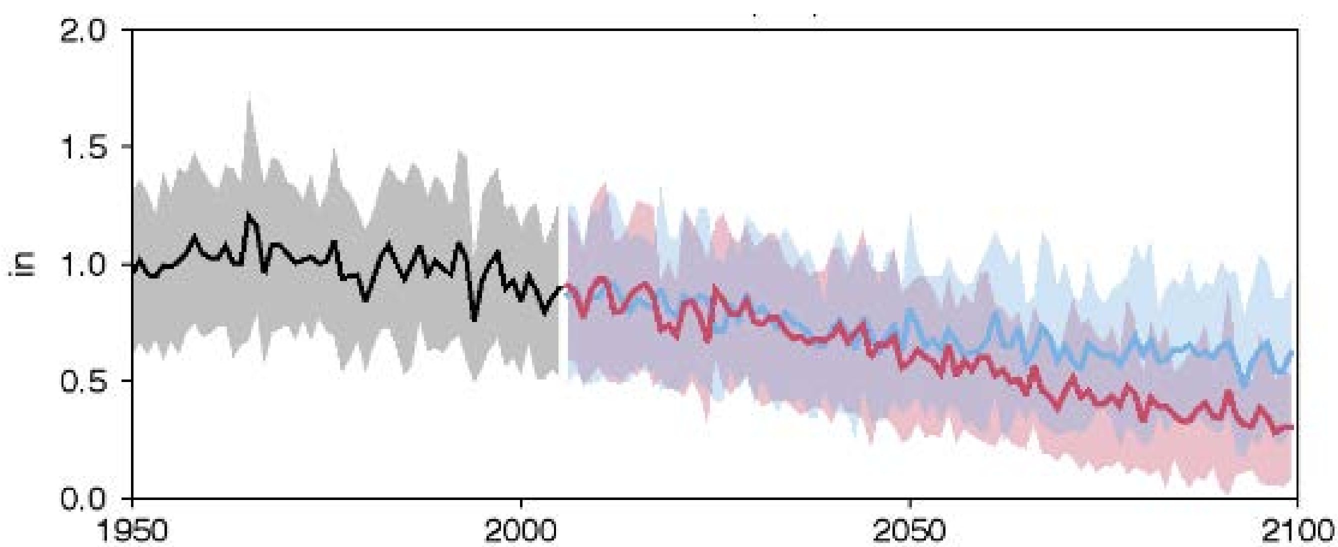


Figure 3. Projected Wyoming average statewide summer (June-August) soil moisture storage through 2100, based on 30 climate models run under a high emissions scenario (red) and under a medium-low emissions scenario (blue). The shading shows the range of projected futures, and the dark lines show the average for each emissions scenario. The gray shading and black line show modeled historical conditions. (Source: USGS National Climate Change Viewer; https://www2.usgs.gov/climate_landuse/clu_rd/nccv.asp)

dence tells us the recent warming trend will continue well into the 21st century, if not beyond. Decades of surface and satellite observations and laboratory measurements show that increasing greenhouse gases in the atmosphere trap heat that would otherwise radiate back into space, and there has been overall warming on a global average, and in most regions around the world, including the western U.S.

We get a very consistent answer when asking global climate models to project what the future climate will be: **expect more warming**. For Wyoming, this means an additional warming of about 2 to 5 degrees F by 2050, with yet more warming later in the century.

The range reflects two kinds of uncertainty: we don't know precisely how much more greenhouse gases will be emitted over the coming decades, and the actual sensitivity of the climate system to each increment of greenhouse gases is not precisely known.

The view of future precipitation is hazier than for temperature. There is disagreement among climate models about whether annual precipitation in Wyoming will go up or down, although the average of the models points to **slightly higher *annual* precipitation** for Wyoming by the mid-21st century compared to the late 20th century, especially in the **northern half** of the state.

Expect More Drought Overall

There is a more agreement among models that winter precipitation will go up, and summer precipitation will go down. We can also say the large swings in precipitation seen in the past, from wet year to dry year, will continue, and possibly get larger.

If we set aside the less-clear picture for precipitation and focus on the more certain additional warming, we **should expect more drought overall** due to the temperature increase and **additional drought effects** during dry years.

For example, a future climate 5 degrees warmer than today – which is possible by 2050 and more likely by the end of the century – would be like having 10-15 percent less precipitation in terms of the land surface moisture balance. That's about halfway to the statewide precipitation deficit in 2012. So even years with near-average precipitation would bring impacts to soil moisture, streamflows, and crop yields only seen in the "dry" years in the past.

This overall tendency toward drying can be seen in Figure 3, which shows the temperature and precipitation output of 30 climate models run under two emissions scenarios (high, and medium-low), run through a simple water-balance model to represent the average statewide summer soil moisture for Wyoming through the 21st century.

The shading shows a range of possible futures, but nearly all have summer soil moisture trending downward because of the warmer temperatures.

So the message is this: while we don't know when the next drought will come, and how bad it will be, we should be prepared for drought conditions coming more often in the 21st century and hitting harder than we saw in the 20th century.

Jeff Lukas is with Western Water Assessment at the University of Colorado, Boulder and can be contacted at (303) 735-2698.
Andrea Ray is with the NOAA's Earth System Research Physical Sciences Division in Boulder and can be reached at (303) 497-6434 or andrea.ray@noaa.gov.