Colorado Agricultural DROUGHT HANDBOOK

Acknowledgments

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This handbook draws heavily on resources including Managing Drought Risk on the Ranch from the University of Nebraska at Lincoln and the National Drought Mitigation Center, and the Guide to Co-Developing Drought Preparation Plans for Livestock Grazing on Southwest National Forests by Kelsey Hawkes et al. from the University of Arizona (See Appendix 5). We have updated and adapted the content in these guides for a Colorado agricultural context. This handbook would not exist without the model provided by these previous resources.

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About Colorado Agricultural Drought Advisors

Colorado Agricultural Drought Advisors is a network of professionals dedicated to building short- and long-term resilience in face of drought amongst Colorado agricultural producers. A collective group of producers, service providers, extension, field scientists, and other agriculture and water resource professionals, the Drought Advisors team works with farmers and ranchers to connect to resources, identify and assess risk, and implement practices that lessen the impact of drought. The vision of Drought Advisors is to remove barriers and share drought coping strategies within individual operations by working holistically and as a network in order to both secure the viability of our state's agricultural businesses and communities and to steward the health and productivity of Colorado's working landscapes.

Drought Advisors began organically with a few agricultural producers and extension specialists who came together during the 2020 drought and COVID-19 pandemic in 2020. With the dramatic dip in available in-person learning opportunities in agriculture, Drought Advisors formed to provide individual advising and a drought resource network for Colorado's agricultural producers. Since then, Drought Advisors has hosted a webinar and in-person workshop series focused on drought planning and training and created this Handbook. In addition, Drought Advisors has developed the Drought Plan Program which provides Colorado farmers and ranchers with personalized advising and financial incentives to develop and implement drought plans for their agricultural operations. This handbook is a technical resources for producers and ag-adjacent professionals to aid them in creating strategic and actionable drought plans.

Introduction

Contrast between heavy (left) and moderate stocking (right) in the mid-20th century. Photo credit: USDA ARS.

Why this Handbook

Since the turn of the 21st century, Colorado has experienced many severe droughts. With the increased frequency and persistence of drought, interest has arisen among agricultural producers and technical service providers for more comprehensive drought resources. In response to this need, this handbook was created to outline the basic steps to drought planning for use by farmers, ranchers, and technical service providers. It also includes accompanying worksheets to guide users through the planning process. We've provided climate and weather information containing critical points for decision-making relevant to both farmers and ranchers during drought. We've also included drought strategies for different production systems, along with links to resources for further information. It is our hope that this handbook will be a valuable resource for all of Colorado's diverse agricultural producers as we all continue to adapt to and learn from drought.

What is a Drought Plan?

Simply put, a drought plan is a risk management strategy for drought. Think of it as a system to integrate weather and characteristics of an agricultural operation into a decision making framework. Drought conditions can cause uncertainty and stress, which can be paralyzing. A drought plan focuses on what factors a farmer or rancher does (or can) control. It helps an individual shift from simply “hoping for rain” to taking timely action, whether or not the rain comes.

Although there are some overarching guidelines, the goals, decision points, and strategies of a drought plan must be customized to the operation and draw on the expertise of the producer. Agricultural producers are incredibly diverse, and drought impacts each operation in unique ways; thus, neither ‘easy solutions’ nor a one-size-fits-all approach are effective. This handbook provides the tools required to create a customized drought plan specific to an individual operation’s needs.

Drought planning can be intimidating, but it doesn’t have to be done alone. Support and technical expertise is available through online resources, peers, and various organizations, including Colorado Agricultural Drought Advisors, Colorado State University (CSU) Extension, Rocky Mountain Farmers Union (RMFU), the Natural Resources Conservation Service (NRCS), and others. Furthermore, a drought plan can be as simple or as complex as an individual chooses. Some producers have one-page drought plans, while others may have a longer document detailing projects that they want to implement over multiple years. This handbook is intended to be a starting place. Regardless of the length, the best drought plan is one that is developed with everyone involved in the operation, one that is written down, and– most importantly– one that the producer/operation will actually implement.

Reasons To Plan For Drought

Adapted from the National Drought Mitigation Center's Drought Management Resources (see Appendix 5)

There is considerable uncertainty regarding how the choices made in preparation or reaction to drought will play out. However, we know for certain that drought will come. Below are some reasons why ranchers and farmers should consider integrating drought planning into their broader operational plans:

Drought is inevitable

Drought is a natural part of climate in nearly every region on Earth. Colorado is no exception. Western Colorado, in particular, has experienced the driest 20-year period on record since 2000. Therefore, adapting to drier conditions is fundamental to maintaining agricultural production in the region. On the other hand, Eastern Colorado has seen both record-setting wet and dry conditions since the year 2000. Thus, considering climate extremes in management decisions is critical to minimizing the negative impact of bad years on production.

Drought planning can help make a profit

The fundamental objectives of drought management are to reduce the risk of economic loss and to minimize stress. Making a plan also helps a producer to prioritize long-term management goals and infrastructure projects. By outlining the steps required to implement a specific project, the producer can slowly invest in the materials, labor, and other necessary inputs over time. Planning for and managing drought protects an operation's bottom line. Further, it creates the opportunity for proactive– as opposed to reactive– decision making.

NDMC NATIONAL DROUGHT MITIGATION CENTER
UNIVERSITY OF NEBRASKA

"It's all that planning and understanding so that you don't have to think about it when you are in the depths of the emotion."

Shamrock Ranch, SW Nebraska

From the National Drought Mitigation Center's Resources on Writing a Drought Plan.

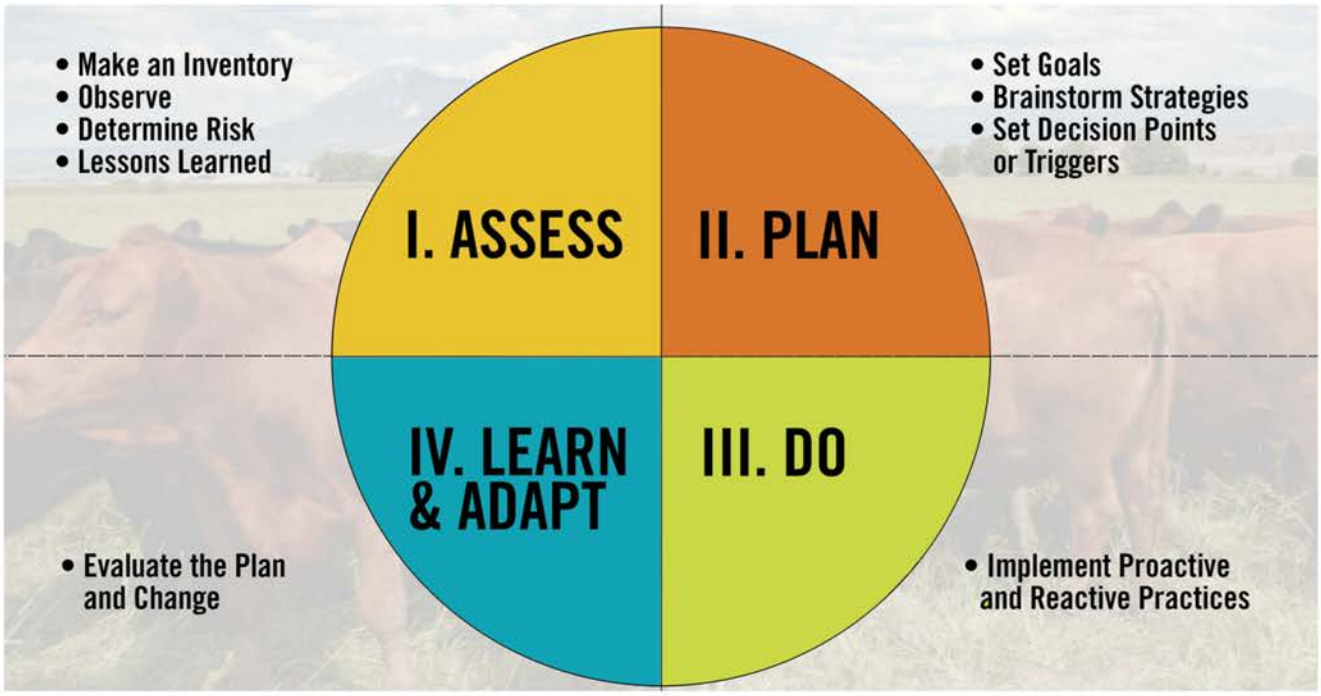
Drought planning can make operations more self-reliant and environmentally resilient

Rather than heavily relying on emergency measures and government assistance during times of drought, planning ahead to prepare for and respond to drought conditions allows producers to approach drought proactively. With the timely evaluation of alternatives and the implementation of sound drought management plans, the need for crisis decision making can be avoided. Successfully utilizing a drought plan requires viewing drought as a normal part of the environment, not as a catastrophic event. Additionally, a robust and healthy environment is most resilient to negative change and maintains consistent production. Managing well before and during drought can steward natural resources so that they continue to contribute to the long-term productivity of an agricultural system.

A drought plan can make drought less stressful and uncertain

Stress management can be one of the most overlooked yet biggest challenges to agricultural producers in a drought. However, in a 2016 study of ranchers in the Northern Great Plains, researchers found that ranchers who had a drought plan reported both decreased decision making angst and uncertainty regarding drought. Furthermore, ranchers with a plan were more likely to take critical action towards drought. They also experienced reduced harm to rangeland during drought as well as faster and healthier recovery to rangeland productivity than those without a drought plan. By identifying strategic actions and pairing them with observable conditions, a drought plan can help reduce the burden and stress of decision making when drought comes.

Making A Drought Plan



Drought planning consists of six parts:

1. assessing the operation and resources,
2. creating a plan which includes
   a. defining drought preparedness goals for the operation,
   b. determining critical points (triggers) for making decisions,
   c. identifying strategies to reduce risk,
   d. using simple scenarios to prioritize strategies,
3. implementing the plan, and finally
4. adapting the plan based on what one learned.

In the following sections, we elaborate on each element of a drought plan and include links to corresponding worksheets which may be used in the planning process.

A drought plan can take many forms. It can be as simple as a one page written document (see examples in Appendix 1 (pg.115), and Drought Plan template (pg.28) below and in Appendix 4 (pg.122)).

In addition, each section of the Making a Drought Plan chapter has worksheets associated with it. These worksheets are intended to help users brainstorm aspects of creating a plan.

Regardless of the written form, the key ingredients are defining goals, triggers, and strategies. How the plan is written down depends on what is meaningful and useful to the producer acting on the plan.

Making A Drought Plan

1. Assessing the Operation and Resources

Assessing how drought impacts all aspects of an operation can make it easier to identify what specific actions can be taken to mitigate the effects of drought. There are many ways one might approach the assessment process. We recommend beginning by looking through the Inventory Worksheet below. This worksheet may be filled out completely or used to start a brainstorming conversation amongst a management team. The Resiliency Self-Assessment may also be a helpful resource for assessing an operation's ability to manage risk in general. Whatever approach is used, the ultimate goal is to identify the operation's vulnerabilities and strengths. Once this is done, efforts can be focused on areas where there will be the most impact. Ideas for strategy and action will inevitably begin to emerge during this step of the planning process. However, it is important to keep the focus on assessment. We will build on the assessment in order to develop the remaining elements of the drought plan– including goals, triggers and strategies– in the following sections.

Assessment Questions to Consider

- How does drought impact your operation specifically?
- What challenges or opportunities have you experienced in drought?
- What are strengths and weaknesses in your operation?

1. Assessing the Operation and Resources

Identify team members before a crisis starts

Identifying the individuals who make up a producer's team is an essential step in the assessment process. Team members can play a critical role in both understanding the unique effects of drought on an operation and identifying appropriate strategies for a specific situation. This team might consist of members of the family involved in– or affected by– the farming or ranching business. Other team members could also include bankers, consultants, advisors, employees, and contract customers. If an operation utilizes leased lands, it is critical to communicate with the necessary land management partners as well. Whoever they are, identifying these relevant partners and establishing communication among them early in the drought planning process will allow potential management strategies to be evaluated from a range of perspectives. This also ensures that everyone is on the same page before proceeding to the following steps of the planning process. Sound and proactive communication can go a long way towards building flexibility when crises emerge.

Drought Inventory Worksheet

- Use the Drought Inventory Worksheet to brainstorm potential areas of vulnerability to drought, as well as strengths to build on.
- This worksheet is intended to prompt thought in various areas (not to be filled out in entirety).

Use Drought Inventory Worksheets (pg.9)

WORKSHEET #1

Drought Inventory

Consideration	Notes
General Considerations • How have previous drought years impacted your farm/ranch. • Were there any opportunities in past droughts that you took advantage of, or that you missed? • What did you manage well in past droughts?	
Weather & Climate • The historic frequency of drought • Average regional precipitation and timing (use CoAgMet or Colorado Climate Center cited in Appendix 5) • The range of annual precipitation amounts • Critical growth periods for crops, rangeland forage or hay (NRCS or Extension) • Future forecasts and expectations for your region	
Water Resources • Well capacity and ability to pump • Flow rate or storage capacity (tanks or earthen structures) • Water quality • Irrigation water availability • Probability of administrative calls on water or water deficits	
Herd Resources (if applicable) • Number and class of livestock • Value of animals, ranked by class and individual identification	

Category	Inventory
Financial Resources Consider how drought impacts: • Your business plan • The cost of production for each of your enterprises, • The riskiness of potential enterprises. • Marketing alternatives	
Human & Personnel Resources • Family member's interests and abilities • Resources for coping with stress in drought	
Soil Characteristics • Water holding capacity • Infiltration rate • Fertility • Soil moisture requirement in inches at critical periods	
Range & Forage Resources • Total average carrying capacity and forage demand by livestock • Average drought reductions in carrying capacity • Critical dates for forage production • Other feed supplies	
Crops (if applicable) • Input availability and costs (seed, fuel, fertilizer) • Dates where additional water or other inputs will not increase yield or create a return on investment • The 'salvage' point - harvesting or use the crop for something else rather than as intended	

Making A Drought Plan

2a. Defining Drought-Preparedness Goals for the Operation

Following the assessment, the next step is to consider specific drought-related goals that fit within the larger vision of a producer's operation.

It should go without saying that the overarching goal of a drought plan is to improve an agricultural operation's preparedness and resilience in the face of drought conditions. We recommend breaking this down further by setting several specific, time-bound, and attainable goals. Without specific goals, a drought plan runs the risk of being over-ambitious or lacking direction. Developing clear goals can also help producers to determine how to prioritize their time and energy.

When setting goals, here are tips to keep in mind:

- Drought related goals should be motivating, important to the producer, and focused on high priorities for an operation.
- Goals should be specific, attainable, and ideally include a time-line for accomplishment.
- Goals should be shared among relevant planning partners.
- Write the goals down. This gives them clarity and accountability, especially because wet years tend to distract from preparing for the next drought.
- Consider the timeline. Goals can be long (10+ years) or short term (1-5 years). A producer may have different goals to cope with an acute drought situation, versus long-term preparedness .
- Consider the overall mission and vision of your operation, and set drought-related goals that help you achieve the broader mission and vision.

2a. Defining Drought-Preparedness Goals for the Operation

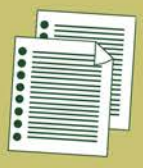
The worksheet below can be used to generate drought-specific goals. Keep in mind that goals are not the same as strategies.

Goals should specify where an operation wants to go and what they would like to achieve, whereas strategies will describe how to get there. Using the example from the worksheet, a goal might be “to build more flexibility into our operation to be able to reduce stocking rate on base property during drought by the year 2025.” There are multiple ways to achieve this goal, including changing the number and class of livestock or leasing additional acreages. To provide another example, a producer may want to add additional stock water to improve grazing flexibility. In this case, “improve flexibility” would be the goal and “develop additional stock tanks” would be a potential strategy. It can be challenging to envision goals without also beginning to think about strategies. However, this part of the planning process should focus heavily on where a producer wants to go in their operation.

Drought Goals Worksheet

- Use the Drought Goals Worksheet to brainstorm and write down goals.
- Clear goals can also help producers prioritize and stay focused amongst competing demands.
- More goals is not necessary better. We suggest limiting goals to a maximum of three.
- Blank worksheets are in Appendix 4 (pg.122).

Use Goals Worksheet (pg.13)



WORKSHEET #2

Goals for Drought Prep and Response

Think back to the first step of this planning process and the assessment of your operation. Consider what you have and where you've been. Where are you trying to go with your operation to lessen the impact of drought? How do goals to lessen the impact of drought help you achieve your overall management goals for the operation? Goals should be specific, and attainable, and ideally include a timeline for accomplishment. We've included three examples to demonstrate what a goal might look like for a ranching and crop growing operation.

Goal	Goal Description
Goal 1 *Example (ranching)*	*Reduce economic impact of drought by making our operation more flexible in drought and more able to reduce stocking rate on the base property. This goal can be reached many ways including changing the number and class of livestock, adding 'temporary' animals to the herd, or leasing additional land.*
Goal 2 *Example (wheat grower)*	*Reduce the economic impact of drought by diversifying crops and increasing acreage using conservation tillage practices, thus increasing the ability to retain soil moisture, improve soil health, and capture more economic and environmental value from existing operations.*
Goal 3 *Example (water development)*	*Reduce economic impact of drought by increasing reliability in our water supply, and extend water availability later in the season by developing additional water storage/supply by 2027.*

Worksheet adapted from: Guide to Co-Developing Drought Preparation Plans for Livestock Grazing on Southwest National Forests by Hawkes et al., 2018. Full handbook at: https://cals.arizona.edu/droughtandgrazing/

"A rain doesn't get you out of the drought the next day. If you don't set a timetable and stick to what you say you'll do, you'll say: 'Well, I saw on the news where there's a 20% chance of rain a week from Friday. So, let's wait until then.' Well, you've got to quit doing that."

- John Welch, rancher and Past-President and CEO of Spade Ranches. Welch Cattle Company is a family cow/calf operation. From the National Drought Mitigation Center's Drought Plan Examples (See Appendix 5).

Making A Drought Plan

2b. Determining Critical Points for Making Decisions

Once an operation's goals are clearly set, a producer can begin to determine "triggers" for action. Successfully managing an agricultural operation during drought requires taking actions to improve an operation's long-term preparedness and resilience. In addition to long-term planning, successful management also involves making well-informed decisions during drought to respond to current conditions (See graphic below). Knowing when to make these decisions– and feeling confident in taking action– is one of the most challenging aspects of managing during drought. Thus, a critical part of a drought plan is identifying in advance the important conditions and dates that "trigger" specific actions. In the context of drought planning, these are known as "trigger dates." Trigger dates tie calendar dates with threshold conditions and paired actions. For example, a trigger date might look like this:

If soils are dry before fall, we anticipate reduced forage production in the spring and will retail fewer replacement heifers to reduce forage demand.

Defining dates and threshold conditions

Making effective decisions during drought does not require a crystal ball when it comes to weather. Rather, it requires an understanding of when moisture is needed for crops, grasses, and resources like streamflow, and what is likely to occur when moisture is absent during those critical windows. We can leverage known relationships between factors– such as the timing of precipitation, rangeland forage production, and annual crop growth– to create reasonable conditions and dates tied to actions. For example, the success of a producer's crop choice decisions may depend upon surface water irrigation availability.

2b. Determining Critical Points for Making Decisions

For them, understanding the relationships between snowpack depth, the timing of snowmelt, and the resulting streamflow for river-dependent irrigators will help them make decisions about what crops to plant in a timely manner and feel confident they've made the best decision they can. Similarly, with rangeland forage production, understanding of forage growth curves and precipitation might help a producer make timely decisions about stocking rates. Deciding in advance when specific conditions warrant action can alleviate some of the stress and guesswork that comes with drought management. Details on critical period by crop, streamflow and forages for Colorado are included in the Critical Periods Section (pg.49) below.

Setting trigger dates can be intimidating, but they can be as technical or non-technical as a producer would like. Similar to the overall drought plan, these dates can change over time as needed to best suit the producer's needs. Worksheet 3 (pg.17) can be used to help define specific triggers for an operation.

Trigger Dates

- Trigger dates can help with proactive vs reactive decisions by leveraging known relationships between current conditions and critical cycles impacting production
- It is common to use multiple 'trigger dates' throughout the year since conditions evolve.
- Trigger dates tie specific conditions to actions (or strategies).
- Triggers leverage what one can know, rather than future uncertainty or hope that conditions will improve.
- Trigger dates can be as technical or non-technical as works for the producer. The most important thing is that they are sensitive to conditions, and that they are meaningful to the producer.
- Trigger dates are most relevant to short-term (within year) drought response.
- Trigger dates must be sensitive to your region and resource of concern. For example, soil moisture before freeze may be significant for runoff projections for west-slope producers, but not for irrigation from aquifers on the eastern plains.

"Sometimes I think it's better just to have [a critical date] than to worry about having the perfect one."

- Myra Hipke-Richardson, Nebraska Rancher

From the National Drought Mitigation Center's Drought Plan Examples (See Appendix 5).

Use Triggers Worksheet (pg.17)

Example trigger date scenario from Nebraska Extension:

April 1
Look at previous growing season precipitation and dormant season precipitation from October – March and dig some post holes to see how much moisture is in the soil profile. A lack of soil moisture in early April will impact growth from cool-season grass species such as Western Wheat and Needlegrasses.

April 15 to May 10
By this time, 30–45-day precipitation forecasts can have a moderate level of reliability. If above average temperatures with average to below average precipitation is predicted, reductions in animal forage demand should be planned.

May 20 to June 10
Needlegrasses will be completing their forage production and western wheatgrass is in its rapid growth window. If March-May precipitation was 50-75% of the long-term average, reduce forage demand 30-40% or more depending upon grass species and plant health. Warm-season grasses such as prairie sandreed and little bluestem are just starting to grow.

June 15 to June 30
More than 60% of grass growth on warm-season dominated range sites will have happened by the end of June. Rainfall after late June will impact less than 40% of grass growth.

July 1 to July 15
Precipitation and available soil moisture sets the final stage for summer grass growth.

July 15
Precipitation after this date will have limited benefit to summer grasses. While shortgrass warm-season species such as buffalograss and blue grama will green up and grow some to rains after July 15, they cannot grow enough to make up for what didn't grow earlier. ie) there is not compensatory gain in grass!

From: Managing Drought Risk on the Ranch: A Planning Guide for Great Plains Ranchers. The National Drought Mitigation Center, the University of Nebraska at Lincoln, South Dakota State University and Texas A&M Kingsville, 2014.

WORKSHEET #3, Livestock Example

Trigger Dates

This worksheet provides a framework for thinking about trigger dates on an ongoing basis throughout the year. The livestock example is adapted from the Central Plains Experimental Range and the Collaborative Adaptive Rangeland Management experiment run by USDA-ARS (see Appx 5). The Central Plains Experimental Range manages ten 320-acre pastures, with two pastures rested per year for reserve forage in drought. Because they run contracted yearlings, they have flexibility on stocking rate but these decisions must be made in April.

Drought Management Goal:
Reduce the economic impact of drought by having full grazing seasons and not having to remove cattle early due to drought. Pastures should not be grazed beyond the drought thresholds in order to avoid lasting damage to vegetation and other objectives (e.g., tall structure bird habitat).

What to Monitor & When	Target Condition	Adaptive Action
Dec - April Pacific Decadal Oscillation Status La Nina/ El Nino Status Drought Outlook Winter precip relative to long-term average current soil moisture	El Nino - increase probability of above normal precipitation	By mid-April, make stocking decisions and contract yearlings. Use decision tree on ENSO / PDO Phase (Appendix 5) and residual biomass to set stocking rate low, moderate or high relative to long-term average.
Previous October Residual Biomass (data summary: measured in Oct.)	Residual Biomass (data summary: measured in Oct.)	
Within-Season Management		
Weekly starting May 15 Cumulative precipitation and soil moisture. Soil moisture and rainfall is monitored continuously.	Minimum thresholds for biomass are specified relative to three precipitation scenarios: > 88.5% of average, , 75-88.5% of average, < 75% of average.	Leave pastures when specified minimum residual thresholds are exceeded for three precipitation/ ecological type scenarios. If the eight pastures planned for grazing have been used, consider using the pastures planned for rest. Consider available biomass, recent rainfall and soil moisture, and other range management objectives. After all ten pastures have either been used or intentionally skipped (due to a decision related to other objectives), consider regrazing previously grazed pastures (see below).
Weekly Starting May 15 Near-real time monitoring products for forage conditions, and GrassCast, VegDri, NDVI and standing biomass from up to 1 week ago.		Calculate whether cattle may need to leave CPER sooner than Oct 1 (decision to initiate discussions with cattle owners/stakeholders); Change rotation based on spatial variation in forage conditions; Implement rotation criteria as planned.
Only after all 10 pastures have been used Biomass values for regrazing	Biomass values must exceed the drought threshold enough to allow for additional regrazing	If conditions are not met, cattle need to be removed from the station if biomass values do not exceed the drought threshold in all 10 pastures. At least two weeks' warning should be given to producers if this is about to happen.

WORKSHEET #3, Crops Example

Trigger Dates

What to Monitor & When	Target Condition	Adaptive Action
September *Fall moisture for winter wheat planting*	*Soil moisture sufficient to plant*	*If moisture is insufficient, do not plant, or consider applying irrigation after planting (if applicable). Apply pre-plant fertilizer if possible when good soil moisture conditions exist or are forecasted short term.*
March *Soil Fertility*	*Understanding of nutrients existing in soil prior to spring fertilization*	*Use soil samples to determine soil existing nutrient credits. Apply fertilizers at rates based on expected crop yields minus credits. Be sure to account for other existing sources such as manure, organic matter, and previous legume crops, if applicable.*
April *Winter precipitation amount*	*Wet soils and positive short term weather forecast.*	*If soil conditions are dry, carefully survey stand to determine appropriate inputs relative to potential yield. If stand is poor, consider crop insurance if eligible (e.g., winter kill).*
April *Short-term weather forecast*	*Positive short-term forecast*	*See above. If residual soil moisture is low, and 10 day forecast does not look promising for precipitation, do not apply fertilizer.*

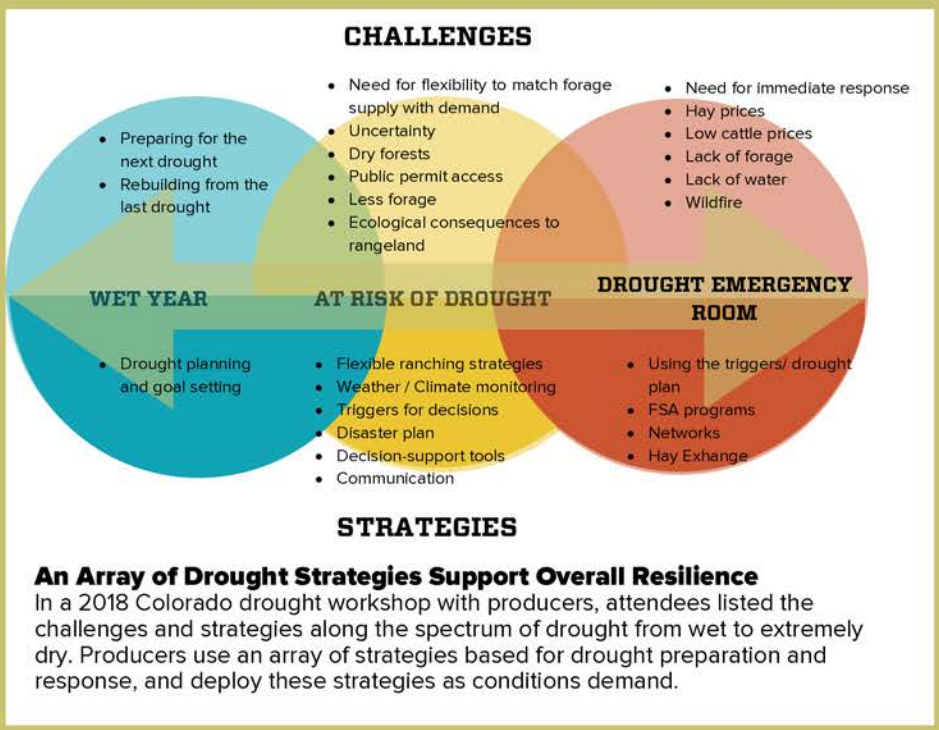
Making A Drought Plan

2c. Identifying Strategies to Reduce Risk

After assessing the operation and available resources, identifying drought-specific goals, and determining critical conditions and trigger dates, a producer's next step in the planning process is to identify potential risk-reduction strategies. Importantly, these strategies should be linked to the specific goals determined in the second step. If goals are "where is a producer trying to go", strategies are the "how" to get to there. Triggers are "when" to take action in response to conditions.

Because producers know their operations better than anyone, they are the most qualified to identify strategies to reduce drought risk. Due to the diversity of agricultural operations and landscapes in Colorado, there is no "one-size-fits-all" approach to drought strategy.

Additionally, improving drought resilience requires both short-term response and long-term preparation. For example, in July of a very severe drought year, a producer is responding to acute conditions and may not be planning ahead for long-term drought preparation. The decision context is different, but effective management in both the short- and long-term is critical. Thus, strategies should be considered from both short-term and long-term perspectives. See Figure 7 below, adopted from the University of Arizona's drought planning guide, which shows the interconnectedness of long- and short-term drought planning strategies.



An Array of Drought Strategies Support Overall Resilience
In a 2018 Colorado drought workshop with producers, attendees listed the challenges and strategies along the spectrum of drought from wet to extremely dry. Producers use an array of strategies based for drought preparation and response, and deploy these strategies as conditions demand.

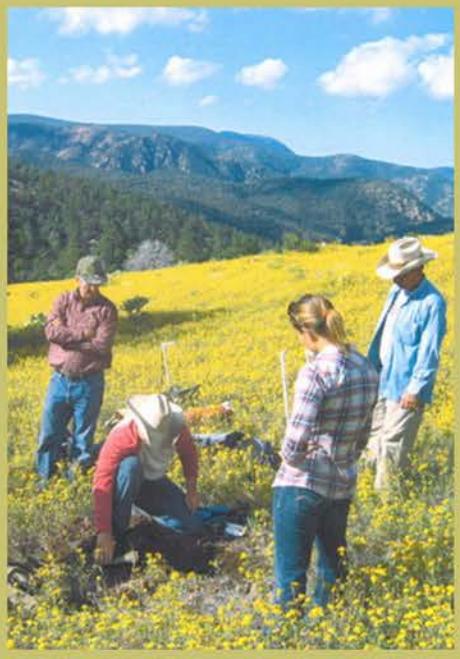
2c. Identifying Strategies to Reduce Risk

Short-term Strategies to Respond to Current Conditions

Short-term strategies are undertaken in response to triggers, as defined in the above section. These strategies involve an action that is immediate or in the near future based on when precipitation, soil moisture, or other conditions identified by a producer indicates that drought conditions exist or may develop. For example, short-term strategies might include finding alternative pastures or harvesting a crop for a different purpose than originally intended (for example corn for livestock feed instead of grain). Other strategies may be conducting a partial budget exercise to estimate short - and long-term tradeoffs of decisions, seeking disaster payments, applying irrigation water on the most profitable crops, preparing a wildfire evacuation plan, preparing a strategic de-stocking plan, prioritizing mental health, and so on. The bottom line is that these strategies should be actionable in the short term when drought is occurring or inevitable. Worksheets 3 or 5 can be used as a framework for thinking about shorter-term decisions.

Ranching Example for Short-Term vs. Long-Term Planning

Arizona cattle Rancher, Mike Hemovich, plans for a drought on Bar X Ranch from both a short-term and long-term perspective. In his long-term plan, Hemovich focuses on drought adaptation. "A lot of people will say we're always in drought in Arizona, so when we looked at setting up a long-range plan for the ranch, it was really focused on drought." This plan ensures the ranch has multiple sources of water and adequate water storage by drilling wells and building trick tanks. A trick tank captures precipitation which is stored in a covered tank to minimize evaporation and maintain water quality. They are useful alternatives for watering cattle where drilling a well is not possible. In his short-term plan, Hemovich lays out the more immediate actions he will take in response to drought conditions within a given year. Visit the The National Drought Mitigation Center (See Appendix 5) for information on Hemovich's approach to drought planning. (Photo credit: Mike Hemovich)

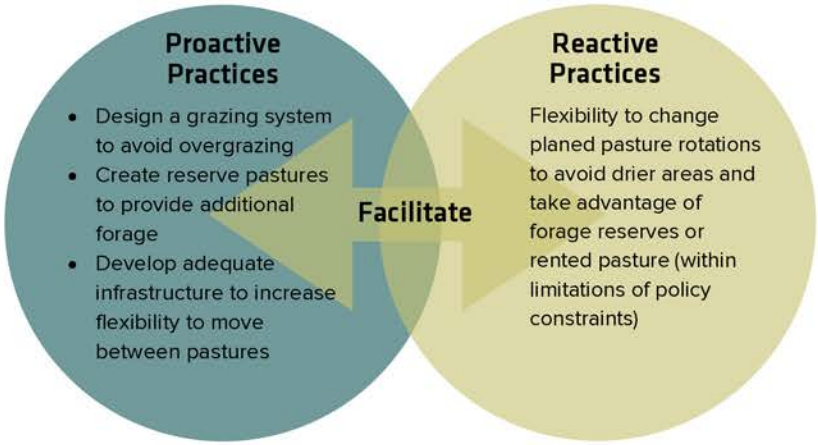


2c. Identifying Strategies to Reduce Risk

Long-range Strategies to Improve Drought Preparation

Short-and-long-term drought planning strategies are interconnected and support each other.

Figure adapted from Hawkes et al. [46].



Alternately, some drought resilience strategies may take multiple years not only to implement but also to begin providing benefits. For example, additional stock water may be critical for grazing flexibility in drought. However, since projects to increase water storage may take multiple years to implement, a producer may not see an immediate benefit from this strategy during a drought. Long-term strategies may include investing in infrastructure for increased water storage, investing in irrigation infrastructure, or developing livestock water to increase flexibility.

Use Worksheet 4 to consider challenges with drought preparation that may have come to mind during the process of taking stock of the operation (Column 1). From there, one can use the worksheet to brainstorm possible strategies (Column 2). After brainstorming potential strategies to issues with drought preparedness, consider how each strategy relates to the broader goals of the operation, its feasibility and impact, and if collaborating with external partners will be necessary to achieve this strategy. Management systems and strategies that are both established and implemented even when drought is not acute are key to overall success in managing during drought. For the final step to creating a drought plan, we will consider how each possible strategy might perform given future drought scenarios. Using Worksheet 7 (pg.27), one can then prioritize where it is most important to spend energy and time.

WORKSHEET #4, Long-term Example

Identifying Issues and Strategies

Issues with Drought Preparation	**Possible Strategies** *What are potential strategies to this specific issue?*	**Farm/Ranch Goal Addressed** *How will addressing this issue enable you to reach your operation's goals?*	**Priority** *What's the feasibility and impact of the strategy?*	**Potential Partners** *Given the cost or scale, do you need additional partners?*
Example (ranching) Cattle herd size is almost at full capacity; any decline in forage likely to result in needing to sell cows	• Change the herd composition to incorporate yearlings or stockers; therefore, more flexible • Consider more conservative stocking rate • Seek alternative forage by renting/leasing pastures	Reduce economic impact of drought by increased flexibility and preparation.	Low Medium High	NA
Example (farming) Profitability of dryland wheat is increasingly unreliable due to warmer temperatures and dry springs.	• Plant perennial forages on a percentage of acres for dryland grazing. • Increase acreage under no-till to improve soil moisture retention • Explore specialty certifications, like organic, to capture value with reduced production.	Reduce economic impact of drought by diversifying crops and capturing value from crops.	Low Medium High	NA
Example (irrigation efficiency) With ongoing/recent drought, irrigation supplies are not reliable and fail to provide as much water as in the past with shorter irrigation seasons.	• Transition percent of fields to more efficient irrigation systems (flood to side rolls). • Build additional storage • Acquire additional water rights • Increase civic engagement in discussion shaping basin-wide policy	Reduce economic impact of drought by increasing reliability in our water supply, and extend water availability later in the season.	Low Medium High	NRCS; water lawyer, seek other potential partners for infrastructure funding

Worksheet adapted from: Guide to Co-Developing Drought Preparation Plans for Livestock Grazing on Southwest National Forests by Hawkes et al., 2018. Full handbook at: https://cals.arizona.edu/droughtandgrazing/

WORKSHEET #5, Short-term Example

Response Strategies to Deal with Current Conditions

This worksheet provides a framework for brainstorming short-term response strategies. Below is a livestock focused example. In cropping systems, in-season response my be less important since adaptation measures take many years (i.e., infrastructure). Conversely, in livestock systems, in-season decisions can have expensive implications and damage rangeland health, so response is critical. However, this sheet can be adapted for use in any system where it would be useful.

	What are you watching for?	**Scenarios** *Available Rangeland forage/ water supply*	**Scenario Likelihood as of (date)...**	**Mgmt. Strategies**
Best Case	• SNOTEL streamflow forecast: 70% chance streamflow will exceed median flows. • Forage: fast growth in spring. • Conditions on the ground: Soils saturated going into winter, pastures in good condition going into winter. Cool, wet conditions in spring	Forage: 800 lbs/acre Water supply: full allocation	By late May, given favorable conditions. If conditions are warm in dry in spring, this scenario becomes unlikely.	Retain steers and extra heifers; defer extra pastures; water hauling likely not needed.
Average Case	• SNOTEL streamflow forecast: 50% chance streamflow will exceed median flows. • Forage: moderate growth in spring. • Conditions on the ground: average going into winter; Average spring conditions	Forage: 500 lbs/acre Water supply: partial irrigation after 1st cutting	Late May	Normal culling and prepare to cull older cows. Planned rotation, and no deferral of pastures. May have reduced hay yield depending on monsoon and temperatures.
Worst Case	• SNOTEL streamflow forecast: 30% chance streamflow will exceed median flows. • Forage: slow spring growth. • Conditions on the ground: dry going into winter; Dry, hot spring.	Forage: 200 lbs/acre Water supply: no water after 1st cutting	Late May	Water hauling and supplemental forage needed. Supplemental forage or culling to base herd likely will be needed. Hay yield likely decreased.

Worksheet adapted from: An Easy to Use System for Developing a Drought Management Contingency Plan by D, Tolleson. 2017. Fact sheet available at: https://cals.arizona.edu/droughtandgrazing/

Making A Drought Plan

2d. Use Scenarios to Prioritize Strategies

Since a producer's time, resources and energy are limited, prioritizing which drought preparedness strategies to invest in is critical. We propose using simplified scenario planning exercises to explore how various strategies may perform given different possible futures.

Short Term Scenarios (Worksheet 5)

One tool to help prioritize is a simplified scenario planning exercise, such as Worksheet 5 (pg.23), to consider if and how future scenarios may be different from past experience. Worksheet 5 can be used for short-term scenarios. For example, some conditions may be difficult to predict, such as a flash drought or an unexpected record month of rainfall. These scenarios can include a few possible trajectories for how a year may progress. This allows the producer to brainstorm an arsenal of possible responses. Ideally, this exercise would also include input from individuals on the producer's planning team.

Long-term Scenarios (Worksheet 6)

For long-term response, consider what could happen if drought conditions continued for several years. How could the operation adapt to those conditions? Remember, just because it has never happened before does not mean it cannot happen in the future. Worksheet 6 (pg.26) provides an example of how to generate a few relatively simple scenarios. Producers might consider what they might do if drought conditions persist for 5+ years and prices are low. Alternately what if drought conditions persist for 5+ years, and prices are high? It may help a producer think about possible future scenarios by looking at data-drive models such as the Climate Toolbox (See Appendix 5).

2d. Use Scenarios to Prioritize Strategies

For example, research has demonstrated that continued warming could lead to flow reductions of 35% or more in the Colorado river [1] and also lead to earlier spring snowmelt in the Rio Grande Basin [2]. Cool-season grasses are expected to decline in western Colorado, so future rangeland production is likely to be less than it was historically [3, 4]. The eastern plains are likely to be impacted by greater precipitation variability, which will impact profitability because of wide swings in production [5]. True scenario planning can be very complex. However, the point of this step is to encourage out-of-the-box thinking by developing a few plausible scenarios.

Scenario Comparison and Prioritize Strategies (Worksheet 7)

Once some scenarios have been developed, they can be used to review the strategies developed using Worksheet 4 (pg.22). How does each strategy hold up given different future drought scenarios? Do the different scenarios change which strategy is most pertinent for drought management? Use column 4 in Worksheet 7 (pg.27) (Priority) to prioritize up to five long-term strategies to increase drought preparedness, given particular scenarios, how they relate to a producer's goals, and their feasibility.

Include the timeline associated with each strategy, how they each help achieve the drought preparedness goals, and rank them based on priority. It's easy to have more than four strategies, but keeping it to four will help focus a producer's time and energy on the top priority action items.

Use Worksheet 7 (pg.27) to prioritize drought strategies

WORKSHEET #6, Scenarios

Drought Scenarios

Scenario #1:
What if... we experience a winter season drought with only 50% average precipitation for 3 consecutive years

- What will we do?
- What flexibility do we have?
- How could we increase preparedness for this possible scenario?
- How do strategies developed in Worksheet #4 perform?

Scenario #2:
What if... receiving 20% of our historical irrigation water allocation becomes normal, occurring 5 out of every 10 years

- What will we do?
- What flexibility do we have?
- How could we increase preparedness for this possible scenario?
- How do strategies developed in Worksheet #4 perform?

Scenario #3:
What if... spring conditions are moderate/ dry, but a early-onset monsoon provides rain to maintain ditch levels and favorable conditions for rangeland forage.

- What will we do?
- What flexibility do we have?
- How could we increase preparedness for this possible scenario?
- How do strategies developed in Worksheet #4 perform?

WORKSHEET #7, Long-term Strategies

Prioritizing Strategies

This worksheet provides a framework for connecting strategies, the timeline, goals, prioritization, and finally, documenting progress. As with all worksheets in this handbook, it can be used in conjunction with others, or separately. The strategies here are different than our example Worksheet 4 (pg.22) to show a broader breadth of examples.

Basic Details of Strategy *Prioritize the top 5 actions you will take based on the above brainstorm in Worksheet #4.*	**Timeline**	**Goal Addressed**	**Priority**	**Done?** *What and Year*
#1 Use trigger dates to make responsive decisions in drought	This year	Reduce stress in managing for drought: protect rangeland health	#1	Used triggers
#2 Update irrigation infrastructure to allow for irrigation scheduling on irrigated meadows (i.e., autotarps)	1-4 years	Manage water for maximum yield of hay crops, and have flexibility when there is not enough water	#3	2021: looked at neighbors' system. 2022: Outfitted 1 meadow with autotarps
#3 Increase access to forage by increasing custom grazing portion of the business to buffer low-production years	1-3	Increase forage base to improve flexibility in drought.	#4	Acquired additional contract
#4 Update infrastructure on irrigation ditches which were last updated in 40 years ago	1-5	Update infrastructure for 21st century flow projections	#2	2022: Submitted grant applications for cost-share programs

WORKSHEET #8

Drought Plan Template

A drought plan can be as simple as a 1-2 page document that includes, goals, a basic inventory, strategies, and critical dates. Use this template to bring it all together.

Goal(s) for Drought Management (max 3):

Inventory:

- **Average Precipitation and Variability:**
- **Other:**

Strategies for Increasing Drought Preparedness and Timeline for Completion (max 4):

Critical Decision-making Dates and Target Conditions:

Strategies for Managing During Drought (max 4):

Making A Drought Plan

3. Implementing the Plan

A plan that is created then never acted on is just a piece of paper. The point of creating a drought plan is to increase the ability of a producer to both respond to and prepare for drought - to move from a piece of paper to action. Producers can use the last two columns on Worksheet 7 (pg.27) to track progress on drought- preparedness goals, and the last two columns of Worksheet 3 (pg.17) to track in-season response. This is not to suggest that the plan is inflexible as there are lots of reasons why reality might require a different action than was in the plan. However, one of the main reasons to have a drought plan is to reduce in-season stress as choices are already delineated. We don't control drought, but acting on the plan can give a sense of control to increase preparedness and response. The final step of drought planning is reflecting on the plan and learning and adapting it in response to experience.

4. Learn and Adapt

Learning from experiences with drought– and responding by adjusting management– is a critical piece of successful drought preparedness and response. Drought planning should be considered an adaptive management process - it is not a 'one and done' endeavor. Ongoing monitoring and evaluation that leads to regular modification of a management plan is necessary to improve one's response. As a part of an ongoing drought response, it's important to take time to reflect on how well a drought plan is performing. Based on these reflections and observations, update the plan's goals, strategies, and triggers as needed.

Consider

- What were the dominant impacts of the drought (crops, pasture, water, livestock, financial, wildlife/environment, and social/family)
  - What was expected and unexpected?
- What proactive practices helped the operation cope?
  - Did they work the way they were intended?
  - Which goals were met?
- What responsive practices helped the operation cope?
  - Did they work the way they were intended?
  - Which goals were met?
- What could have been done differently to improve the success of coping with drought?
- What can be changed to better prepare?
- Do strategies and goals need to be revisited and re-prioritized?
- Are there any operational or business changes needed?
- Were there any opportunities brought about because of drought?
- Did or could external forces alter the drought recovery plan? (market prices, costs, weather, etc.)

Habitat Partnership Program

Partners for Fish & Wildlife

Making A Drought Plan

Funding Sources for Drought Resiliency

The Natural Resources Conservation Service (NRCS) can provide technical assistance to achieve drought preparedness goals for both cropland and range/livestock projects. Financial assistance through Farm Bill Conservation programs managed and administered by the NRCS may also be available. County level NRCS field offices are located within local USDA Service Centers. NRCS contact information can be found within the blue pages of your telephone book or online at http://www.co.usda.nrcs.gov.

Irrigation and Water Storage

Irrigation drought strategies include water storage, integrated conservation practices, structurally sound infrastructure, efficient management and measurement, and delivery systems. For many entities these are critical additions or updates for a system, but funding is typically not readily available. This makes grant and loan programs essential for implementation.
For a comprehensive list of funding opportunities for ditch, reservoir and irrigation companies, check out the most recent edition of the DARCA (Ditch and Reservoir Company Alliance) Funding Guide (See Appendix 5).

Rangeland Conservation Practices

As with irrigation and water storage, many drought mitigation and preparation practices come with a price tag that may exceed what a producer can pay. No one funding source is available everywhere to everyone, but there is an ever evolving list of entities that fund projects on rangelands that can be a win-win for drought preparation and wildlife conservation. Funding sources can include the Colorado Parks and Wildlife's Habitat Partnership Program (HPP), US Fish and Wildlife Service's Partners' for Fish and Wildlife (See QR codes), NRCS, and Bird Conservancy of the Rockies (See Appendix 5). Water development, wet meadow restoration, and range seedings are just a few examples of possible projects these programs may be able to help fund.

Climate, Drought & Trigger Dates

Snapshot of Precipitation in Colorado

- Precipitation in Colorado is irregular and extreme in nature, and highly variable across space, time, and seasons
- The majority of annual precipitation received during high intensity, low frequency storms
- Western and Eastern Colorado differ:
- Lack of moisture has a bigger impact during a month/season that is typically wetter than a traditionally dry period. I.e., a dry June in western Colorado is less significant than a dry March.
- Know your area's wet and dry season to effectively interpret forecasts.
- Increased temperatures in recent decades have impacted runoff timing and volume.
- Average temperatures will continue to increase.
- Rather than guessing, checking knowledge with actual weather records (available at the Colorado Climate Center or CoAgMet (See Appendix 5)), is critical.

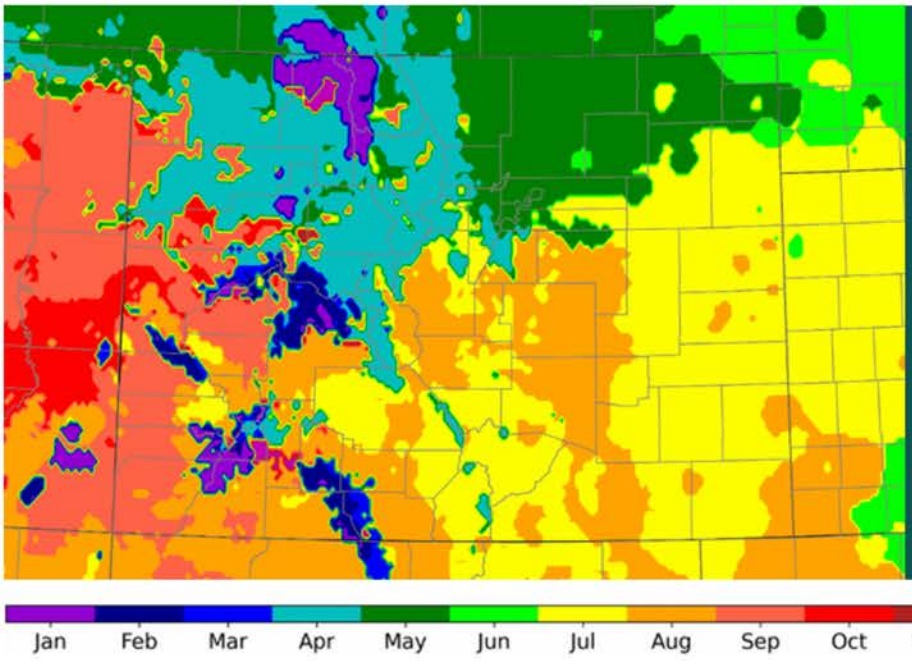
Weather Patterns in Colorado

While Colorado is spectacularly diverse and variable, one of the state's defining features both geographically and meteorologically is the Continental Divide. During the winter and spring most of Colorado's moisture comes from large-scale weather systems that transport moisture from the Pacific Ocean. As storms travel eastward over the Rockies, the air rises over the Western Slope of the Continental Divide, eventually reaching the mountain peaks. As air rises it cools, and as it cools the water vapor in the air is condensed. Thus, moisture is squeezed out, like wringing a wet towel. Consequently, air is typically much drier on Colorado's Eastern Plains after making it over the Continental Divide. This is known as a rainshadow effect and it occurs around mountainous regions all over the world. For this reason, much more precipitation accumulates in the higher elevations west of the Continental Divide than the lee (east) side of the mountains.

Elevation

The climate in Colorado is deeply affected by the extreme differences in elevation (See Appendix 5). There are 59 mountains standing over 14,000 feet and 830 mountains between 11,000- 14,000 feet in elevation. The lowest elevation lies at 3,350 feet near the eastern Colorado/ Kansas border. Lower elevations east of the divide experience a distinct precipitation pattern. The cold season is dominated by dry westerly winds, that warm as they descend from the mountains, and cool, dry northerly winds. In summer we see a shift to more variable winds and precipitation patterns that are more locally driven. Higher temperatures and more moisture lead to regular afternoon thunderstorms.

Climate, Drought & Trigger Dates



This map shows the maximum average precipitation by month in Colorado. Throughout the state, this is vastly different.

Figure: Russ Schumacher/ Colorado Climate Center
Data: PRISM Climate group.
Available at: http://climate.colostate.edu/precip_prop.html

There is no "Average" Colorado

Statewide, Colorado receives an average of 18 inches of annual precipitation. Using statewide averages to describe weather and climate patterns is about as useful as saying that 'the average elevation in Colorado is roughly 6,800 feet' to describe the state's geography. Even in "typical" years, annual precipitation can range from 8 inches at lower elevations in western Colorado to more than 60 inches in parts of the high mountains (http://climate.colostate.edu/climate_long.html). At any given location, annual precipitation totals can vary from only about half of average in a dry year to nearly double the average in a very wet year! At any given time, parts of the state are likely under drought conditions; however it is rare for the entire state to be experiencing drought in the same intensity at the same time of year.

Temperature is more predictable and is strongly connected to elevation. While the high mountains remain relatively cool year-round, Colorado's continental interior location exposes lower elevations to extremely hot and cold temperatures at different times of the year as well as large daily swings in temperature.

The percentage of annual precipitation that falls as snow varies greatly across Colorado and from year-to-year. For example, the percentage of precipitation that falls as snow may be less than 15% over southeast Colorado and may exceed 70% in Colorado's northern mountains. In addition, Colorado is unique among the U.S. states in regards to its amazing diversity of precipitation. Any given month is the wettest month of the year for some part of the state. For example, June is normally the driest month of the year in the Southwest corner of the state but May/June are the wettest months in the Northeast corner. We will discuss the implications of this in later sections on interpreting forecasts (pg.43).

Climate, Drought, and Trigger Dates

Sunshine Has A Cost

Colorado is a state known for its abundant sunshine, but that much sun comes with a cost. For most Coloradans, precipitation is a rare and welcome sight, even if it's often just a short-lived afternoon thunderstorm. Substantial precipitation events are less common, but crucial. In fact, one fifth of the precipitation events in a given year are responsible for more than half the annual precipitation total in a typical year, even when including high elevation areas. Therefore, the difference between a very wet year and a very dry year may come down to the presence or absence of just a few major storm systems (see A History of Drought in Colorado)[6].

Timing is Everything

Colorado's regions differ significantly in terms of the timing of precipitation, and the significance of precipitation (or lack thereof) during a specific season. For example, the wet season acts as a double-edged sword in determining drought conditions. The wet season brings the best chance of drought recovery, however, a drier than normal wet season can quickly create a long-term precipitation deficit. In the next section, we describe the seasonality of precipitation by region in Colorado.

Early Warning of Drought and Interpreting Outlooks

A dry forecast has a bigger impact during a month/ season that is climatologically wetter. This varies by region.

- High Elevations
  - Pretty much any time of year, a dry forecast could become quickly problematic.
  - Dry in the winter could inhibit accumulating snowpack
  - Dry in the summer could dry out soils
- Southern CO
  - A dry forecast in the late summer and early fall could mean weak or lack of monsoon, which could dry the soils out before cold season sets in.
- Eastern Co
  - in the spring and summer, this will quickly lead to large precipitation deficits that could be hard to recover.
  - in the winter drier than average is probably more common than being wetter than average.

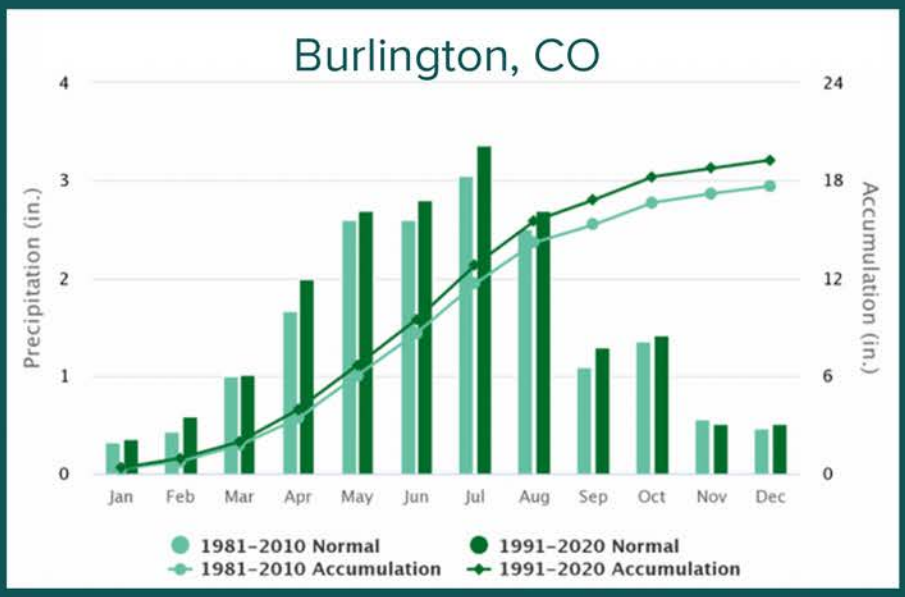
From Becky Bolinger, Assistant State Climatologist, Colorado Climate Center
Available at: https://droughtadvisors.org/webinars/using-forecasts-in-drought-planning/

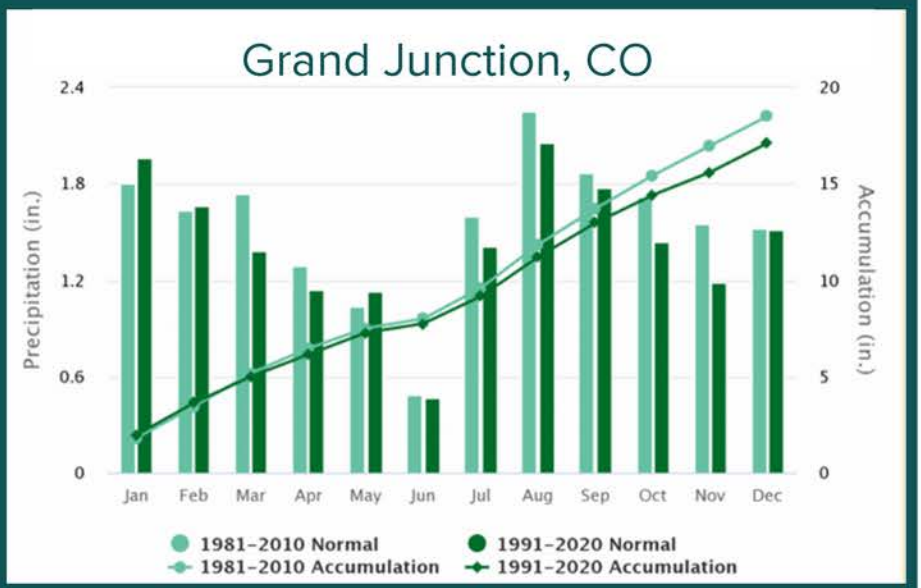
Colorado has three quarters of all the land in the continental United States that exceeds 10,000 feet in elevation! Not only does Colorado have more high elevation and rugged terrain than any other state in the country, it also has the highest average elevation, all of which impacts the weather patterns in the state.

Climate, Drought, and Trigger Dates

Seasonality of Precipitation Varies Greatly

Compare the difference the shape of the curve showing average precipitation between Burlington and Grand Junction. While June is among the wettest average month in Burlington, it is the driest on average in Grand Junction. These patterns impact the ecology and production of the regions. Knowing this information for the region of interest is critical to interpret forecasts. From: The Colorado Climate Center, Station Normals (See Appendix 5).





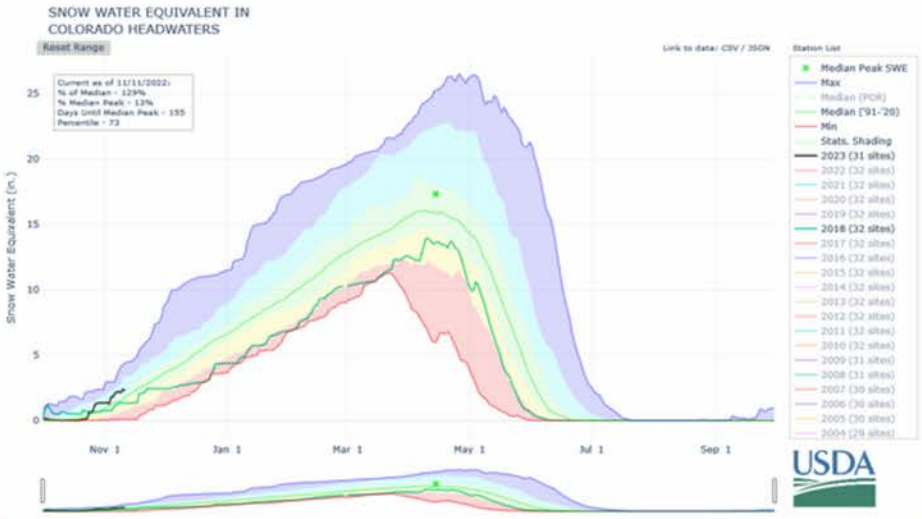
SNOTEL Interactive Map (or search "Snotel Interactive Map" in your browser.

Climate, Drought, and Trigger Dates

High Mountains and Water Supply

Colorado's high mountains capture more precipitation than anywhere else in the state. Most of this precipitation falls in the form of snow between the months of October and May. Effectively all surface water irrigation is supplied by snowmelt. NRCS-SNOTEL has developed an interactive and easy-to-use tool (See QR code) that enables users to see statewide and basin-wide snow water equivalent accumulation in real-time. Sub-basin specific graphs compare the current snow water equivalent (in inches) to all other years from the historical record. Graphs also include maximum, normal, and minimum water years, as well as shading based on the 10th, 30th, 50th, 70th, and 90th percentiles.

Additionally, the Snow Water Equivalent Projections show projected snow water equivalent (in inches) for a range of possible outcomes. The user can select and compare any year(s). These charts can help the user weight the likelihood of outcomes, even if future weather is uncertain.



Example graph from USDA-Snotel. Users can see the snow-water equivalent (or how much water is in the snowpack) in the current year compared to other years or averages. In this graph, the black line is 2023 and the teal is 2018. Users can highlight specific years to get a sense of how the current year may compare to other years in recent memory. From USDA-SNOTEL Interactive map.

High Mountains and Water Supply

Current and Future Trends

Since 1978 the timing of snowpack melt and the resulting stream runoff has been shifting to earlier in the year by 1-4 weeks depending on the watershed [8]. Increasing temperatures and dust-on-snow events (See QR code) have resulted in a shortening of the snow accumulation season in the mountains and an earlier beginning and end to the seasonal snowmelt cycle, leading to reduced flows late in the season [9]. Producers which rely on surface water for irrigated agriculture are and will be significantly impacted by earlier runoff. Climate models project that runoff will decrease between 5-10% for every one degree Celsius that the climate warms [10]. Thus, irrigation from surface water will continue to be negatively impacted by warming trends. The location of crops, crop yield, and/or crop type could change depending on each specific crops' seasonal water needs. Using streamflow forecasts is discussed in the triggers section below.

For more information on typical wet and dry seasons by river basin in Colorado, please refer to Appendix 2.

High Mountains In Brief

- Colorado's mountains capture moisture, mostly in the form of snow.
- Snowpack data is essential input for predicting runoff and surface water supplies in Colorado.
- Tools (See QR code on page 35) exist to help assess snowpack and streamflow.
- The timing of snowmelt and runoff has been occurring earlier in the year since the late 1970's. Changes in timing, and expected continued warming will result in earlier and decreased runoff [7].

Dust on Snow Events

Colorado Plateau In Brief

- Precipitation is distributed throughout the year, but the late summer monsoon provides the lion's share of precipitation.
- Indicators of increasing drought on the Western Slope can be indicated by a weak or absent monsoon, but snowpack is also significant because it drives runoff.
- The Colorado Plateau has experienced a warming trend in the last several decades and scientists have high confidence this will continue.
- With increased temperatures, precipitation has a less beneficial impact because more is lost to evaporation.

Climate, Drought, and Trigger Dates

Colorado Plateau

The western-most reaches of the state make up the most northeastern parts of the Colorado Plateau. Precipitation is more evenly distributed throughout the year on the Plateau than on the Eastern Plains, but the late summer monsoon often provides the lion's share of precipitation to the region and can make or break a growing season for most producers (although it is highly dependent on the crop). Increasing severity of drought on the Western Slope is most frequently indicated by a weak or absent monsoon season. Irrigation water provided by mountain snowpack is also crucially important to agricultural productivity in the region (see above section). For this reason, peak snowpack and snowmelt runoff occurring earlier and/or lower than normal can also indicate impending drought for this region.

Current and Future Trends

The Western Slope is also vulnerable to aridification, or a gradual change towards a drier climate. This change is primarily driven by warmer temperatures. Average temperatures have increased in the last 40 years, but average precipitation does not show a significant trend in either direction. Increased temperatures dry the soils faster and result in higher evaporative losses. Because more water is lost to the atmosphere or to replenishing drier soils, the same amount of precipitation results in less surface water availability, thus reducing flows and water supply. There is high confidence that temperature trends will continue.

Climate and Weather Terms

Evaporative Demand	Evaporative demand is the potential loss of water from the earth's surface by the atmosphere or the "thirstiness" of the atmosphere. In other words, it describes the 'drying power' of the air. The atmosphere's ability to evaporate water from the surface of the earth is estimated using quantified atmospheric factors such as temperature, wind speed, humidity and cloud cover. High levels of evaporative demand cause plants to consume more water to stay healthy, this process is known as evapotranspiration (ET). Evapotranspiration is estimated by measuring the same factors used for evaporative demand and adjusted to reflect a specific crop's needs. Colorado has an ever-growing network of weather stations known as CoAgMET that is used to estimate real-time ET rates for different crops all over the state. Peruse the Crop ET Access page to see if any of the information provided could help you manage your operation.
Flash Drought	Rapid onset or intensification of drought due to increased temperature, winds, and solar radiation that significantly increase evaporative demand and lower soil moisture. Conventional droughts are mainly driven by a lack of precipitation over time. In contrast, flash droughts are more often driven by periods of abnormally increased evaporative demand that rapidly draw down soil moisture. Atmospheric conditions responsible for flash drought include heat waves, wind events, or abnormally dry periods occurring in seasons of high evaporative demand. Heat is unsurprisingly the main culprit for these events in Colorado. Flash droughts can be smaller in geographic area and often exist on shorter timescales, but have major agricultural consequences nonetheless. Flash Drought prediction and detection is difficult but improving all the time. Paying close attention to changes in local soil moisture conditions and precipitation patterns will aid producers in the detection of flash drought development.
Aridification	A gradual, long-term, and non-reversing drying of regions whereby conditions that may have previously been considered a drought are now normal. Though it can be driven by a reduction in precipitation and/or an increase in evaporative demand, a consistent reduction in average soil moisture content over time is perhaps the ultimate indicator of aridification. Research shows droughts in the Southwestern United States make up part of a longer-term trend of aridification [11]

Climate, Drought, and Trigger Dates

Eastern Plains

The climate across the eastern plains of Colorado is relatively uniform due to lack of topographical variation. The Eastern Plains experience cold, dry winters, warm, sunny summers, and routinely windy weather. Temperatures in the summer regularly climb above 95°F, and winter cold snaps can push the temperature well below 0°F.

Precipitation patterns are more seasonal on the plains than in the other two regions of the state. 70-80% of total annual precipitation falls during the growing season, from April through September. Cool (spring/fall) season precipitation can be important for soil moisture recharge, but midwinter precipitation is light and infrequent. More often, winter brings dry air and strong winds contributing to the aridity of the area. From mid-March through early June, periodic widespread storms bring heavy, wet snow, or cool, soaking rains. These storms are essential for the health of local crops and grasslands. Below-normal precipitation during April, May, and June, however, can completely ruin the winter wheat and significantly reduce grass production, even if the rest of the year receives normal precipitation.

The region is particularly vulnerable to drought. Multi-year droughts have occurred several times over the last century (specifically the 1930s, mid-1950s, and in the 1970s). Since 2000, drought periods have been increasing in frequency. Summer precipitation over the plains comes from intense thunderstorm activity which can include heavy rains, flooding, and hail. While crops and vegetation rely on moisture from intense summertime downpours, they sometimes can do more harm than good. Hailstorms can have a massive impact on yields locally, and even a marked impact regionally.

Photo Credit: Mary Ashby

Eastern Plains

Wind is commonplace on the plains year round. Wind during dry periods not only increases the evaporation rate from the soil, it also increases the water needs of the plants and can even lead to soil erosion. Spring (March-May) is the windiest season for eastern Colorado.Sustained wind speeds increase as one approaches the eastern border of the state. However, the area immediately East of the Front Range often experiences gusty conditions as frequently, or more frequently, than those experienced further east despite lower average wind speeds overall. This is due to Front Range downslope, or 'Chinook' wind events. Sometimes during the cold season a strong pressure gradient develops across the Colorado Rockies with high pressure to the west and low pressure to the east. This forces air over the Continental Divide, which gains momentum as it descends onto the plains. Areas around Denver immediately downstream of the Rockies see high bursts of wind on these days, sometimes in excess of 70 miles/hour. Air also warms and dries as it descends. These warm, dry, fast winds melt snow rapidly hence the term "Chinook," which means "snow eater."Though spring is the windiest season on the Plains, windy conditions are also far more common on the plains during mid-fall and winter than they are in the Western parts of the state on the Colorado Plateau.

Eastern Plains In Brief

- 70-80% of total annual precipitation falls during the growing season, from April through September.
- Seasonality is important - a dry winter may not impact agriculture, but dry conditions in April, May, and June, can completely ruin the winter wheat and significantly reduce grass production.
- The eastern plains are particularly vulnerable to drought.

Photo credit: Edward J. Raynor

Climate, Drought, and Trigger Dates

Using Forecasts

Using Forecasts In Brief

- Long-term forecasts products, like the Seasonal Precipitation or Temperature Outlook and the Drought Outlook (See Appendix 5) are one tool in the toolbox to inform decisions.
- Forecast products like the seasonal precipitation outlook (See Appendix 5) must be interpreted in context of the time of year, and how much that time of year contributes to overall conditions.
- These products do not tell you what the average is, the magnitude, or indicate the onset or recovery from drought.
- They do tell you the probability of future conditions being above, near, or below average.

Climate forecasts are generated using models to predict weather averages using a vast array of information from many sources. NOAA's Climate Prediction Center generates 30 and 90 day seasonal temperature and precipitation outlooks every month, drawn from a compilation of various models and tools.

These products tell you the probability of future conditions being above, near, or below average. What they don't tell you is seasonal context as discussed above. For example, an above average precipitation forecast during the dry season may look promising, but provide minimal relief when in drought. Long term precipitation outlooks forecast (See Appendix 5) how precipitation patterns will fare in comparison to average precipitation patterns for a given region.

When considering these forecasts, it is imperative to consider the time of year, and how much that time period contributes towards the entire year.

For example, below normal winter precipitation outlook is concerning for the mountains because winter is part of the wet season. Furthermore, minimal winter precipitation limits snowpack accumulation, and subsequent runoff. On the other hand, a below normal winter precipitation outlook for the plains of eastern Colorado is not necessarily concerning. A drier than normal winter can be made up for with brief bursts of precipitation in May. Additionally, forecasts must be interpreted in historical context: even if an above-average precipitation year follows a below-average year, the impact on reservoir storage, grass production, and other variables, can last for many years into the future.

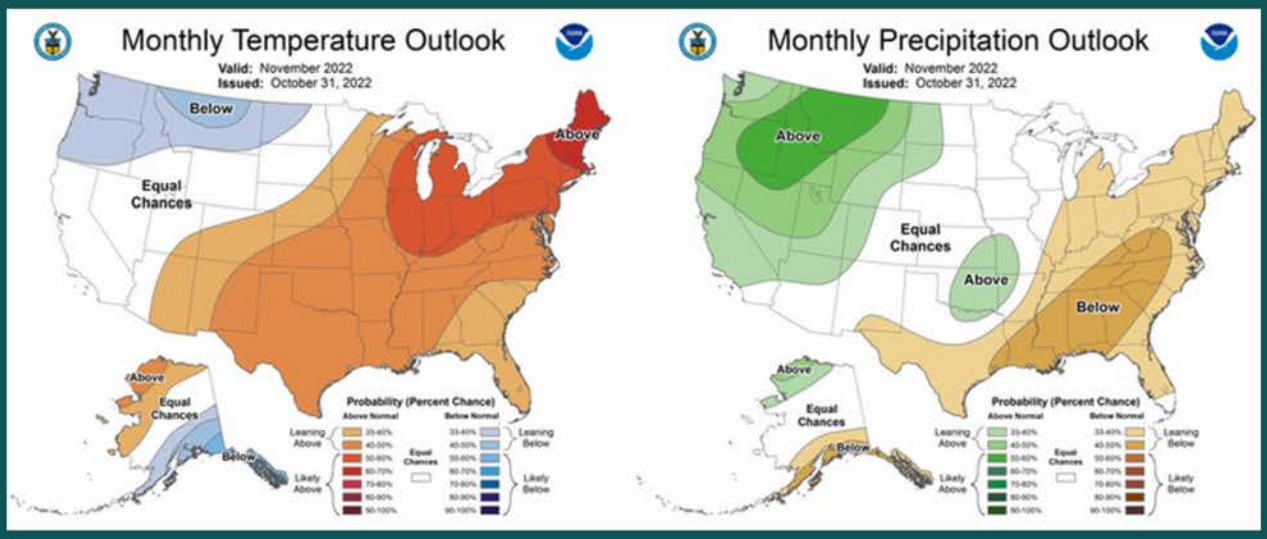
Climate, Drought, and Trigger Dates

Using Forecasts

When used as a guide for future planning, the temperature and precipitation outlooks can be one tool in the toolbox for making more informed decisions. The outlooks can be used to determine which scenarios are more or less likely. Another application is to use them with tools like GrassCast (discussed below in Triggers and linked in Appendix 5). This is a product that shows what grassland production may look like in near average, wetter than average, and drier than average conditions. Using the seasonal outlooks with GrassCast can inform a producer which scenario may be more or less likely to occur.

Using 30-day Temperature & Precipitation Forecasts from the Climate Predication Center

Climate forecasts are generated using models to predict weather averages using a vast array of information from many sources. While conventional weather forecasts make predictions ranging from 1-10 days in advance, climate forecasts predict climatic conditions on a larger timescale of at least one month up to several years. NOAA's Climate Prediction Center maps, like the images displayed below, generate 30 and 90-day seasonal temperature and precipitation outlooks every month.

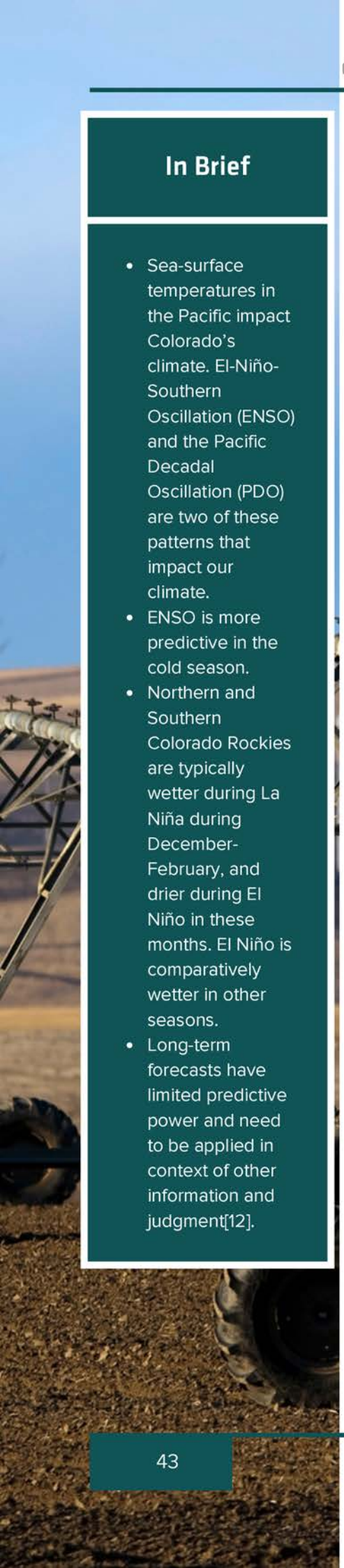


What They Tell You

- These maps tell you the probability of above or below average conditions occurring.
- The darker the color, the higher the likelihood of an outcome. For example, the darker the red the stronger the probability of warmer temperatures for that region, and conversely the darker the blue the stronger the probability of below average temperatures.
- Intended to be used on a broad scale to help analyze temperature and precipitation predictions.

What They Do Not Tell You

- Do not tell you what is average
- "Leaning/Likely above/below normal" does not provide context for how much above or below normal temperatures or precipitation will be.
- These maps do not indicate the onset or recovery status of drought.
- For day-to-day decisions, it is strongly recommended to rely more on site-specific observations and knowledge.



In Brief

- Sea-surface temperatures in the Pacific impact Colorado's climate. El-Niño-Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO) are two of these patterns that impact our climate.
- ENSO is more predictive in the cold season.
- Northern and Southern Colorado Rockies are typically wetter during La Niña during December-February, and drier during El Niño in these months. El Niño is comparatively wetter in other seasons.
- Long-term forecasts have limited predictive power and need to be applied in context of other information and judgment[12].

Climate, Drought, and Trigger Dates

Forecasting Accuracy & Climate Patterns

Climate describes an average of weather conditions over a longer time scale while weather is used to describe short-term atmospheric conditions, like what is happening outside right now. In other words, "climate" is like clothes in your closet and "weather" is what you are going to wear today.

Broader patterns in global climate, such as the El-Niño-Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO), can provide some predictive power for agricultural producers. ENSO refers to the sea surface temperatures along the equator in the Pacific Ocean, and generally includes the area east of the International Date Line. The PDO describes sea surface temperatures in the North Pacific Ocean. While Colorado lies far from the Pacific Ocean, sea surface temperatures influence precipitation patterns in the tropics, which have semi-predictable ripple effects all across the globe.

Colorado is more likely to experience cool and wet conditions during El Niño in both fall and spring. Winter is a little more complicated: The northern Rockies are typically wetter during La Niña, and drier during El Niño in the months of December-February. El Niño is typically comparatively wetter in other seasons. Most of ENSO's predictive power comes from the cold season, so it is less utilized during summer. However, it cannot be overstated that long range forecasts may have limited predictive power and need to be applied in combination with other sources of information. When combined with localized data and personal knowledge, these large-scale metrics can help guide on-farm and on-ranch decision making. See the Triggers for Decision making section for more information on using weather and climate info in drought decisions.

Appendix 2 has more information on larger climate patterns and their influence on local weather trends.

Climate, Drought, and Trigger Dates

Current & Future Trends

Overall, Colorado has been experiencing warming temperatures since 1976 (See Appendix 5), particularly during the months of March, June, September and November. This trend has a wide range of impacts to agriculture. Warmer winters and summers may exceed a crop's optimal growing or dormant season temperature, decreasing crop yield. In addition, warmer climates result in a higher evaporation rate and therefore drier soils, premature budding, and increased insect and weed pests. Heat stress impacts animal health, increasing their vulnerability to disease, and reducing fertility and milk production. Increased heat has also decreased the quantity of rangeland forage for cattle on the west slope (see Triggers section), and projected lower streamflow.

It is projected that the eastern plains will experience warmer and longer growing seasons, increased variability (swings from year to year in terms of production and precipitation), and more extreme events [13].

Precipitation, on the other hand, has been variable in Colorado since 1976, with no clear trend. However, there may be more localized precipitation trends. The Climate Mapper Tool (https://climatetoolbox.org/tool/Climate-Mapper) examines projections of climate for a specific area. The tool maps real-time conditions, current forecasts and future projections of climate to assist with decisions related to agriculture, fire, and water.

Climate, Drought, and Trigger Dates

Water Storage in Colorado

Ground water

In Colorado, there are two main classifications of groundwater: tributary and non-tributary. Tributary water is hydrologically connected to a surface stream (meaning the stream is fed by groundwater) so the amount of groundwater has the ability to influence the amount or direction of flow of water at the surface. All groundwater in Colorado is presumed to be tributary to a surface stream, unless otherwise defined. Therefore, groundwater is treated like surface waters in the prior appropriation doctrine administered by the Office of the State Engineer. In the case where tributary groundwater is the irrigation water source, the aforementioned surface water guidance applies.

Groundwater that is deemed tributary must replace past pumping by “time, place and amount” as its impact to surface water flows. This is done so Senior Water Rights downstream of the pumping influence are not impacted. Referred to as augmentation, surface water is placed into seepage ponds during times of no calls at strategic locations. The water seeps through the soil, eventually making it back to the stream and replenishing streamflow. There are times even in normal years however, when augmentation of full water use can be difficult resulting in less than adequate streamflow to meet the demand. In drought years, this situation is all the more difficult.

Non-tributary water is groundwater that will not, within 100 years, deplete the flow of a natural stream at a rate greater than 0.1% of the annual withdrawal rate.Simply put, it is not connected to surface waters in a significant way over a lifetime. These waters are allocated on the basis of overlying land ownership, and not prior appropriation.While drought can impact non-tributary water due to higher needs, it is not as susceptible to shortages during drought as tributary water.

Water Storage in Colorado

Soil moisture

Streamflow, water from reservoirs, dams and ditches, and groundwater are measured forms of water that a farmer or rancher may depend on. However, moisture stored in the soil is the most critical source of water for plant growth.Many irrigators report that crop yields suffer when rainfall is limited and the only source of water is irrigation, and it goes without saying that rangeland production is entirely dependent on soil moisture.

Following dry winters or summer droughts, soils may be dry in the top layers with moisture only in deeper layers. Following extended drought it is possible the opposite is true, that soils may be dry in deep layers and wet only in the top few inches following a light, or even moderate rain, or irrigation. There are three critical terms related to soil water:

1) Field capacity

The situation when a field has filled and excess water has drained out by gravitational pull. Air occupies the large pore space. Water coats the soil particles and organic matter and fills the small pore space. A handful of soil at or above field capacity will glisten in the sunlight. In clay dominant and/or compacted soils, the lack of large pore space slows or prohibits water movement down through the soil profile, keeping soils above field capacity for a longer period of time and limiting plant growth.

2) Permanent wilting

The situation when a plant wilts beyond recovery due to a lack of water in the soil. At this point the soil feels dry to the touch. However, it still holds about half of its water; the plant just does not have the ability to extract it. Plants vary in their ability to extract water from the soil. Notably, the plant will not recover unless water is added to the soil.

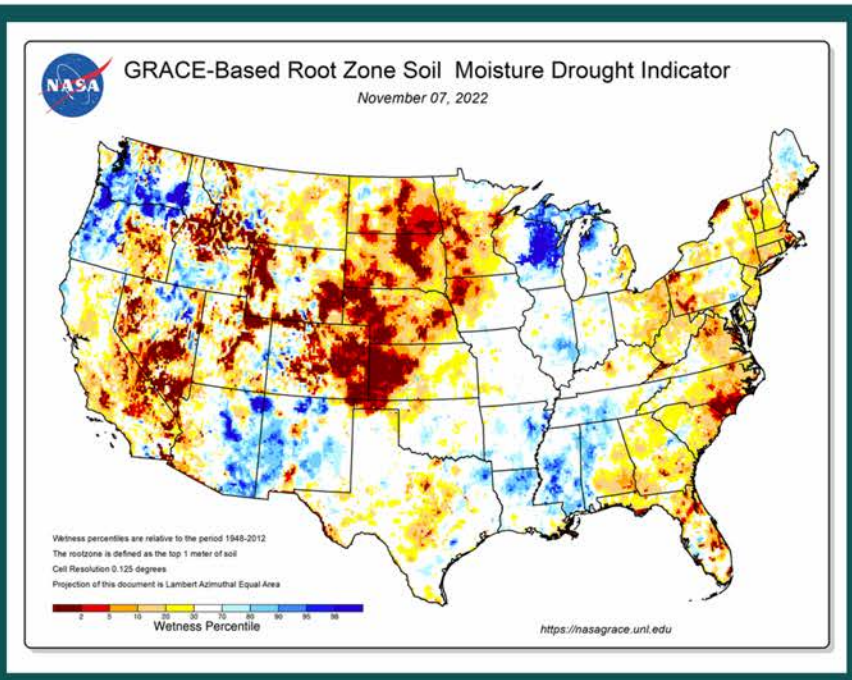
3) Available water

The amount of the water held in a soil between field capacity and the permanent wilting point. This represents the quantity of water “available” or usable by the plant. Note that the amount of available water is low in a sandy soil. Loamy soils have the largest amount of available water. In clay dominant soils, the amount of available water decreases slightly as capillary action holds the water so tightly that plants cannot extract it.

Water Storage in Colorado

Soil moisture, continued

Dry soils tend to resist wetting. It can take several, slow precipitation or irrigation events to condition soil to take in water after becoming severely dry. Drought combined with high heat can make soils 'oven dry' - where most or all of the soil water is gone. In these conditions, the first water a soil takes will fill the soil to the permanent wilting point. Only then will additional moisture become available to plants. This explains why rains after drought can sometimes appear to have no impact on the plant condition - the soil takes its share first.

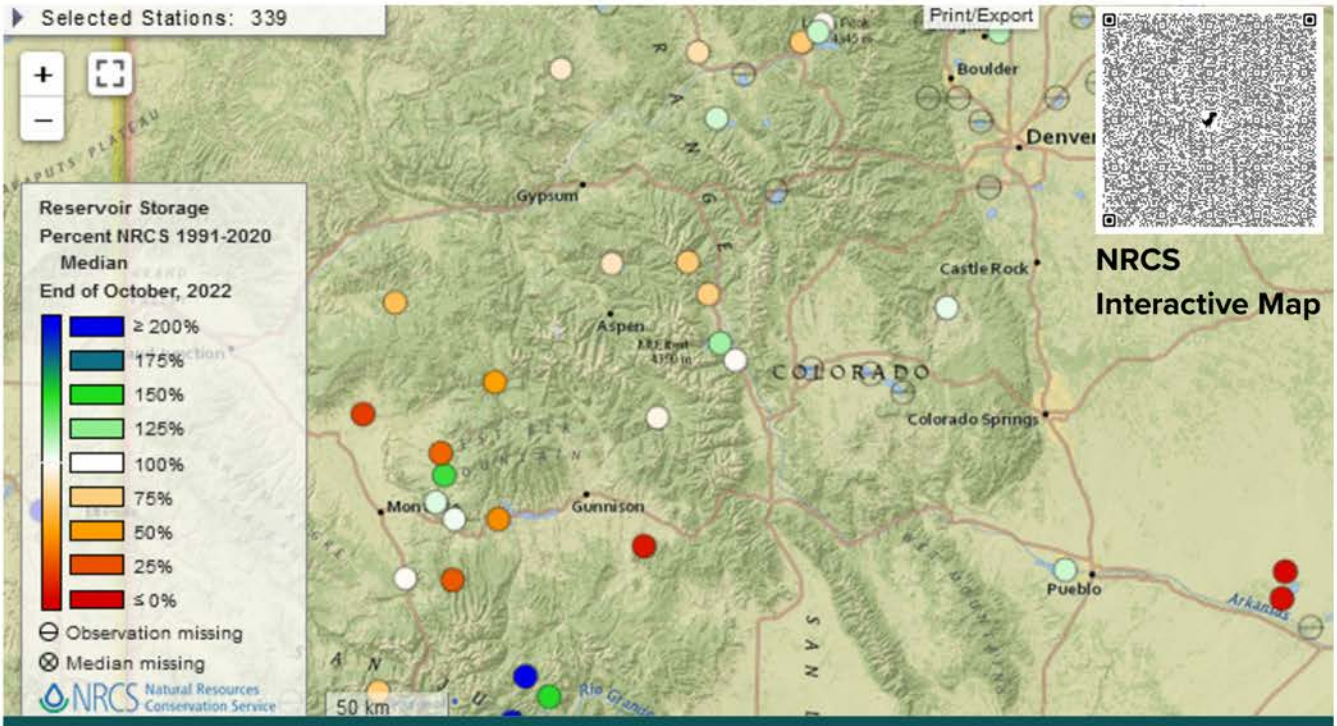


Scientists at NASA's Goddard Space Flight Center have developed the satellite-based GRACE map product that can be used to view soil moisture estimates. Users can also look at forecasts (See Appendix 5).

Reservoir Forecasting

Water availability also depends on reservoirs. Managing entities– including the United States Army Corps of Engineers, Bureau of Reclamation, and reservoir companies– are the best predictors of reservoir fill levels. In addition, these entities would be the most aware of any unique circumstances which may impact fill levels, such as when reservoirs will not fill because they are in need of maintenance or due to water needs upstream and downstream.

Water Storage in Colorado



Using the NRCS Reservoir Storage Interactive Maps
The interactive map allows users to click on a specific reservoir to see current fill levels. The colors represent the range of fill levels of specific reservoirs. One can also click to view them individually.

Reservoir Forecasting, continued

Storage levels of major reservoirs can be viewed on the Bureau of Reclamation's website (See Appendix 5). For smaller basins, use the NRCS's National Water and Climate Center Reservoirs Storage Interactive maps (See QR code).

Water delivery amounts and storage can be unpredictable and depend on many factors such as volume to distribute water, available storage, water rights, and beyond. It is essential that producers are in touch with their ditch company as the best source of information, as well as being a partition member to ensure infrastructure is maintained and updated. Critical periods by irrigated crop

If a producer does not think they will have enough moisture for a particular crop, it will likely influence planting and management decisions. In Strategies we've included information on water use by crop and season needs by crop. If one anticipates a lack of water, look for flexibility in terms of cropping decisions.

Climate, Drought, and Trigger Dates

Triggers for decision making by crop

As discussed above in the Making A Drought Plan chapter, managing well in drought means both taking actions to improve long-term preparedness and making decisions during drought to respond to conditions. Knowing when to make these "responses" decisions, and feeling confident in taking action, is one of the most challenging aspects of managing during drought. A "trigger date" combines a calendar date, with a threshold condition that can be observed. Thus, trigger dates enable a producer to base decisions on what one can observe, rather than what one hopes will happen. If a date and condition are defined, and there is a specific action already tied to that indicator, a producer does not have to think about what they have to do if a condition is or is not met. The 'what to do' is already defined based on whatever criteria the producer has previously specified.

In many cases, we can reasonably specify dates and conditions in advance because of known relationships between the timing of precipitation, soil moisture, temperature, etc, and critical cycles impacting crop or forage production (Crop critical cycles are described in the Drought Strategies section of this book). In other words, some criteria are reasonably predictive, even if future conditions are unknown. "Triggers" can help with decisions in drought such as deciding if, where, and what to plant, the cost-effectiveness of nitrogen application to dryland crops, or the probability of need for additional forage, culling, etc.

Below we've included information on known critical dates for crop and forage production in the state that could be used in drought planning.

Triggers for Decision Making by Crop

Critical Periods for Irrigation Supply

For irrigation-dependent crops, the most important questions are, what are my crop needs (water and fertilizer), and when will I know if I can meet them?

A producer's ditch and/ or reservoir company is the best source of information on allocations, and has the final say. However, using known relationships between snowpack, weather and runoff, producers can assess likely scenarios for streamflow volume in the spring before the growing season.

Snowpack is a major driver of streamflow volumes, but spring moisture can change projected streamflow volume, even after peak snowpack has occurred.

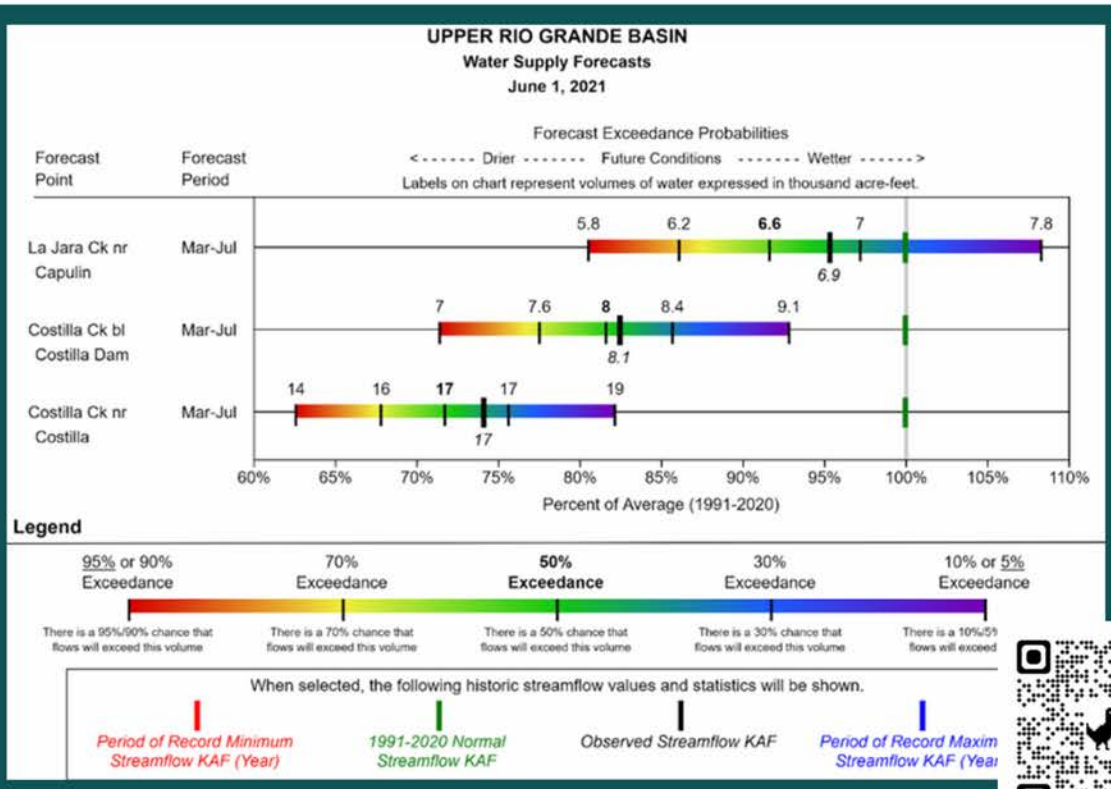
Irrigation Supply - In Brief

- Streamflow represents the net outcome of many natural and man-made influences, including precipitation, snowmelt, groundwater infiltration and recharge, evapotranspiration, irrigation diversion, and reservoir storage. Forecasts represent 'naturalized' streamflow - what would flow down the river if there were no reservoirs or diversions.
- Snowpack is the largest driver of streamflow, but base streamflows, precipitation and soil moisture are also significant.
- There is no one point where a streamflow outcome is guaranteed, but the range of possibilities narrow as spring approaches.
- If streamflow forecast is below normal volumes, it becomes less likely that volumes will return to normal and takes more precipitation to do so as spring approaches.
- Rather than a specific cut-off date, forecasters recommend examining the range of possibilities at any given point in the year. Water Supply Forecasts (see below) inform possible scenarios and show the likelihood of certain outcomes.
- Local knowledge and experience provide valuable insight in assessing future streamflow scenarios.

Critical Periods for Irrigation Supply, continued

Generally, however, the later it is in the spring, the less opportunity there is for a big change. For example, it takes more precipitation to change the trajectory of a low snowpack year as spring progresses, so the likelihood of low volumes is higher. However, there is no one single point in time where forecasters can guarantee low or high streamflow.

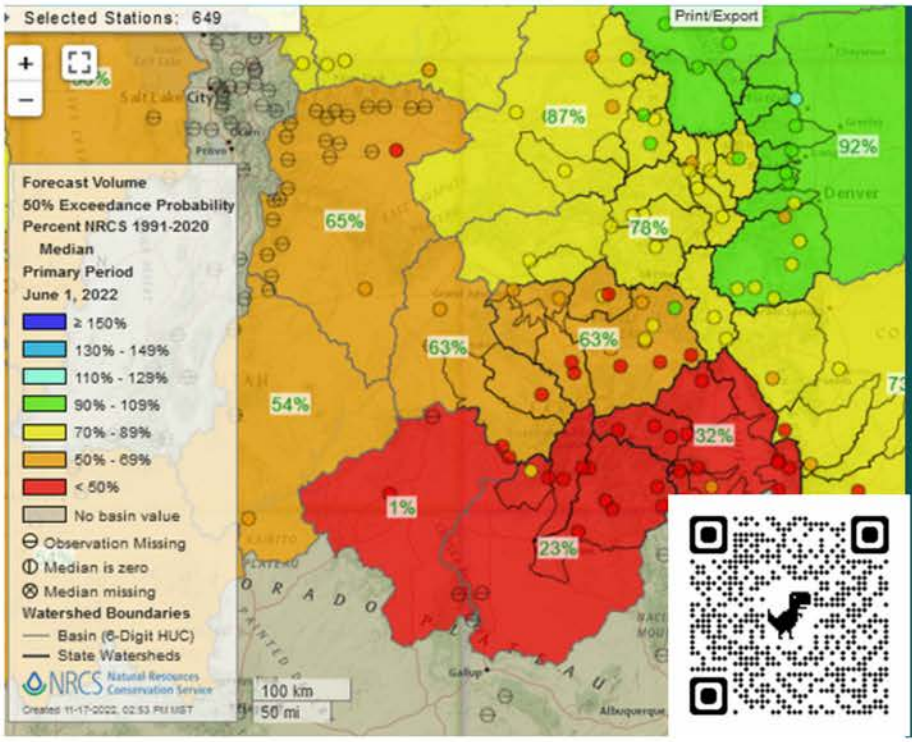
Instead, NRCS creates a variety of products to view streamflow forecasts and probabilities, updated in near real-time. The NRCS National Water and Climate Center streamflow forecast interactive map and the water supply forecast chart can help inform scenarios for spring and summer streamflow volumes. Official streamflow forecasts are produced monthly, and unofficial "guidance" forecasts are updated daily for selected points to provide insight into how things may change in before the next official forecasts are released. Streamflow forecasts made by the USDA-NRCS use a statistical model that integrates base streamflow, snowpack, and observed precipitation and represent "naturalized" streamflow volumes (what would flow down the river if there were no reservoirs or diversions). They provide the likelihood of a range of possible outcomes for the season (called exceedance probabilities).



Using the Water Supply Forecast Charts

NRCS produces Water Supply Forecast charts (See QR code) to help assess the likelihood of streamflow volumes going into spring. Users can select the basin, publication date, forecast period, etc, and compare how observed streamflow compares with median, as well as probabilities that streamflow will exceed or be below historic levels. For example in the chart below, for La Jara creek, on June 1 there was a 30% chance that volumes exceeded the median. Conversely if drier than normal future conditions occur the 70% exceedance forecast may be more likely. These charts enable users to view data-informed scenarios of what streamflow volume may be like for the upcoming growing season.

Triggers for Decision Making by Crop



Using the Streamflow Forecasts Interactive Map

The Streamflow Forecasts interactive map (See QR code) provides another way of viewing the probability of exceeding the median based on date. Users can specify the probability, date and observe the basin. The numbers/ colors on the map represent streamflow volumes at the specified exceedance probability. In this case, in the red basins, there is a 50% likelihood that streamflow volumes will exceed 1-32% of median volume. In other words, the likely outcome is not very promising for average flows in this example.

USDA United States Department of Agriculture
Natural Resources Conservation Service

Critical Periods for Soil Moisture - Dryland Crops

Critical periods for dryland crops occur at the time of planting, green up (late March/ early April) and floral initiation (May or early June depending on spring temperatures).

At these junctures, producers can make strategic decisions based on soil moisture.

At Planting

- The dryer the conditions, the deeper you plant.
- If the seed is planted too deep, it will run out of energy before emergence.

Spring Green Up: Late March/ early April

- Depending on soil moisture or lack thereof, there may be opportunities to reduce financial losses by choosing to top dress winter wheat (or not) with nitrogen.

Floral Emergence: Early June

- During floral initiation, if there is not enough soil moisture to make moist pollen, there is the opportunity to cut losses and not apply nitrogen.

Crop insurance is another commonly used tool. Deadlines vary based on the crop and location. Producers can review potential payouts at the Risk Management Agency's website (See Appendix 5).

Triggers for Decision Making by Crop

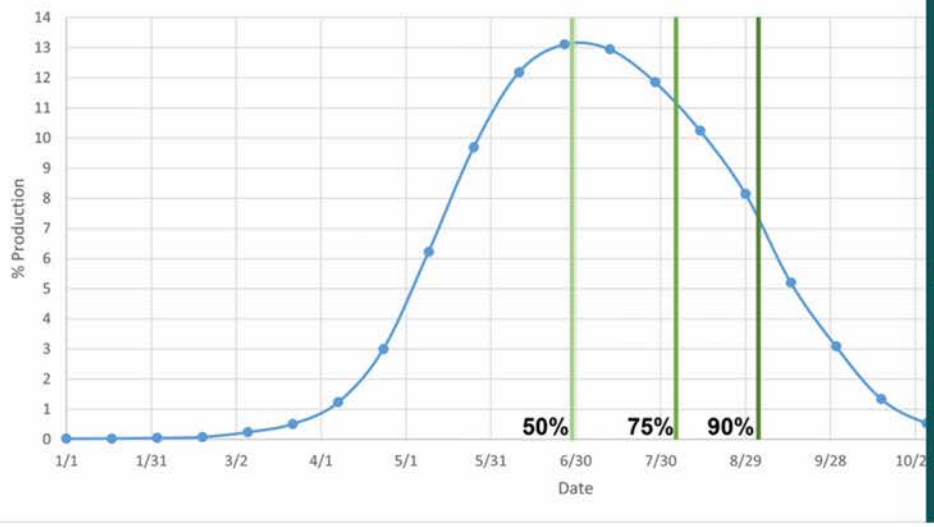
Critical Growth Periods on Rangelands

Rangelands, unlike many other crops in Colorado, rely exclusively on precipitation that falls from the sky rather than supplemental irrigation. Thus, understanding the relationship of timing and amount of precipitation and forage growth is one of the best tools in the toolbox. All precipitation is not the same in terms of rangeland forage production, however. There are critical windows in which having, or not having adequate soil moisture will make or break overall production. Below are key points for both the eastern plains and western slope.

Rangeland Production - In Brief

- Spring (i.e., April - May) soil moisture is critical for grass production on rangelands in eastern and western Colorado.
- Dry soils in spring limit overall production
- Grass growth is limited by moisture, temperature, and daylight hours.
- Monsoonal moisture in July and August can contribute to improved quality and vigor of grasses or prevent mortality of grasses, but doesn't contribute substantially to production overall.
- Dry spring conditions provide early warning of rangeland production deficits.
- 'Banking' on late season moisture is not a reliable strategy on the eastern plains or western slope.
- Soil moisture is likely more important than precipitation to predicting grass growth.That is, a full soil profile can carry plants through a dry summer whereas it is hard for precipitation alone to keep grasses growing when starting with a dry soil profile in the spring.

Critical Growth Periods on Rangelands



Generalized Forage Production Growth Curve as Percent-of-Total for the Western Slope

Green lines represent the average date by which 50%, 75% and 90% of the forage is produced.

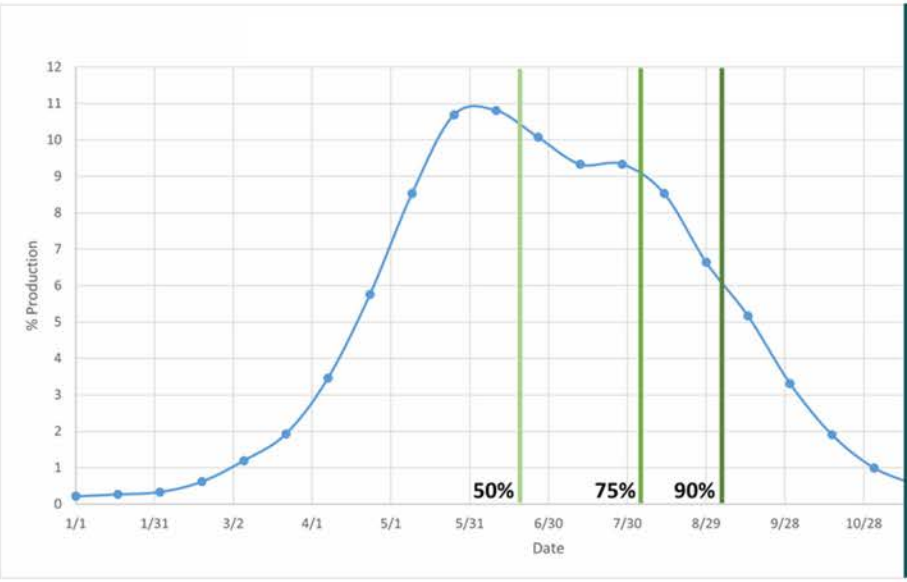
Figure: Grace Campbell, the National Drought Mitigation Center

Eastern Plains

Summer precipitation patterns on the plains follow a distinctive 'bell curve' pattern.Most of the precipitation falls during the summer (70% or greater of seasonal precipitation), with little precipitation during the winter months. Grasses have adapted their growth pattern to fit the rainfall and maximum daylight pattern. In addition, the eastern plains have both warm and cool season grasses, expanding the temperatures within which rangeland forages can grow. Cool-season grasses grow best between 50-75 degrees, whereas warm-season grasses grow best between 75-95 degrees. Not surprisingly, the bulk of production on the eastern plains comes from warm-season grasses, whose growth is driven by spring & early summer moisture. Recent studies [14] have found that looking at phenomena such as La Niña/ El Niño is reasonably predictive of forage production and livestock weight gain on the eastern plains (La Niña/ El Niño combined with the Pacific Decadal Oscillation prediction 70% of livestock weight gain in data collected over a 80 year period near Nunn, CO).

Moisture received up to 30 days prior to peak grass growth is the best predictor of total production on the plains. As day length gets longer and peaks, summer plants focus on growing as much leaf and stem as possible. Then the shortening day length triggers plants to shift energy from growing leaves to making seed heads, setting buds for next spring, and storing energy for winter survival. Therefore, if moisture is not received in the spring/early summer, late season moisture is unlikely to make up for the deficit.

Critical Growth Periods on Rangelands



Generalized Forage Production Growth Curve as Percent-of-Total for the Eastern Plains

Green lines represent the average date by which 50%, 75% and 90% of the forage is produced.

Figure: Grace Campbell, the National Drought Mitigation Center

Western slope and Mountains

In western Colorado there is more variation of when growth peaks by elevation, but despite this, the majority of cool season growth will occur before the end of June. Lower elevations on the high desert of the Colorado Plateau may peak by May, most elevations peak in June similar to the Eastern Plains but higher mountain elevations can peak in early July.

Grass production on western slope rangelands is dominated by cool-season grasses which reflects the historically more reliable timing of precipitation in the fall and spring. Monsoonal moisture between June and September can increase growth of forages and favors warm season grasses which are a minority of grasses in Western Colorado. Cool-season grass production is more influenced by precipitation between October-May. Despite major differences in both plant community and precipitation patterns from the plains, like the plains, west slope forage production is most responsive to spring soil moisture.

Elevation plays a large role in when grasses mature and grazers can use this to match vegetative growth or plant dormancy to their advantage. In low elevation deserts, grazing can be saved for winter while at high elevations grass growth will peak in July.

Consider

- How much effective moisture has been received?
- What does the soil water profile look like?
- How rapidly, or slowly, are the plants growing?

Critical Growth Periods on Rangelands

Table: Key similarities and difference among east and western rangelands in Colorado

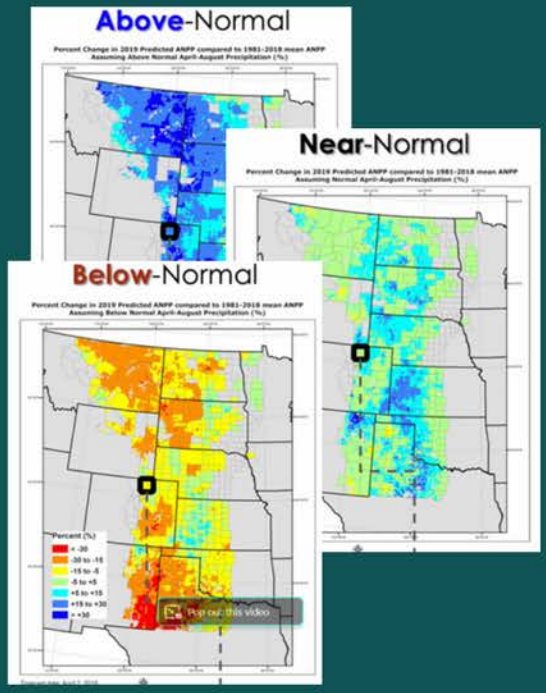
Eastern Plains	Western Slope
Dominated by warm season grasses with a strong component of cool season grasses, thus expanding the temperatures within which forages can grow.	Dominated by cool season grasses, which grow best when temperatures are below 75 degrees F. This limits the window of growth on the western slope.
Grass production is highly variable, depending on growing conditions. It can vary from less than half to well above the long-term average. E.g.) 800 to 2,400 lbs. in the same plant community	Production is fairly stable compared to the eastern plains. However, it is much less productive on average. Average production is 376.3 lbs./acre/year. The western slope has large differences across the landscape, with some sites producing much more and some much less based on site properties (soil, elevation and aspect). Production on sites can range from 120 lbs./acre to 1,500 lbs./acre in the same year on different sites.
Future projections are that the eastern plains will experience warmer and longer growing seasons, increased variability (swings from year to year in terms of production and precipitation), and more extreme events [13]. Producers may need to adopt strategies to improve flexibility.	Preliminary observations indicate the amount of available rangeland forage has declined since 1984 [15] and is projected to decline further with warmer temperatures [3, 4, 16]. Producers will need to anticipate the same areas producing consistently less forage compared to historic norms.
More uniform elevation. Monthly summer grass growth patterns across the plains all peak in June/early July, regardless of soil type or location: north or south, near the mountains or the eastern border.	Rangelands go from 4,000-14,000 feet, although cattle are not typically grazed above 12,000. While peak growth differs among these elevations, generally growth has peaked at all elevations by early July.

Key Similarities
• Rangeland grass grows fastest in the spring and early summer, and slows dramatically after late June, regardless of late season precipitation. The exact date varies by location. • Late season rains can improve forage quality, and provide the opportunity for grasses to grow roots, but does not contribute significantly to production. • Because of rangeland forage growth curves, if soils are dry in the spring, late season moisture is unlikely to make up for the deficit in production.

Using Technology to Understand Forage Production

Grass-Cast for the Eastern Plains

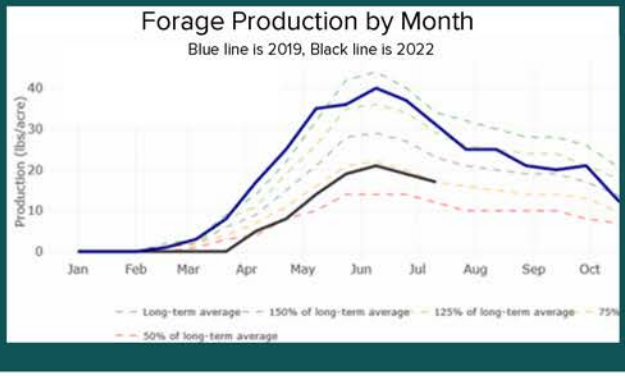
Grass-Cast is an end of season, total production forecast model that can help ranchers see how much grass production might be lying ahead (See Appendix 5). The tool uses information about soils, plant communities, and up-to-date weather information. It combines this with three future possible precipitation scenarios (above, near, and below average), forecasting grass growth for each situation. Users can zoom in on their location of interest to get a more specific forecast for that area. Grass-Cast always projects to the end of August: it does not reflect how much production is currently available. Grass-cast is depicting total production, not grazeable production. Also Grass-Cast cannot know how much or what types of plants are growing in any particular place, nor how much of the moisture soaked in versus ran off or evaporated. Production forecasts must be interpreted with knowledge of local conditions. Go to https://grasscast.unl.edu/ for forecasts, how to use the maps and more. Webinars and informational videos on Grass-Cast are available.

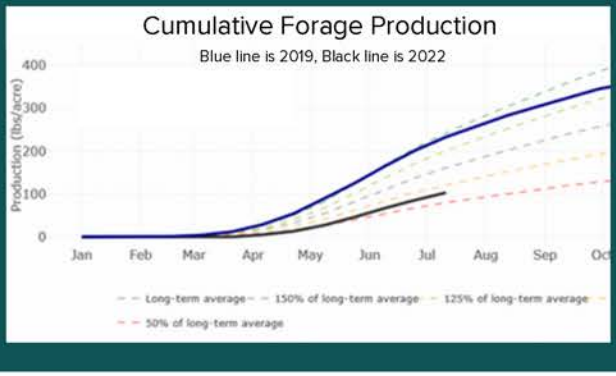


The Rangeland Analysis Platform for the Western Slope

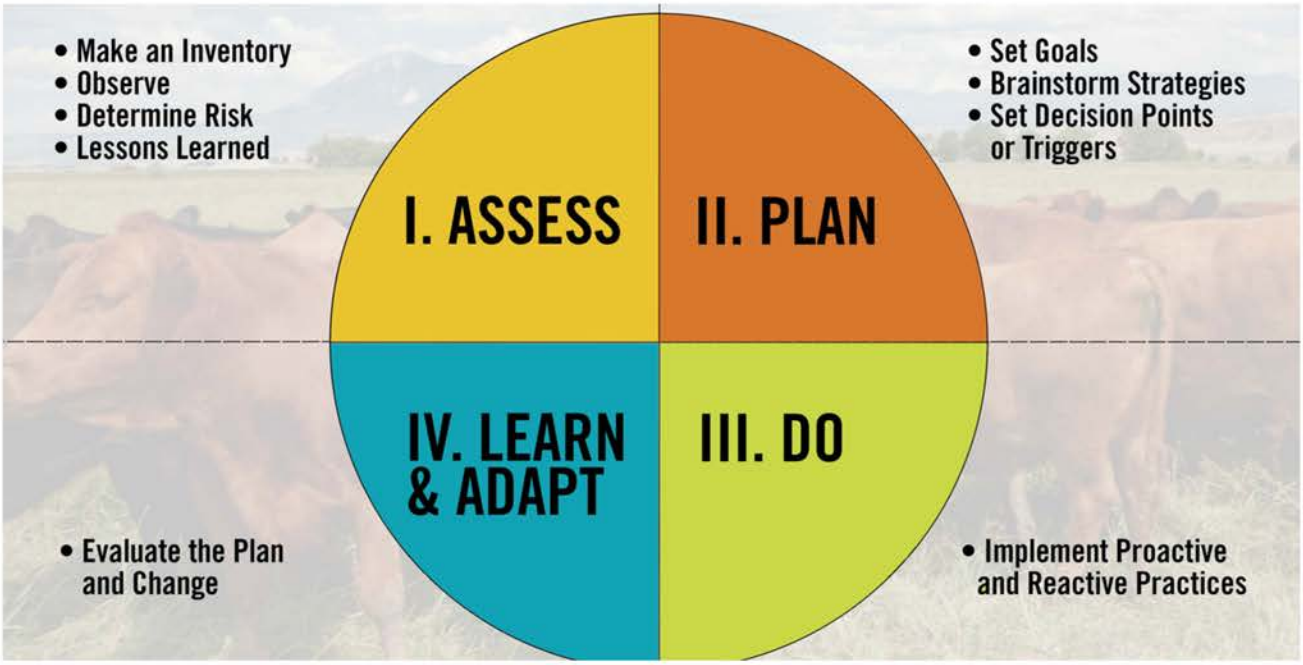
Grass-Cast does not currently expand to the western slope. However, uncertainty about forage forecasts can be reduced by 1) paying attention to local conditions and how they relate to grass growth, and 2) applying this knowledge with available technology. The Rangeland Analysis Platform (See Appendix 5) is a web-based tool that uses a forage growth prediction model to estimate forage growth in near-real time (every 16 days). One can use it to examine how a current year compares with other years to understand production and how much (or how little) can be expected. When combined with the knowledge that the bulk of the volume is produced before the end of June, and June is typically one of the west slope's driest months, users can get more information on likely cumulative production based on how growth is tracking in spring/ early summer. The below graph (left) shows growth in lbs/ acre by month over the year for an area in south-central Colorado. Users can see how forage growth is fastest in the spring, peaks, and then the growth rate decreases.

Users can also view cumulative growth (right). By comparing known high, low, or average years, users can see how the current year is tracking. The cumulative graph also demonstrates the importance of rapid spring growth for overall production.





Drought Strategies



Introduction

This section contains information on a menu of drought response and preparation strategies, organized by production system (livestock and range versus crops) and based on short-term response versus long-term preparedness. Short-term strategies are what a producer can do immediately when drought strikes, or when drought is imminent. Long-term strategies are actions that help prepare the operation for drought by changing the physical and planning characteristics of the operation over time. After assessing the operation and available resources, identifying drought-specific goals, and determining critical conditions and trigger dates, the next step in the planning process is to identify potential risk-reduction strategies. Importantly, these strategies should be linked to the specific goals determined in the second step of the planning process. If goals are "where is a producer trying to go", strategies are the "how" to get to there. Strategies are tied to triggers, which specify "when" to act in response to conditions.

Because producers know their operations better than anyone, they are the most qualified to identify strategies to reduce drought risk. Due to the diversity of agricultural operations and landscapes in Colorado, there is no "one-size-fits-all" approach to what strategies are appropriate or useful for a producer.

Additionally, we have found that the impacts of drought are not always only or even exclusively physical in nature. For example, for some operations, reducing the impact of drought might address succession issues with a farm or ranch family (covered in the risk management section). For this reason, our strategies are fairly broad.

In This Section

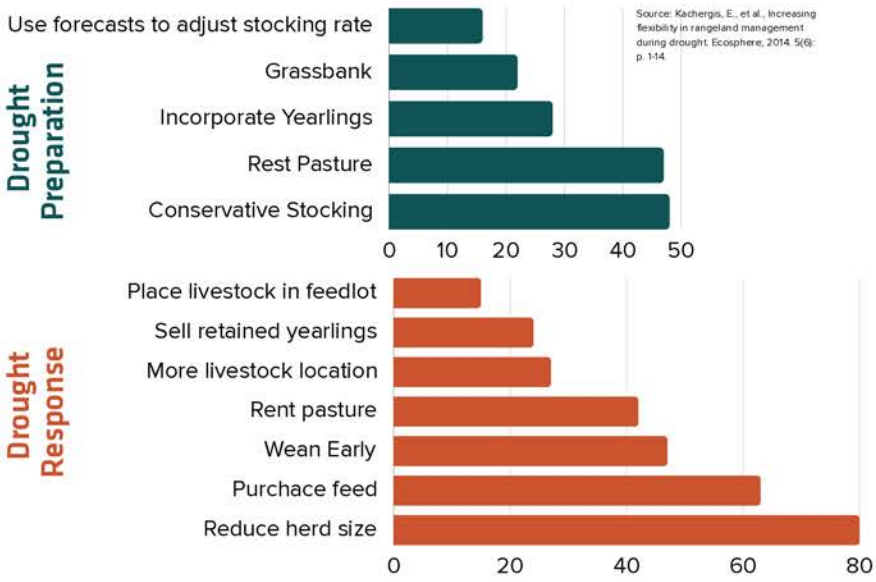
Drought Strategies

Range & Livestock

Introduction

Most ranchers in Colorado and throughout the western United States have experience with drought, and they use both reactive (short-term) and proactive (long-term) strategies to manage the impacts of drought on their operations. [Figure below [17]. Long and short term drought management strategies are interdependent and reinforce each other. In other words: the more prepared a producer is for drought, not only are they better equipped to respond and persist through acute drought conditions, but they are also better prepared for future droughts. For example, if a rancher implements a long-term strategy– such as maintaining flexibility in their herd composition– they can respond more easily to immediate drought. Thus, the producer can both de-stock without impacting the base herd and reduce the need to buy hay. While buying hay is a common drought-management strategy, it can be expensive and may ultimately undermine financial viability.

The ultimate goal of drought planning is to expand the number of strategies in a producer's toolbelt so that they may have more operational flexibility while reducing risk, maintaining economic viability, and acting as stewards of rangeland and agricultural resources. The following section provides examples of common strategies.



Results from a survey of 307 ranchers in Wyoming . Ranchers have an array of preparation and response strategies for dealing with drought. A greater majority use response versus preparedness strategies [17].

"The man who has a short pasture needs a rain much worse than his neighbor who has ample forage on the range. But when rain comes, it does the least good for the fellow who needs it most."

- E.J. Dyksterhuis, USDA Soil Conservation Service

Drought Strategies

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Rangeland Management Before Drought

Rangelands that are healthy and in better condition before drought have more resilience to drought conditions (Howery 2016) because they generally:

1. Have a higher diversity of species,
2. Feature plants with more robust root systems and are thereby are more able to extract soil moisture, even when soils are dry, and
3. Have higher amounts of litter (i.e., plant material) which cools the soil surface and helps retain moisture.

Since different plants are impacted in different ways by drought, a higher diversity of species means that there is a higher probability something will grow and be successful in adverse conditions. A combination of high plant diversity, more robust root systems, and high litter often results in a more resilient landscape and higher forage production during drought.

Further, improving rangeland condition is nearly impossible during a drought on arid rangelands. This is because plants may not be growing or producing seeds, and there is little opportunity to build out root systems. There may also be less litter deposited on the soil surface due to the lack of plant growth. Thus, the ideal opportunity to improve range conditions occurs when rangelands are not currently being impacted by drought. This underscores the importance of maintaining proper grazing management before drought conditions are present.

In order to manage for drought-resilient rangelands, producers need to develop a grazing strategy that accommodates what plants need to grow and thrive. From a plant's perspective, photosynthetic leaf area provides the energy source for plant growth, and reductions in leaf area suppress both plant photosynthesis and root growth [18]. Thus, maintaining adequate leaf area is critical.

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Stocking Rate and Rangeland Drought Resilience

Stocking rate is the 800 pound gorilla driving intensity of defoliation and therefore leaf area. Stocking rate is the number of animals per area per time. In other words, it is the total demand for forage. Since stocking rate is a rate, it can be lowered or increased by modifying the number of animals, or the duration they are present in a given area. In other words, if we compare two areas that are the same size and have the same productivity, and same number of animals, but different grazing periods (longer and shorter) they have different stocking rates. Carrying capacity is the stocking rate that is sustainable over time per unit of land area [19]. This depends on the productivity of the site/ land, and is discussed in more detail below. For information on stocking rate calculations, see Determining Your Stocking Rate (See Appx. 5) or a range of other Extension resources [20, 21].

Stocking rate is a dominant driver of both forage use and the types and amounts of plants present on a rangeland over the long-term.

A general and widely accepted goal is to leave 50% of aboveground production ungrazed, measured in pounds per acre, not plant height. This helps ensure root growth, adequate ground cover, and litter production (see Why 50% box below (pg.67)). Twenty-five percent of the total production is subject to environmental losses (trampling, defecation, urination, etc.) while the remaining 25% is allocated to animal consumption.

Additional tools to manage grazing are deferral of grazing and rest, but these tools will not be effective if the stocking rate is too high. Regardless of grazing strategy, demand for forage by grazing animals (i.e., stocking rate) cannot exceed the supply of forage available. Ranchers need to know their forage supply relative to forage demand (see section below), how much it fluctuates year to year, and how it responds to timing of precipitation (discussed in Triggers (pg.54) for Colorado rangelands).

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Why Stocking Rate Is Important In Drought

Producers have no control over the timing or the amount of precipitation, but they can control how much leaf area they leave behind. As described in the above Climate section, some parts of Colorado do not typically receive the bulk of their moisture during the growing season (i.e., the west slope, where productivity is driven by spring soil moisture). What can be controlled is the intensity of defoliation by managing stocking rate and the grazing period. A producer can also optimize opportunity for plant regrowth by allowing recovery periods during conditions in which grass plants are physiologically able to recover. Further, a rancher can control livestock distribution and observe use of forage by livestock and respond appropriately. While spring soil moisture drives volume in terms of forage production, late season moisture is important for survival and root maintenance, especially on the Colorado Plateau. Grasses can die or lose strength vigor in response to dry and/or hot conditions because they have relatively shallow roots [22, 23].

Using Ecological Site Descriptions in Drought Planning

Ecological Site Descriptions are tools that describe the ecological potential (based on soil, site, and weather/climate) of land areas (See Appendix 5). They can be resources for range management. Grouped by general soil and climate characteristics, ESDs include site-specific management information about natural vegetation, weeds, forestry, grazing, wildlife, and dynamic soil properties. Areas of land are classified by their distinctive types and amounts of vegetation as well as how it responds to management and natural disturbances. ESDs can help a land manager determine if a site is close to potential, the suitability of the land for their intended use, or what strategies managers can use to reach their goals. Unfortunately at the time of writing, many ESD's for the western slope of Colorado are still unavailable. ESD's are published online and can be found by searching for 'Ecological Site Descriptions'.

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Understanding Forage Supply & Matching Supply & Demand

Determining animal demand is usually fairly straightforward, but determining rangeland forage supply is more challenging. Forage amounts change from year to year, and vary based on soil and site characteristics. There are multiple sources of information to help producers and managers assess forage supply to help arrive at a proper baseline stocking rate. No way of estimating has 100% accuracy. Instead, there are pros and cons of each knowledge source, presented below. Combining methods, knowledge, and judgment is likely the best approach.

Exclusion Cages		**Rangeland Analysis Platform or CSU App**		**Ecological Site Descriptions**	
Pros	**Cons**	**Pros**	**Cons**	**Pros**	**Cons**
Provides in season monitoring opportunities. Specific to the management unit, accurate, and distinguishes between what grew and what was used [47].	Time consuming. Needs to be repeated because of yearly fluctuation in precipitation. Location influences results. Many cages across the landscape may be needed to capture variability [47].	Relatively fast and accessible. Can compare with historic values. Can compare data from the Rangeland Analysis Platform and NRCS estimates from Web Soil Survey in both apps.	Raw values may not correspond to reality. Calibrating with judgment, consultation with local experts, and local data, is highly needed. Percent change indicated may be more reliable than raw production values.	Relatively fast and accessible. Lots of information about the plant community and grazing resources.	Gives production values as low, average and high, rather than specific years. Doesn't capture all possible plant communities, and may not be available in all areas. Interpret values with judgment, and consultation with local experts.

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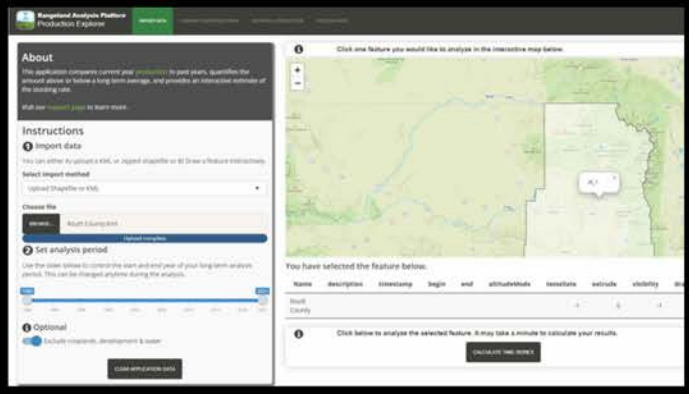
Resources for Assessing Production: Satellite-based Tools

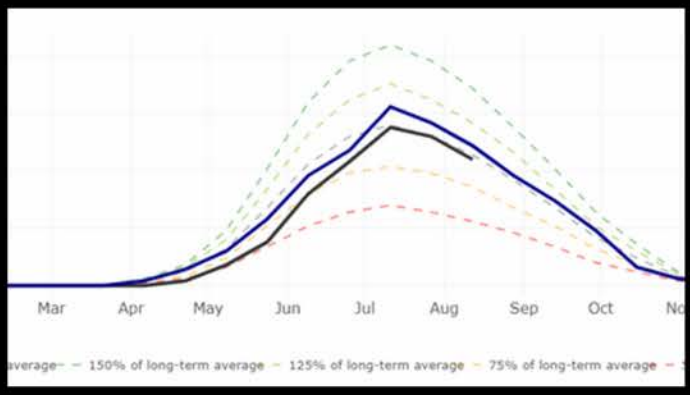
Satellite-based tools such as the Rangeland Analysis Platform (See Appendix 5) may help provide estimates of production on rangelands. This tool uses satellite data going back to 1986, along with a forage growth prediction model that researchers have correlated with hand-collected data. The app allows a user to see how much rangeland forage fluctuates year to year in a particular area of land, how current estimates track with overall production, and get near real-time estimates in the growing season. CSU Extension also developed an app (See Appendix 5) to assess supply relative to demand in years of low (bottom 10% of years), average, and high (top 10% of years) precipitation. Users can use Rangeland Analysis Platform data, or Web Soil Survey data (See Appendix 5) with the CSU Extension app. Both apps have how-to videos on their websites.

Using the Rangeland Analysis Platform

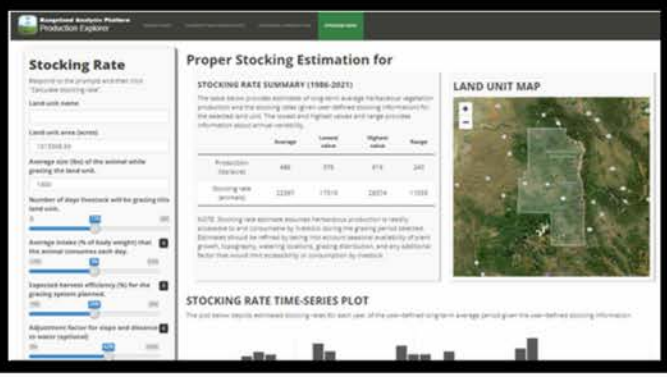
1. Import or draw area of interest (can simply draw or use a KML or shapefile)



2. View current year production relative to other years (available in cumulative or by month)



3. View stocking rate tab, and adjust conditions such as average size (lbs) of the animal, average intake (% of body weight), number of days livestock will be grazing this land unit, etc.



Drought Strategies

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Resources for Assessing Production: Exclusion Cages

Exclusion Cages

One can set exclusion cages for the growing season to protect grasses from livestock grazing. A person can learn a lot about how much grass has grown, or not grown, and how much has been removed by the livestock by just looking at the heights and productivity of the grasses inside the cage compared to areas a distance away from the cage. Clipping and weighing the production inside the cage can help determine pounds of production and calculate stocking levels. It is important to use a particular clipping frame size and method of weighing to easily convert the sample to pounds per acre. The NRCS or the local Extension office may have clipping frames and scales that they will lend out. They may also be able to provide general information on average rangeland production for a particular area.

Exclusion Cage

Keeps graziers out to measure total biomass produced in a growing season.

Range Hoop

Clip forage to ground level using a hoop allows for calculations of production per acre. Using a known size of range hoop or clipping frames allows for easy calculations of pounds per acre.

Dry and Weight the Forage

Dry clipped forage in a paper bag and weigh. You can use a kitchen scale or a hanging scale. Don't forget to subtract the weight of the bag!

Example : 9.6 ft2 Plot

Conversion Factor:
Grams collected X 10 = pounds per acre

Radius:
1.75 feet Circumference of Hoop = 10.996 ft

Dimensions of Square Plot:
3.098 ft x 3.098 ft

Drought Strategies

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Using Forage Estimates

Once a producer has their baseline estimate of available forage and variability of production, they need to convert total pounds available to pounds available for grazing. As discussed earlier, 50% of average total production needs to be left behind to maintain the health of the plant community and protect the soil. Of the remaining 50%, half of that will be trampled, defecated and urinated on, eaten by small animals and insects or otherwise lost (sometimes referred to as environmental losses). That leaves 25% of the total production to be allocated to livestock. Both the Rangeland Analysis Platform and the CSU Extension Carrying Capacity app have a tab to estimate stocking rate based on a user-specific utilization level.After running these calculations, users can then understand what a drought-resilient stocking rate may be. In drought-prone rangelands, the recommendation is to allocate 50-70% of average grazable forage to the cow herd (if a cow-calf operation) and the remaining available forage to a flexible enterprise, such as leasing forage or stockers. This strategy helps to protect the core cow-herd from liquidation and avoid expensive relocation or hay purchases by allocating expected drought production to the cow-calf herd [20, 25]. This is discussed in more detail below.

General Production Trends

New access to data via the Rangeland Analysis Platform allows us to see that the average amount of forage has generally decreased on western Colorado rangelands since 2000 [15], While this observation is preliminary, it is consistent with expectations for forage production based on habitat modeling and experiments for cool-season grasses [3, 4, 16, 26, 27]. This trend is likely driven by already observed increased temperatures, which reduce soil moisture [1, 11]. In western Colorado, it is likely that the average production per acre is declining, so stocking rates need to reflect that decline.

Key Take Homes

- Proper grazing management when not in drought ensures more resilience when drought occurs.
- On rangelands, it is not possible to make gains in rangeland health, soil health etc. during a drought. This underscores the need for proper management beforehand.
- Stocking rate, the demand by grazing animals, per area, per time, relative to forage production, is a principal driver of intensity of use and plant community composition.
- Distribution and observing actual use are in addition to stocking rate key to grazing management.
- On the western slope of Colorado, production of forage has decreased since the 1990's on rangelands.
- Technical support is available from NRCS or CSU Extension to help producers work through the math and create a grazing plan.

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General Production Trends, continued

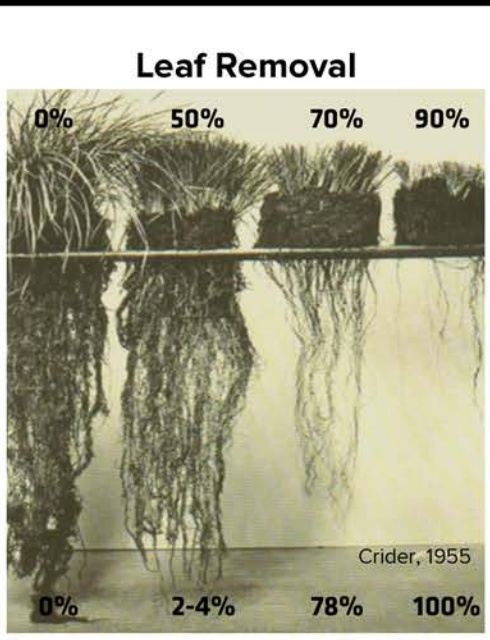
The same analysis on the eastern plains reveals increasing variability in production since 2000, ranging from near 50% of the average to 150% of average. Grazers who utilize a flexible stocking strategy as described above will be prepared to manage and protect their rangelands, financial security, and core cow herd in unstable production conditions.
For more on differences in eastern plains and west slope production, see the Triggers section.

Utilization Triggers

Because conditions can change, even the best plans can result in exceeding the 50% "left behind" threshold. Therefore, it is critical to watch residual forage levels during a grazing period to ensure environmental losses + grazing does not exceed 50%. The percentage of forage that has been removed by grazing animals (i.e., “used”) relative to total produced plus environment losses is called utilization. Observing how much forage has been used relative to what was produced ensures that 50% of total production by weight is left behind, which is what grass plants need to grow and thrive, as discussed above.

Why 50% Use?

- The 50% number is based date that shows that when a plant loses more than 50% of its leaf volume – whether to hail, or grazing, drought, or a mower – root growth is stopped until the leaves can regrow.
- Leaving 50% behind can help ensure that key forage species have robust roots.
- Managers typically allocate 25% of the total production to be allocated to livestock. This is because of the 50% "used" half of that will be trampled, defecated and urinated on, eaten by small animals and insects or otherwise lost. The plant still needs 50% to be left behind.
- If more than 70% of the leaf volume is lost, then almost 80% of the root growth is stopped.
- In drought, managers may need to plan to graze less than 25% of the total production. For example, if a rangeland typically produces 1000 pounds, 500 pounds should be left to maintain plant health. In a drought, if that rangeland only produces 700 pounds, those plants still need 500 pounds to maintain themselves, plant community and protect the soil. Of the 200 remaining pounds, 25% (or 100 pounds) will still be lost to trampling, urinating and defecation, leaving 100 pounds allocated to the animal.
- There are times in drought, or even severe hail, where everything that grows should be left alone to insure survival of the plant community.



Drought Strategies

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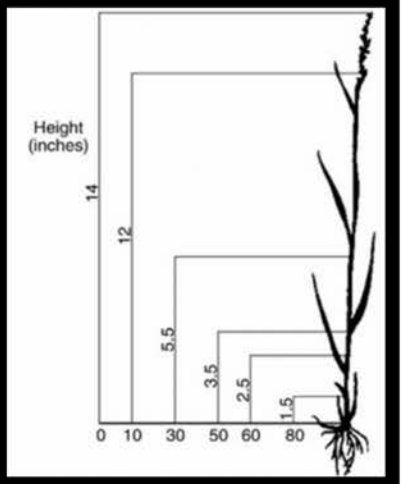
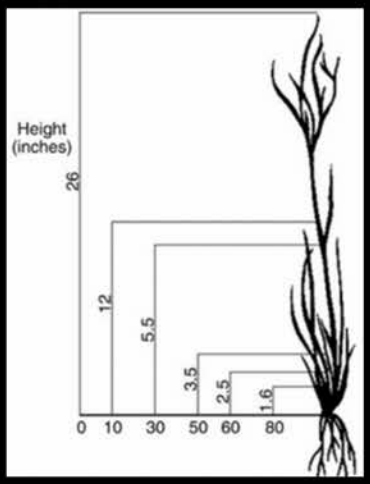
What to Watch on Utilization

As stated above, proper grazing needs to ensure that 50% of the total plant weight (not height) of key species has been left behind. Due to differences in grass species, the height of removal will vary among species, so knowing the key forage species in pastures and rangelands is essential [28]. The tables below shows how height (Y axis) corresponds with percent removed (X Axis) on several grass species.

Use (%) of western wheatgrass as it corresponds to various stubble heights



Use (%) of needle-and-thread as it corresponds to various stubble heights



Percent Weight Removed as a Relationship to Percent Height Removed

The relationship of height and weight on grass plants is not one to one. This is because most of a plant's weight is in the base of the plant.

The graphics to the left and table below show how height and weight correspond.

Table adapted from Montana State University. 1987 and Meehan et al. 2021.

Relationship of Height to Weight

This table shows common species and the height-weight relationship.

To use this table, first calculate the percent of the height of the plant removed by grazing. Find this figure on the top line of the table and then follow that column down to the appropriate species. This figure represents an estimate of the percent of the weight removed.

Available at: https://efotg.sc.egov.usda.gov/api/CPSFile/23663/528_ND_GD_Prescribed_Grazing-Appendix_A_2010

Species	10	20	30	40	50	55	60	65	70	75	80	85	90	95
Big Bluestem	2	6	11	17	23	30	35	41	46	54	62	71	79	89
Blue Grama	2	4	6	9	13	15	17	20	25	28	35	42	53	75
Buffalograss	2	5	7	11	18	21	32	35	38	45	53	62	71	77
Crested Wheatgrass	2	4	7	11	18	24	29	33	38	44	53	60	68	83
Green Needlegrass	2	4	6	11	16	20	25	30	36	44	52	61	71	85
Kentucky Bluegrass	1	3	5	9	14	16	20	26	34	40	47	57	71	85
Little Bluestem	1	4	9	15	23	27	32	37	41	47	53	61	70	82
Needleandthread	1	2	4	6	10	12	15	19	24	29	36	46	56	73
Wetland Sedge	2	5	9	13	18	21	26	31	39	46	54	62	73	86
Prairie Junegrass	2	4	6	9	13	16	18	21	25	30	35	42	55	69
Prairie Sandreed	2	6	11	17	23	30	35	41	46	54	62	71	79	89
Prairie Threeawn	2	6	11	17	26	30	36	42	46	53	61	70	78	89
Sandberg Bluegrass	1	2	4	8	11	14	16	19	24	30	37	46	56	75
Sand Dropseed	1	3	5	8	12	17	21	25	30	35	46	56	68	83
Sideoats Grama	1	3	5	9	14	18	23	27	32	39	47	56	66	80
Slender Wheatgrass	2	6	9	12	17	21	27	31	36	42	51	59	69	80
Smooth Bromegrass	3	6	11	15	19	27	32	37	45	52	58	63	82	92
Switchgrass	2	5	9	13	20	26	30	36	42	50	59	58	76	89
Upland Sedge	2	4	6	10	15	17	21	27	34	41	48	59	73	86
Western Wheatgrass	2	6	11	17	26	32	37	44	50	58	66	74	82	91

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What to Watch on Utilization, Continued

There are multiple ways to observe utilization, ranging from easier to harder or qualitative to more quantitative. The NRCS and Extension rangeland staff can advise on methods. For starters, the visual appearance methods provide basic guidelines (see table below).

Estimated Utilization of Native Rangeland

Utilization measures the percentage of annual herbage production that has been removed by weight. Utilization data, along with trend data, climatic information, actual use data and other information, should be used to adjust stocking rates to meet management objectives.

Slight to Moderate < 40 percent use	A few of the key grazing species have short stubble heights, but most are slightly used or not at all. Height of grazed desirable/key plant species is 65% or more of the same species of ungrazed plants. Animals, particularly cattle, tend to be grouped into small bunches and graze primarily in early morning, late evening and cool times of the day in the summer.
Full 40 to 60 percent use	Stubble heights of key grazing species are not uniform, with varying degrees of grazing between individual plants. Some use of less preferred species. Undesirable species show no use. Height of grazed desirable/key plants is 45 to 20 percent of the same species of ungrazed plants.
Close 60 to 80 percent use	All rangeland shows use and large areas closely grazed. Height of desirable/key species grazed is 20% or less of ungrazed plants of the same species. Heights of desirable/key species are fairly uniform and short. Less preferred species have some use. Greater than 10 percent of low-value species have been grazed. Trampling damage is evident and there is more bare ground than ungrazed pastures of similar type. Manure deposits are readily visible in short distances.
Severe > 80 percent use	Key forage species completely used (as short as grazing animals can bite them). Low-value forages are dominant. Heavy use of less preferred species and low-value species have been grazed. Large areas of trampling effects of concentrated animal use is evident. Manure deposits are readily visible from a distance in non-shrub dominated landscapes. Animals tend to be spread out and are grazing during the heat of the day in the summer.

*Adapted from E.J. Dyktserhuis (1951) and Meehan et al. 2021[28] by R. Bruegger and J. Elliott.

Range & Livestock

Basic minimum height guidelines for introduced/ irrigated pasture

Species	Begin Grazing (inches)	End Grazing (inches)
Alfalfa	6-10	3
Crested wheatgrass	4-6	3
Intermediate wheatgrass	8-14	4
Kentucky bluegrass	4-6	3
Intermediate wheatgrass	8-14	3
Kentucky bluegrass	4-6	2
Reed canarygrass	8	4
Smooth bromegrass	8-14	4

Grass and legume mixes should be grazed in a manner that favors the dominant desired species.

*Adapted from NRCS Field Office Technical Guide [29], and Meehan et al. 2021 [28].

Drought Strategies

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Stocking Conservatively

Conservative stocking or basing the cow-calf herd size on 50-70% of the annual average available forage, enables producers to have increased flexibility in drought because grazing resources are not already maxed out [20]. Economic research has found that allocating 50% of average annual grazable forage to cow-calf enterprises, and 50% to yearling enterprises optimizes profit [25, 30]. Even those who are not equipped to handle yearlings can use a conservative stocking approach to structure their business with flexibility for dry and wet periods. Adding classes of livestock, or groups of individuals, that are easy (both mentally and on the pocketbook) to liquidate during dry periods is one approach.Leasing extra forage in wetter times, adding more rest to pastures and grassbanking (discussed below) are all options worth considering. Over the long-term, it is not cost-effective to be over or even fully stocked relative to carrying capacity, because selling cattle at low prices and buying back at high prices, or buying hay is expensive [31].

Resting Pastures and Grass banking

If rangeland and forage resources are not stocked at capacity (i.e. 50-70% of average annual grazable forage is allocated to an operation), then there are other drought preparedness opportunities, such as resting pastures and grass banking. “Resting” or “recovery” is allowing the grass plants to fully regrow both leaves and roots after a grazing event.This non grazing period can improve the range health and therefore range drought resilience by ensuring the grass plants have the maximum root mass possible to reach moisture and provide energy during dry times. “Grassbanking” is setting a pasture/pastures aside for one or more growing seasons, so they can be used as emergency feed in case of drought.

Drought Strategies

Range & Livestock

Long-term Preparedness

Herd composition/ diversification

It is not economically viable to flex stocking rate with cow-calf operations in response to variability, so another enterprise would be needed to take advantage of high production years and minimize the impact of the bad years. For some, adding a yearling enterprise may provide a way to take advantage of high production years, and reduce stocking rate in drought years . Certainly, the viability of this option depends on production costs and producer comfort level. This strategy does carry its own unique risks and increased production costs [25].

Another consideration is matching cow size to available forage. The average cow weight has increased in the last 30 years from 1000 lbs to 1400 lbs. As a cow's mature weight increases, feed efficiency and reproductive efficiency decreases and feed requirements for maintenance increase. Naturally, supplemental costs per head for hay and range cubes (protein) also increase with body weight. Thus potential costs are lower and they may do better on marginal feed. Producers must make choices on cow size based on their operation's needs and judgment [32].

Investing in Infrastructure

In some cases, forage may be adequate but lack of stock water limits how much of the grass is available for grazing. This can be particularly true when temperatures are high and livestock don't want to travel. Dividing large pastures with fencing may help keep animals from hanging out in their favorite areas near the water as other areas go unutilized. However, neither water development nor fencing are short term, quickly implemented strategies to use to navigate an ongoing drought. Carefully planned and researched, investing in stock water development and/or fencing may be helpful strategies to increase grazing capacity, flexibility, and range preparedness for drought.

Drought Strategies

Range & Livestock

Long-term Preparedness

Investing in Infrastructure, continued.

The University of Arizona's Guide to Co-Developing Drought Preparation Plans for Livestock Grazing on the Southwest National Forests (See Appendix 5) is an excellent guide to collaborative planning with public agencies and navigating the NEPA process on public lands for producers interested in increasing stock water on public rangelands to improve resilience and flexibility in drought.

Multiple Enterprises

Many producers take advantage of the opportunity to add additional sources of revenue to their operation, such as outfitting, leasing land to wildlife enthusiasts, and even agrotourism. While the need for outside sources of income are already evident, it seems apparent that there will be an increasing need to diversify income sources and/or enterprises with additional variability between high production and low production years [33].

Proactive Leasing Agreements (Also in Risk Management)

Proactive leasing may be one way to prepare for drought by expanding the forage base. For cow calf operations, de-stocking and restocking can be expensive and/or not feasible. Long standing and proactive leasing arrangements may be one way to expand the forage base, rather than selling cows. Read more about leasing agreements in the Risk Management Section (pg.100). One can use the Rangeland Analysis Platform or CSU's Carrying Capacity App to get a sense of the productivity of land in consideration for leasing. One can use the Strategies for Cattle Herd During Drought tool developed by CSU's Ag Business Management Team (See Appendix 5) to evaluate the cost trade-offs of leasing relative to other strategies.

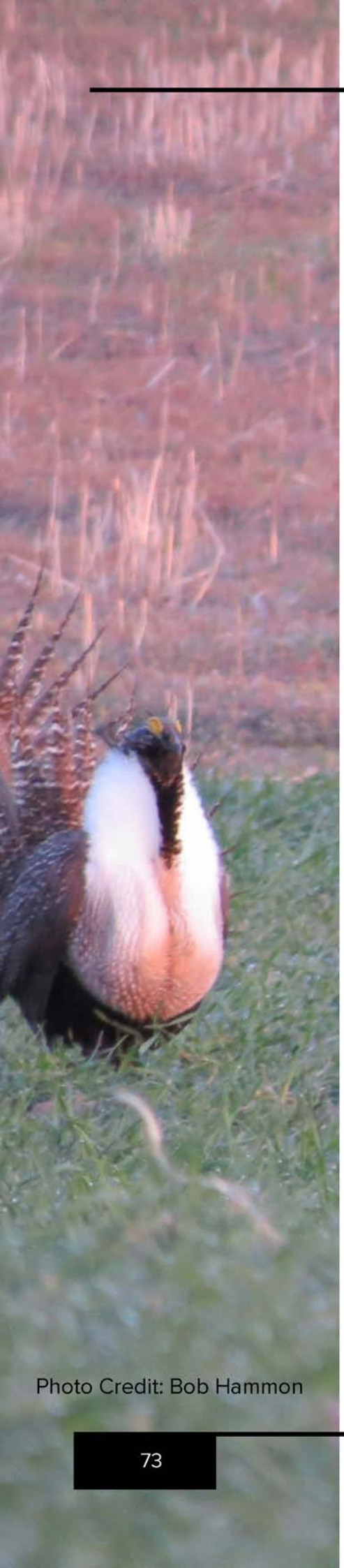


Photo Credit: Bob Hammon

Drought Strategies

Range & Livestock

Long-term Preparedness

Public Agencies & Cooperative Resource Management Plans

During drought, or even after a severe drought, public agencies who manage grazing lands (the US Forest Service and Bureau of Land Management) can opt to reduce AUM's (Animal Unit Months), either by a reduction in numbers or duration that the animals can stay on pastures. Permittees should stay in contact with managing agencies before the grazing season so that it is not a surprise if and when such a change occurs. Proactive and good communication beforehand with rangeland specialists usually helps to reduce uncertainty at the very least, and at most improves flexibility. As long-time range manager with the US Forest Service, Sheila Lamb says, "Agency policy and direction exist for a reason, but at the same time, agency folks have to be flexible and understanding. If we are not communicating and getting along with the people we work with, we are nowhere. Ranchers are the ones that are doing the work on the ground and providing a service for the land. We have the same goals, but ultimately, it is up to the people we have this relationship with to manage the resource."

Rangeland Restoration

Restoration methods, such as wet-meadow restoration, can improve retention of water on the landscape, especially in areas where channels have become incised.When stream channels become deeper than the surrounding land, the water table is lowered and historically wetter areas become dry, changing the plant community. Reversing this trend can improve water availability, extend forage quality and boost quantity, as well as improve wildlife habitat. Techniques to restore wet meadows can be relatively low-cost and often cost-share programs and funds are available, especially if there is a value for wildlife (see Funding Sources). Like many of the other strategies included in this section, this kind of project is a multi-year endeavor, but can be one tool in the toolbox for increasing drought resilience.

In This Section

Strategies for Short-term Response

Drought Strategies

Range & Livestock

Short-term Response

Drought management requires both preparedness actions that may years to implement, and responding in drought. Here we discuss the array of strategies to respond during a drought.

Anticipate Forage Supply

Managing well in drought requires both preparation for and appropriate, timely response to emerging drought conditions. Overusing forage in drought, especially combined with chronic overuse beforehand, can contribute to long-term declines in productivity, and poor nutrition for livestock. Depending on ecosystem type, it may take decades to recover from a loss in productivity [34, 35]. If the plants have died or become weak, production may be lower both in pounds and in quality than before the drought, even after the rains have returned. This underscores the need to respond promptly to drought conditions when they emerge. As discussed above, this means the forage demand (stocking rate) must be reduced in response to less available forage.

Anticipate Drought

Using information about climate and critical periods, we recommend anticipating drought conditions and potential forage supply. Information for doing this semi-reliably is described above in Triggers. In the spring of a potential drought year, producers can be anticipating forage supply scenarios and pursuing strategies to address potential deficits. These “triggers,” or indicators linked with actions, should be part of the drought plan (see Making a Drought Plan (pg.6) chapter). Going into drought, it is essential to act on the drought plan.

Drought Strategies

Range & Livestock

Short-term Response

Reduce herd size strategically

When reducing herd size is necessary, it is important to decide what animals to sell versus keep. There are many factors that go into this decision for producers, including: profitability of the animal, class of animal, genetics, behavior, producer goals, and beyond. Detailing how and which animals will be culled beforehand can reduce stress in the moment. Common strategies are to wean calves early, or sell retained yearlings, however the particulars are highly dependent on context. Some producers and ranch business advisors suggest selling the thin, poorly performing animals instead of investing money into them as feed. Livestock that can maintain their condition in tough times require fewer inputs (money & care) for the same, or maybe better, return than their poorer performing herd mates.

Example Pop-Out Box: De-stocking example from the Welch Ranch. Learn more on his drought plan.

1. Stocker cattle. "If you've got a combination of stocker and cow-calf operation, those stockers are your buffer group that is easy to either move or sell and not have to disturb your core cow herd."
2. Old cows. Selling or relocating the old cows.
3. Bred heifers. "That seems terrible to do because that's the future of your herd, but they are the most difficult to get rebred after they calve. They have to have the most nutrition in order to rebreed for their second calf, of anything that you own, so although you hate to give up on them, that was the next group to destock."
4. Young cows. "This is assuming you've taken out any unproductive cows or anything like that. Then you've got to start in on your youngest."
5. Yearling replacement heifers.

"My recommendation would be to set down to make a list of here's how we'd destock when it's necessary. And everybody always says you never make a good decision in a drought and you never make a bad one when it's raining, and that's pretty much right. But you've got to start."

-John Welch, rancher and Past-President and CEO of Spade Ranches. Welch Cattle Company is a family cow/calf operation.

From the National Drought Mitigation Center's Example Plans (See Appendix 5).

Drought Strategies

Range & Livestock

Short-term Response

Evaluate cost trade-offs of buying hay vs selling cows

Another common response is buying hay, especially in operations where there is risk associated with destocking such as cow-calf operations. The CSU Ag Business Management Team has developed a tool to help evaluate the costs of buying hay versus selling cows. This tool makes it easier to see financial trade-offs in such decisions.

Sometimes feed quality is limited but the quantity is not, such as late rotation grass banked pastures or Conservation Reserve Program fields for example. In these cases, providing a protein supplement, in the form of hay or cubes fed a few times a week, or providing lick tubs can help the animals utilize the lower quality forage. However, these supplements should not be used when the quantity of gras production is limiting animal performance. They only facilitate over-utilization of the existing grasses if quantity is limited. Even providing full feed (i.e., feeding hay on rangeland) on the range will not prevent animals from walking around the pasture and seeking out any desirable plants. Just the impact of their hooves on the grasses is detrimental to health and ability of the plant to survive until better times. If a corral area is not available, animals should be confined to a designated sacrifice area that will not be used for 'normal' grazing once the drought breaks.

Annual Forages

One strategy to reduce feed costs may be growing an annual crop for fall or spring grazing. Triticale, oats, turnips and peas as well as planting teff to increase forage during the summer slump when most cool season forages produce less biomass or in a year where water might be limited. Opportunities for annual crops are highly dependent on region and resource availability.

Drought Strategies

Range & Livestock

Short-term Response

Evaluate Alternative Feeds

During drought, another option may be to utilize a limit-fed, high grain diet fed in dry lot or semi-confinement. This is especially true for cow/calf producers, where flexing stocking rate is more challenging. The fact sheet, Alternative Feeds for Cattle During Drought (See Appendix 5) details strategies and what to watch for in alternative feeds. Key points are:

- Consider the full cost of alternative feeds. If you must travel a long distance to get a 'cheap' alternative feed, make sure the transportation makes financial sense.See the Production Risk Management section to learn more about conducting a partial budget to analyze cost effectiveness of alternative types of feed.
- Feed strategically based on cattle nutritional needs individually and throughout time. You can waste money by overfeeding a cow that does not need it. Consider whether some cattle need more nutritional support than others.
- When considering alternative feedstuffs, conduct a nutritional analysis. In addition, testfor nitrates in annual forages, including sorghums and for prussic acid levels in sorghums,sudans, and sorghum-sudan varieties. (See fact sheets Nitrate Poisoning [36] and Prussic Acid Poisoning in Livestock.) (See Appendix 5).
- Since intake on concentrate diets is restricted, cattle may appear gaunt and behave as though hungry, however, after 14 to 21 days, they will adapt to the reduction in feed intake.

For sheep similar principles exist. Producers should actively use regular body condition scoring to determine feed requirements. This ensures efficient and economical use of feed resources. Thin ewes will require more nutrients than fat ewes and can be fed accordingly when identified and fed separately. Over-fatness can be avoided by only feeding extra food to those that need it. Sheep Feeds and Management Guidelines During Drought (See Appendix 5) has guidelines for alternative or composite feeds in sheep.

Drought Strategies

Range & Livestock

Short-term Response

Nitrates, continued

General guidelines for testing, harvesting and feeding drought damaged crops include [37, 38]:

1. Test forages to be fed to livestock for nitrate levels (always recommended).
2. Don't graze crops such as corn, wheat, sunflowers, sorghum, or millet that have been abandoned due to drought or hail stress, without testing first.
3. Delay harvest to the afternoon as nitrates can be higher in the morning.
4. Nitrates accumulate the most in the lower third of the stalk so cutting higher may reduce nitrate levels.
5. In cereal forages, delaying harvest from flowering to soft dough stage can significantly decrease nitrate levels but will decrease nutritional quality.
6. Waiting at least a week to harvest or graze following a drought ending rain or irrigation can help mitigate the accumulation of toxic levels of nitrates. Testing is still recommended.
7. Test livestock water sources also for nitrates because nitrate toxicity results from total daily consumption from both feed and water. Feeds that may be safe under normal conditions may cause nitrate poisoning when water levels are also moderate to high in nitrate levels.
8. Use approved sampling methods for testing baled or ensiled forages. Take multiple samples from throughout the pile, field or lots of hay.
9. While challenging, obtaining a representative sample is important. Cattle are selective in the plants and plant parts they consume, and a clipped sample will not represent what is actually being consumed. However, sampling can be used to identify fields that are high risk and allow you to manage the grazing of high-risk forages to reduce the problems due to nitrates. In fields that will be grazed, clipping the forages to the lowest level the animals will graze will give you an idea of the highest nitrate content in the plant. Samples of each individual species in a forage mix can again tell you the maximum amount of nitrates if animals select a single species.

Feeding Guidelines of Feeds According to Nitrate Concentrations

From Nitrates in Livestock Feeding by Mary E. Drewnoski, Bruce E. Anderson, Paul J. Kononoff, Extension, M. Beth Reynolds, Nebraska Extension

Nitrate Ion (NO3-)ppm	Nitrate-N (NO3-N)ppm	Recommendation for unadapted animals
<4400	<1000	Safe, nontoxic level
4400–9300	1000–2100	Safe for nonpregnant animals. Adapt pregnant animals slowly or mix with low nitrate feed.
9300–15,000	2100–3390	Limit to less than 50% of ration DM. Do not feed to pregnant animals without mixing with low nitrate feed. Adapt animals to mixture.
>15,000	>3390	Limit to less than 25% of ration DM. Do not feed without diluting with low nitrate feed. Adapt animals to feed mixture.

Drought Strategies

Range & Livestock

Short-term Response

Respond to Animal Health Concerns

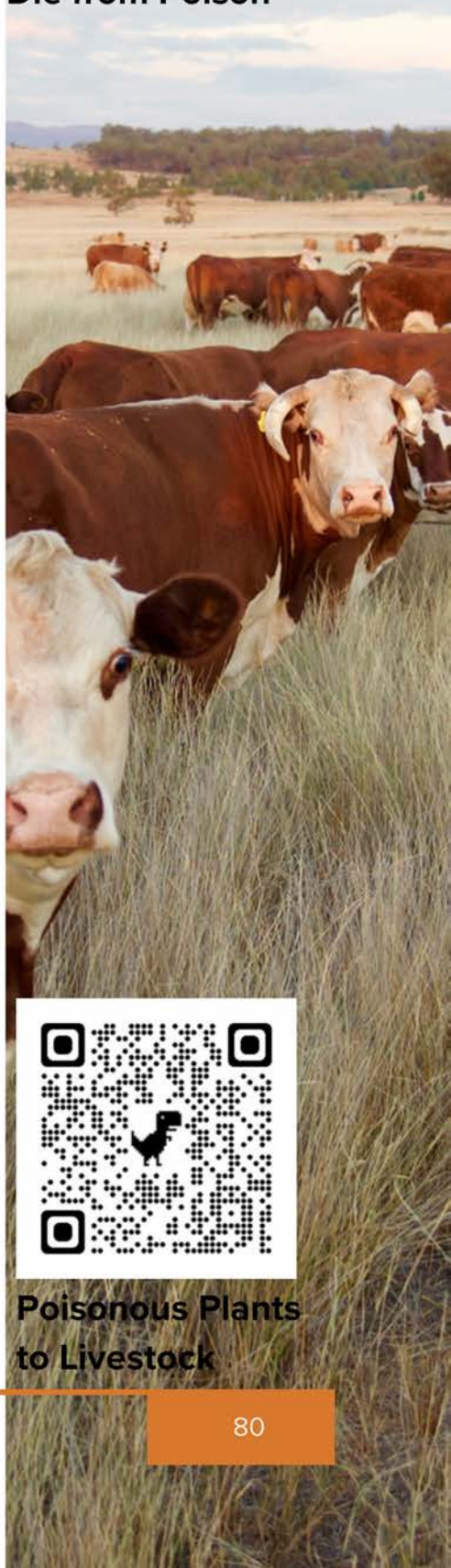
Toxicity on the Landscape

The best way to minimize the risk of plant toxicity is to ensure that animals have enough feed and adequate water in drought. When feed is scarce and animals have poor body condition, they may eat plants they would otherwise avoid. The fact sheet, Why Livestock Die From Eating Poisonous Plants (See QR code), is a useful summary of the mechanisms behind ingestion of toxic plants. If a producer experiences an unexpected death of livestock, a necropsy is recommended. The CSU Veterinary Diagnostic Labs (See Appendix 5) can perform necropsies, or a local veterinarian can do a field necropsy. It can be extremely difficult to diagnose the particular plant, since some toxins do not cause acute toxicity, and instead may cause birth defects or health problems over the longer term. An animal could have ingested a plant months before a problem emerges. Plants Poisonous to Livestock in the Western States (See QR code) from the USDA-ARS describes common toxic plants found on western rangeland, and symptoms in livestock. The difficulty of diagnosing the particular plant underscores the need to ensure livestock have access to adequate forage and water.

Other Animal Health Concerns in Drought

Other health conditions can emerge in drought, such as "fog fever" or Atypical Interstitial Pneumonia. This condition can be seen in cows as an unintended consequence of changing from dry rangeland grazing to lush pasture too quickly. As always with livestock, changes in diet should be made slowly. Introduction to lusher pastures should be initially made 2-3 hours per day increasingly slowly over two weeks. Since this is often difficult, cutting and drying the lush pasture before cattle are allowed to graze is helpful.

Why Livestock Die from Poison



Poisonous Plants to Livestock

Drought Strategies

Range & Livestock

Respond to Livestock Water Quality Needs

While livestock can tolerate water quality that may be unsuitable for human consumption, fresh water is required by all classes of livestock on a daily basis and very poor water quality will negatively impact livestock health, reproduction and performance. Water quality should be tested for salinity, pH, sulfate, nitrate and potential toxic elements such as selenium. If water quality tests show toxic levels water may need to be treated or alternative sources of water identified [39, 40].

In Colorado the lack of water during drought may be more of an issue than toxic algae it is important to identify Cyanobacteria which in excess can can create Harmful Algal Blooms (HABs) in stagnant water. If a toxic algae bloom is suspected the Colorado Department of Public Health and Environment (See Appendix 5) can assist in the identification of toxic algae.

Recommendations for livestock water used based on total dissolved solids (TDS).

The table below shows the health effects associated with the consumption of different levels of total dissolved solids.

From Livestock Water Quality by Miranda Meehan, Gerald Stokka and Michell Mostrom (See Appendix 5)

TTD (ppm or mg/L)	Effects on Livestock
<3,000	Usually satisfactory for most livestock
3,000-5,000	Should not be consumed by pregnant or lactating females.
5,000-7,000	Should not be consumed by pregnant or lactating females. Usually a laxative and may result in reduced water intake.
7,000-10,000	Do not use for swine. Do not use for pregnant or lactating ruminants or horses.
>10,000	May cause brain damage or death

Drought Strategies

Range & Livestock

Short-term Response

Drought Disaster Compensation Programs

Livestock Forage Disaster Program - The Farm Service Agency has payment programs for livestock producers to pay for qualifying losses due to drought. The Livestock Forage Disaster Program is one of the main programs. Livestock Forage Disaster is not an insurance program, and a producer does not need to have purchased insurance to qualify. Instead, counties qualify based on the Drought Monitor. The best way to learn more information and participate is to contact the local FSA office. In addition, the FSA maintains a page of qualifying counties (See Appendix 5).

Another potentially useful program is the Livestock Indemnity Program. This program can cover excess livestock death due to anthrax during drought, or for livestock death due to adverse weather that is not drought such as a blizzard, etc. Other disaster payment programs can offset the cost of hauling livestock water during drought.

These programs are not insurance programs. They are available to qualifying producers based on the drought monitor.

While payments can take months to be issued, they can be a lifeline in a drought. Programs change, so the best option for a producer is to talk with an FSA representative.

Rangeland Recovery After Drought

If a drought is particularly severe, rangeland production is likely to suffer in subsequent years regardless of weather. During drought, plants do not grow as much, so there is less plant material covering the soil surface. Soil that is not protected by plant litter and standing plant material is less able to optimize infiltration and minimize evaporation. Additionally, grasses lose vigor during drought, and in some cases, die [16, 18, 41, 42] (National Drought Mitigation Center - Management Priorities after Drought (See Appendix 5)).

Drought Strategies

Range & Livestock

Short-term Response

Rangeland Recovery After Drought, continued

Managers should expect reduced forage production after drought, and plan stocking rate with this in mind. Managers should plan grazing to allow for root recovery, which happens to be the same mechanism that also results in litter and standing plant material production. In short, managers must allow for uninterrupted and relatively rapid plant growth, since green leaves are critical for maximum root growth. Doing so may require deferment for a few weeks following drought (i.e., delaying entry into a pasture), or in the case of very severe drought, full-season recovery may be needed [18]. The bottom line is that forage plants may not bounce back immediately after drought and managers need to account for this reality.

Plan for Wildfire Emergencies

During drought, a producer may not have the capacity, time and resources to make big operational changes, but there are still actions they can take to improve resilience. One of these is preparing for wildfire and creating an evacuation plan. Livestock producers face unique challenges in wildfire emergencies, and emergency managers and staff may not understand the situations of livestock producers. For example, when a fire occurs, emergency managers may close roads into the national forest. Cattle may be in allotments beyond the closure.

A producer can also review information on three Fact Sheets, Caring for Livestock Before Disaster, Caring for Livestock During Disaster, and Caring for Livestock After Disaster (See Appendix 5).

Drought Strategies

Range & Livestock

Short-term Response

Plan for Wildfire Emergencies, continued

Recommendations to livestock producers are to:

1. Coordinate with emergency management staff and public land management agencies before a fire emerges. Colorado Cattlemans' Association has been working on an effort to identify knowledgeable farmers/ranchers to work locally as agriculture liaisons with their emergency managers during wildfire incidents. Contact the Colorado Department of Agriculture, Animal Health Division for more information: (303) 869-9130.
2. Make a list of all relevant contacts from family members, neighbors, service providers and trusted information sources. Keep electronically and in hard copy. Distribute it among family and business partners.
3. Make two maps: One of your properties labeled with use of each building or field, locations of utilities and key hazards. The second identifying surrounding properties, use and owner contacts.
4. Make an evacuation plan including hard copy maps of evacuation routes, transport vehicles in working condition, multiple dependable ways to receive information,identification of animals, food and water for 3-5 days, basic handling equipment, and medical supplies.
5. Make a shelter-in-place plan that includes obtaining a generator, 3-5 days of food and water, medical supplies and product (meat, milk, eggs, etc) storage.
6. Improve defensible space around the home/ ranch. There are now well established practices that can reduce the likelihood that structures will burn in a wildfire. The Colorado State Forest Service has info on well-established practices that decrease risk of structural fires.

In This Section

Drought Strategies

Crops & Cropping Systems

Introduction

The goal of drought planning in cropping systems is to provide information on various strategies so that producers have more flexibility to reduce risk, maintain agronomic and economic viability, while continuing to be responsible stewards of agricultural resources.

Overview

Cropping systems are an important part of the state's agricultural production. Many of the practices and concepts mentioned below may apply to dryland and irrigated systems, although more options are available to producers with irrigation capacity. Often, the most productive operations in Colorado require supplemental irrigation water to maximize yields.

Irrigation water resources critical to cropping systems in Colorado can include both surface and groundwater sources. Surface waters are naturally fed by precipitation, and lost through transpiration, evaporation, and seepage. Groundwater is replenished by seepage from surface water, and is reduced through withdrawals by natural springs, or artificial pumping for human use.

The water resource goal for drought preparedness is to implement practices that ensure sufficient water is available during the periods of growth most critical to productive crop development. To meet this goal, managers can focus on reducing water demand by 1) reducing consumptive uses (i.e., water used by the crop), 2) reducing non-consumptive losses (e.g., evaporation, non-crop transpiration, and seepage losses), and/or 3) considering storage or augmentation pathways to make water available when needed without interrupting supply for other users.

Most farmers in Colorado and the western US have experience with drought and use many strategies to cope with drought, including 'short-term' and 'long-term' strategies. Long and short-term drought management strategies are interdependent and reinforce each other; the more prepared a producer is for drought, the more able they are to respond, and the more able they are to respond when conditions are acute, the more likely they are to be able to persist through drought and better prepare for future droughts.

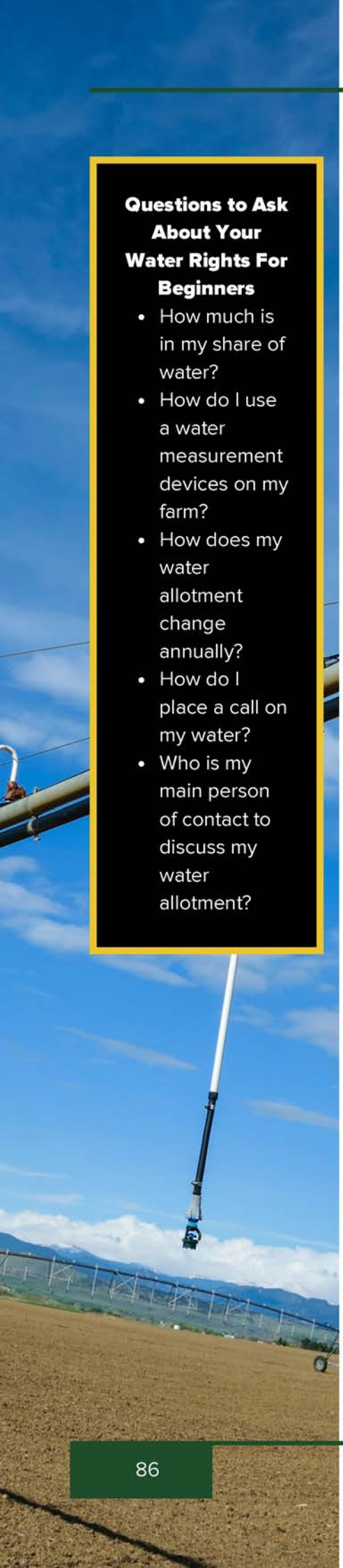
Drought Strategies

Crops & Cropping Systems

Long-term Preparedness

Questions to Ask About Your Water Rights For Beginners

- How much is in my share of water?
- How do I use a water measurement devices on my farm?
- How does my water allotment change annually?
- How do I place a call on my water?
- Who is my main person of contact to discuss my water allotment?



Reducing water transportation losses

Reducing non-consumptive uses can focus on reducing surface evaporation, transpiration by non-beneficial plants, and seepage losses when conveying water to and within a particular field. This may be done at the farm or regional scale if collaborative opportunities exist with water districts of ditch companies. Examples of possible approaches include:

- Lining earthen ditches with concrete, polymers, or plastics to reduce seepage during water transportation to and from water sources.
- Installing pipelines for water conveyance when possible to reduce evaporative and seepage losses.
- Having a long-term integrated pest management strategy for reducing the presence of non-beneficial plant species along waterways, as well as in-field.

Irrigation delivery system modification and monitoring

Reducing water transportation losses can be accomplished by modifying the ditches/canals that water flows through. For example, unlined channels may be straightened to minimize the distance water travels between users, thereby reducing the seepage losses.

It also often offers the opportunity to install flow monitoring equipment. Check structures may be installed to regulate and measure water flow. There is now technology available that can automate these structures, making flow regulation more precise, which ensures that users consistently receive their allotted amounts. This can also be done with individual diversion structures such as a headgate.

Augmentation

Augmentation is a method of making water available to users with junior water rights without reducing water available to senior water rights users. Augmentation plans must replace pumping impacts to stream flows in time, place and amount.

Drought Strategies

Crops & Cropping Systems

Long-term Preparedness

Augmentation, continued

This is typically done by diverting water during non-call time periods and putting that water into seepage ponds to retime that water and when it will make it to the river to supply senior water rights downstream. For example, if a user installs a new alluvial ground well (i.e., it's hydrologically connected to surface water), that user would have to return a portion of the water pumped back into the surface water source to maintain streamflows. Augmentation allows for more flexibility in water distribution, critically important during times of drought.

Crop selection to reduce water consumptive use

Reducing consumptive use can be achieved by using lower water use crops species when drought is expected. For example, silage sorghum may be planted in substitute for corn as it requires less water annually to produce a crop.

The tables (pg.88) on the next two pages summarize the average seasonal water use by various crops on the east and western slopes of Colorado. This information can be used to better decide which crop makes the most sense for a given agronomic system. It is often optimal to plant a crop with the highest expected market value possible that simultaneously doesn't demand more water then what is expected to be available over the growing season.

The timing of precipitation and/or irrigation must also be considered to maximize profit. Water must be applied during critical growth periods and in sufficient quantities to avoid decreased production or plant death. Another important point is that many crops can withstand a certain amount of water stress (i.e., not receive the full seasonal amount of water) and still be more profitable than an alternative crop (see crop growth stage section below). Using grain corn and silage sorghum as an example again, a producer may still opt to plant corn because it may be more profitable relative to silage sorghum even if only 60-80% of crop water demand is expected as corn grain is often worth more per bushel.

Drought Strategies

Crops & Cropping Systems

Estimated seasonal water requirement (consumptive use) in eastern Colorado (inches/season).

Table from: https://extension.colostate.edu/docs/pubs/crops/04718.pdf

	Burlington	Cheyenne Wells	Penrose	Holly	Greeley	Lamar	Ft. Lupton	Rocky Ford	Walsh	Iliff	Trinidad	Wray
Alfalfa	44.1	51.6	46.2	46.3	37.1	49.7	43.5	45.7	59	39.2	46.4	26.2
Grass hay/pasture	29.9	35.2	31.4	31.5	25.7	33.8	29.8	31	39.9	26.9	31.5	25
Dry beans	15.7	21.8	19.7	19.3	15.7	20.8	17.7	18.4	24.6	16.9	18.4	16.6
Corn, grain	26.2	28.2	26.6	26.3	23.9	27.4	25.9	26.5	29.3	24.5	26.7	24.5
Corn, silage	25.2	27.2	25.6	25.3	22.9	26.4	24.9	25.5	28.3	23.5	25.7	23.5
Corn, sweet	24	25.8	24.3	24.1	21.9	25.1	23.7	24.3	26.8	22.5	24.5	22.4
Cantaloupe	17.2	23.3	20.8	20.8	17.2	22.3	19.1	20.6	26.2	17.9	20.6	16.4
Potatoes	24	30	27.1	26.9	20.2	29.3	25.3	25.5	36.2	21.7	26.3	20.5
Onion	27.6	31.3	28.5	28.6	24.2	30.2	27.5	28.2	34.1	25.3	28.6	24.2
Small vegetables	22.7	31.5	28.5	28.2	22.7	30.2	25.4	27	36	24.1	27	23.2
Sorghum, grain	20.9	28.8	25.7	25.6	20.9	27.4	23.4	24.9	32.7	22.2	24.9	21
Soybeans	22.2	26	23.2	23.3	18.7	25	21.9	23	29.7	19.7	23.3	18.2
Spring grains	22.6	30.6	24.7	25.8	20.6	27.7	23	23.4	36.7	24.8	24.3	18.9
Sugar beets	33.7	37.9	35	34.7	27.1	37.3	32.8	34.9	43.6	29	35.3	28.4
Wheat, winter	18.7	19	19	18.5	17.9	19.1	18.4	19.2	19.8	17.9	19.2	15.5
Av. Precipitation	10.3	9.1	6.4	8.3	8.6	9.2	4.6	6.2	8.5	10.9	6.1	10.4
Av. Effective Precipitation Summer Crops	8.1	7.8	5.2	7.0	6.5	7.8	3.6	5.1	7.4	8.7	5.1	7.2
Av. Effective Precipitation Winter Wheat	6.8	6.3	4.6	6.6	5.4	6.4	5.8	4.9	7.0	6.5	5.2	7.4

Drought Strategies

Crops & Cropping Systems

Estimated seasonal water requirement (consumptive use) in western Colorado (inches/season).

Table from: https://extension.colostate.edu/docs/pubs/crops/04718.pdf

	Canon City	Cortez	Mancos	Gunnison	Fruita	Silt	Bedrock	Salida	Walden
Alfalfa	41	37.3	38.4	27	44	29.3	37.6	36.2	35.1
Grass hay/pasture	28	25.5	26.2	19.1	30	21	25.5	25	24.4
Dry beans	15.4	18.1	15.4	12.7	18.1	14.6	13.4	14.3	15.1
Corn, grain	25.5	24.7	24.9	19.5	26.9	20.8	24.6	24.2	23.6
Corn, silage	24.5	23.7	23.9	18.5	25.9	19.8	23.6	23.2	22.6
Corn, sweet	22.3	20.3	20.9	14.7	24	15.9	20.5	19.7	19.1
Cantaloupe	17.4	20.3	17.4	12.6	20.3	14.6	16.9	16.3	15.9
Potatoes	24	30	27.1	26.9	20.2	29.3	25.3	36.2	21.7
Onion	27.6	31.3	28.5	28.6	24.2	30.2	27.5	34.1	25.3
Small vegetables	22.7	31.5	28.5	28.2	22.7	30.2	25.4	36	24.1
Sorghum, grain	20.9	28.8	25.7	25.6	20.9	27.4	23.4	32.7	22.2
Soybeans	22.2	26	23.2	23.3	18.7	25	21.9	29.7	19.7
Spring grains	22.6	30.6	24.7	25.8	20.6	27.7	23	36.7	24.8
Sugar beets	33.7	37.9	35	34.7	27.1	37.3	32.8	43.6	29
Wheat, winter	18.7	19	19	18.5	17.9	19.1	18.4	19.8	17.9
Av. Precipitation	6.2	4.0	6.3	4.9	3.6	7.3	9.5	5.3	5.0
Av. Effective Precipitation Summer Crops	5.2	3.3	5.2	3.7	3.1	5.5	7.6	4.3	4.2
Av. Effective Precipitation Winter Wheat	5.1	5.4	6.9	4.0	4.1	5.2	5.6	4.0	4.6

Drought Strategies

Crops & Cropping Systems

Long-term Preparedness

The table below represents two net profit scenarios for an individual field facing a limited water situation, assuming equal water availability for both scenarios. Scenario 1 illustrates an example of grain corn production when 80% of normal yield (in this case, 250 bushels per acre) is expected (i.e., 200 bu./ac.). Scenario 2 is an example of silage sorghum production on the same field, but 100% of yield is expected because the limited water amount still satisfies the need for sorghum production. In this case as presented, corn still yields a higher net profit ($41,400 v. $36,960 for corn and sorghum, respectively) even though a yield loss is incurred due to drought.

CSU Extension provides updated enterprise budget tools for individual producers to estimate net profit and can be found at: https://abm.extension.colostate.edu/enterprise-budgets-crop/

	Scenario 1: Grain Corn	**Scenario 2: Sorghum Silage**
Gross Income	*Assuming 80% expected yield*	*Assuming 100% expected yield*
Yield	200 bushels/ac.	12 tons/ac.
Price	$5.65/bu.	$38/ton
Total Income	$135,600	$54,720
Total Direct Costs		
Cost/ Acre	$785/ac.	$148/ac.
Total Costs	$94,200	$17,760
Total Profit	**$41,400**	**$36,960**

Drought Strategies

Crops & Cropping Systems

Long-term Preparedness

Types of irrigation systems and their expected ranges of irrigation application efficiency (%)

Type	Percent
Micro sprinklers and drip	80-95
Low pressure center pivots	80-90
High pressure center pivots	75-85
Side roll/hand move sprinklers	60-70
Flood irrigation	20-50
Border irrigation	40-60
Furrow no cutback	40-60
Furrow with cutback	60-80
Furrow with surge	70-90

Improving Irrigation Infrastructure

If feasible, use irrigation systems that give higher application efficiencies. Application efficiency is a performance criterion that expresses how well an irrigation system performs when is operated to deliver a specific amount of water. It is defined as the ratio of the average water depth applied and the target water depth during an irrigation event. The average water depth is the average height of water applied in a field during an irrigation event. The target water depth is the desired water to be supplied in a field during an irrigation event and often equivalent to the cumulative crop water use since the last irrigation plus an extra water when accounting for inefficiencies in the irrigation system itself. This value is determined by water distribution characteristics, system management, soil conditions, the crop, and weather conditions. Water application efficiency pertains to an individual irrigation event. Below is a table of general application efficiencies observed in various types of irrigation systems to help inform management decisions for adoption.

Conservation tillage

Conservation tillage can be defined as any tillage that leaves at least 30% of residual on the ground. Many types of conservation tillage exist including: no till, in row subsoiling, strip till and ridge till. The main goal of this practice is to prevent erosion and conserve soil moisture. Other benefits include: improving soil quality, restoring degraded soils, increasing nutrient cycling, soil moisture retention, reducing nutrient loss through leaching and runoff.

Drought Strategies

Crops & Cropping Systems

Long-term Preparedness

Short-term Storage

Creating short term storage is also an option to ensure water can be available when needed most, especially during times of drought. Often, this comes in the form of a lined, earthen pond installed on a farm with a delivery system that can deliver water to the field(s) when needed within certain limitations. It is important to understand that evaporative losses are also considerable, as annual free surface evaporation rates in the Colorado High Plains range from 40 to 60 in. Evaporation losses cannot be reduced from farm ponds unless the surface of the pond is covered. Short-term storage as an option in on-farm water resource management is often costly, and comes with legal considerations for design and water rights, but can be an incredibly useful tool if feasible.

Demand management

Another way to reduce consumptive water use that requires more collaboration and planning is through the temporary, voluntary reduction of use by managers in exchange for compensation from another entity. This concept is called demand management. Colorado, along with other western states, has been investigating the use of demand management with the hopes that producers can maintain the sustainability of their operation, while also allowing governing agencies to have water when needed. Contact the local Colorado Division of Water Resources Engineer's office to learn about locally available programs in this area.

In This Section

Strategies for Short-term Response

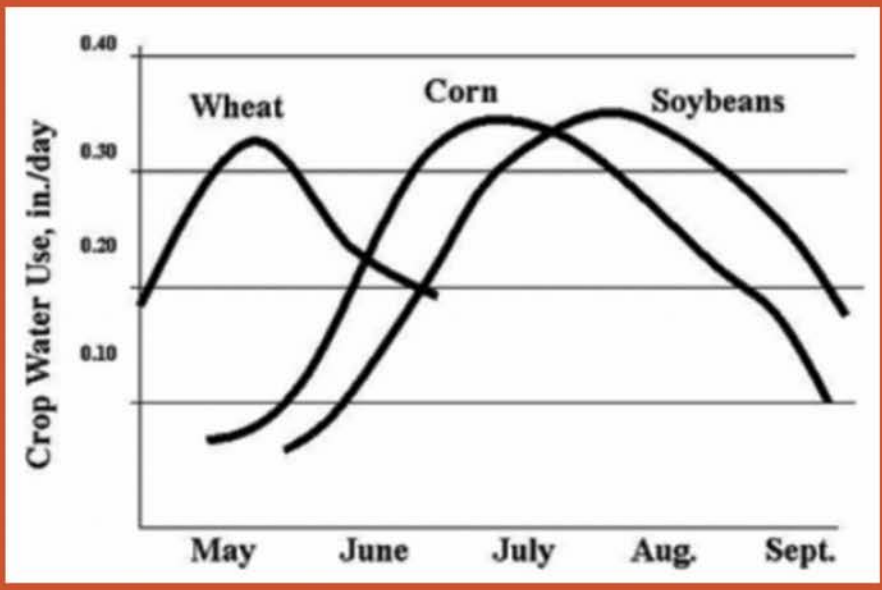
Crops & Cropping Systems

Short-term Response

Crop water use and growth stages

Often, the most challenging part of irrigation scheduling is determining how much water the crop is actually using in order to best make irrigation management decisions that optimize crop productivity while minimizing water waste. It is critical to apply water at critical growth periods if water is available. In dryland systems, it is important to select crops such that critical growth periods overlap with expected periods of precipitation based on historical data and current weather outlooks. Generally speaking, adequate moisture is critical for all crops during seed germination and stand establishment. After that, more drought tolerance is established because there is a greater shoot-to-root ratio if the ground gets a little dry. Additionally, drier soils may encourage roots to grow deeper into the soil profile, which allows the plants to utilize more of the water stored within a deeper soil profile making them more drought resilient. All plants need adequate water while setting fruit or seed (i.e., anthesis) for maximum yield.

Figure: Example of Daily ET During the Growing Season by Crop



Source: https://extension.colostate.edu/docs/pubs/crops/04720.pdf

The table on the following page shows the critical growth stages identified for individual crops found in Colorado.

Drought Strategies

Crops & Cropping Systems

Critical growth stages for major crops

Table from: https://extension.colostate.edu/topic-areas/agriculture/crop-water-use-and-growth-stages-4-715

Crop	Critical period	Symptoms of water stress	Other considerations
Alfalfa	Early spring and immediately after cuttings	Darkening color, then wilting	Adequate water is needed between cuttings
Beans	Bloom and fruit set	Wilting	Yields are reduced if water short at bloom or fruit set stages
Cool season grass	Early spring, early fall	Dull green color, then wilting	Critical period for seed production is boot to head formation
Corn	Tasseling, silk stage until grain is fully formed	Curling of leaves by mid-morning, darkening color	Needs adequate water from germination to dent stage for maximum production
Fruit trees	Any point during growing season	Dulling of leaf color and drooping of growing points	Stone fruits are sensitive to water stress during last two weeks prior to harvest
Onions	Bulb formation	Wilting	Keep soil wet during bulb formation and dry near harvest
Potatoes	Tuber formation to harvest	Wilting during heat of the day	Water stress during critical period may cause cracking of tubers
Small grain	Boot and bloom stages	Dull green color, then firing of lower leaves	Last irrigation at milk stage
Sorghum	Boot, bloom and dough stages	Curling of leaves by mid-morning, darkening color	Yields are reduced if water is short at bloom during seed development
Sugar beets	Post-thinning	Leaves wilting during heat of the day	Excessive full irrigation lowers sugar content
Tomatoes	After fruit set	Wilting	Wilt and leaf rolling can be caused by disease

Drought Strategies

Crops & Cropping Systems

Short-term Response

Monitoring crop water use (i.e., evapotranspiration)

Crop water use, also known as evapotranspiration (ET), is the water used by a crop for growth and cooling purposes. This water is extracted from the soil root zone by the root system, which represents transpiration and is no longer available as stored water in the soil. Consequently, the term "ET" is used interchangeably with crop water use. All these terms refer to the same process, ET, in which the plant extracts water from the soil for tissue building and cooling purposes, as well as soil evaporation. The below table shows sources to learn about and obtain ET data for irrigation scheduling purposes.

CSU has put considerable effort into providing resources to producers to help better manage irrigations in the context of ET. One helpful tool, the Water Irrigation Scheduler for Efficient Application (WISE) (See Appendix 5) uses local weather conditions, coupled with user-notated field boundaries to estimate crop growth and water use to better provide soil water status at any given time. This status can then be used to determine irrigation event timing and quantities. The WISE tool can be accessed at: http://wise.colostate.edu/

Table: Hyperlinked online resources for assessing ET data for irrigation scheduling

Colorado Agricultural Meteorological Network (COAGMET): https://coagmet.colostate.edu
Use of Soil Moisture Sensors for Irrigation Scheduling (ARS): https://www.ars.usda.gov/ARSUserFiles/60663500/Publications/Sui/2017/Sui,%20R.%202017_Irrigation%20Today_%201-3-16-17.pdf
OpenET: https://openetdata.org

Drought Strategies

Crops & Cropping Systems

Short-term Response

Weed management

Eradicating invasive plant species along waterways and within fields that uptake water for growth will increase resources available to desired crops. Best management practices such as crop rotation and rotating herbicide mode of action to reduce resistance can help reduce weeds and unintended consequences of repeated use of the same herbicide. Length of herbicide residual may differ during drought because microbes break down herbicides and occur in greater numbers when soils are moist. Furthermore, it is important to avoid spraying weeds in agricultural fields that are facing drought conditions as it is usually a waste of resources; if the field is too dry for plant production, the weeds will also not be growing and therefore spraying may not be an effective use of money.
Source: https://www.ndsu.edu/agriculture/ag-hub/ag-topics/crop-production/diseases-pests-and-weeds/weeds/herbicide-concerns-after-drought

Soil Fertility Management

Drought and heat stress impact the amount and type of nutrient availability to plants. The key challenge of soil fertility managers during times of water scarcity is to match expected yield potentials determined by water supply with fertility requirements to meet that expected yield. If to few fertilizers are applied, crops will become more susceptible to water stress and yield reduction. This is because they won't be able to activate physiological coping mechanisms needed to account for water stress.

Nitrogen (N) is significantly impacted by water scarcity, as the primary form of nitrogen uptake in plants is via N dissolved into water used by the plant for transpiration. Timing of N fertilizer application needs to occur immediately prior to expected precipitation or irrigation events to minimize N losses from volatilization while maximizing N delivery to the plant. Additionally, it is critical to avoid over-irrigating after N application to avoid leaching of N beneath the crop roots. In the case of chemigation, leave room in the soil profile (10 to 20 percent) to store potential rainfall to avoid runoff or leaching.

Continued on next page

Drought Strategies

Crops & Cropping Systems

Short-term Response

Soil Fertility Management, continued

Phosphorus (P) is an immobile nutrient in the soil, and therefore does not depend on water as much to be uptaken by plants. However, this means roots have to directly intercept pockets of P found in the soil from fertilizer or natural sources. As such, it is ideal to precisely apply P via banding when possible to place P near plant roots, which may already be restricted in growth due to drought conditions.

For more information on soil fertility and irrigation management for drought conditions, visit: https://erams.com/agnutrient/co-bmp-library/nitrogen-irrigation-management/

Surge and cutback irrigation

Surge irrigation is the practice of intermittently applying water to an irrigation furrow (i.e., surging water), as opposed to continuously as in standard practices. Simply put, surge irrigation creates an opportunity for water to soak into the soil between surges, thereby reducing runoff and increasing the application uniformity. This also ensures that deep percolation losses are reduced near the top of the field where water would normally be over-applied.

Cutback irrigation is another way to improve water application efficiency. Cutback irrigation is simply reducing the inflow rate of water to graded furrows after the water reaches the lower end of the field. The basic objective of cutback irrigation is to reduce surface runoff from the field by matching the inflow rate with the average infiltration capacity of the soil.

Flow measurement

Use measuring devices such as flumes and water meters to determine how much water you apply. When using siphon tubes or gated pipes, the flow can be estimated by multiplying the stream flow rate by the irrigation duration.

Continued on next page

Drought Strategies

Crops & Cropping Systems

Short-term Response

Flow measurement, continued

Monitoring flow informs users if adjustments need to be made to water pathways to maximize transportation and application efficiencies, but also lets them check if the correct amount of water is being delivered to them according to their water allotment. Recording irrigation dates and amounts can be useful for understanding past use of water during normal, wet and dry periods. They can also be used to prove irrigation water diversions in for water right purposes.
Reference: Irrigated Field Guide and Record Book XCM-228

Prevented planting

Prevented planting is a failure to plant an insured crop with the proper equipment by the final planting date designated in an individual's insurance policy's Special Provisions or during the late planting period, if applicable. Prevented planting provisions in insurance policies can subsidize or maintain a producer's income when extreme weather conditions prevent expected plantings. This type of insurance coverage is available for a substantial number of spring crops produced in Colorado including apples, barley, corn, dry beans, grain sorghum, oats, onions, peaches, potatoes, popcorn, sugar beets, sunflowers and wheat. Producers should make planting decisions based on agronomically sound and well documented crop management practices. For a crop to be determined as a case of prevented planning, a third party expert who would not fiscally benefit from the judgment must verify and document environmental conditions leading to the inability to plant a crop. Often this comes in the form of a university extension agent. More information on prevented planting can be found at: https://www.rma.usda.gov/en/Topics/Prevented-Planting

Drought Strategies

Crops & Cropping Systems

Short-term Response

Deficit/limited irrigation management

When water supplies are restricted, full crop water demands cannot be met, limited or deficit irrigation results. When producers are faced with reduced surface water availability, they have three management options that can be utilized. Producers could

1. reduce irrigated acreage,
2. reduce irrigation to the entire field or
3. include different crops that require less irrigation.

Option 1 idles potentially productive ground which can be utilized for dryland production, while option 2 reduces yields for the irrigated acres unless precipitation is above normal. Option 3 incorporates the use of crops that require less irrigation for maximum production and then uses the "saved water" for traditionally irrigated crops.

For perennial crops like alfalfa concentrating irrigation during the spring and limiting or withholding water during hotter periods of the growing season improves water use efficiency (WUE) more than limiting irrigation uniformly through-out the growing season and still allows for a partial crop. This strategy can be implemented with few long-term impacts to an alfalfa stand while also allowing for significant water savings.

In irrigated systems, the best way to prepare for a drought is to have a solid knowledge foundation of how to schedule irrigations according to crop water use. When irrigation water is limited, matching the needs of crops can minimize water applied that isn't utilized by the crop. Or water can be strategically applied during critical growth stages to maximize production. Below are resources for irrigation scheduling and management that may help during drought.

For more resources, go to the Drought Advisors Web Page and filter for "Irrigation". See the Drought Advisors web page at: https://droughtadvisors.org/resources/

For more information on Managing Alfalfa and Other Forages with Less Water Visit: https://droughtadvisors.org/webinars/crops-drought-management/f

Drought Strategies

Risk Management

In This Section

Becoming a resilient producer is imperative for managing drought in an operation for the long-term. Risk management allows a producer to identify, analyze, monitor, and mitigate risks that threaten the objectives identified by the operator. Every business decision and action can be classified within one of the five sources of risk:

1. Financial
2. Marketing
3. Legal
4. Human
5. Production

Managing for risk is being intentionally proactive, not reactive. Mitigating drought risk can be the difference between profit and loss for a farm or ranch.

It's important to be resilient in all five areas of risk, especially when managing drought. The resiliency self-assessment tool developed by the CSU Extension Agriculture and Business Management (ABM) Team (following page) is a set of statements and a self-ranking scale that producers can use to determine where to prioritize their efforts. This tool can help farmers and ranchers absorb and recover from shocks and stresses to their agricultural production and livelihoods.

The following section follows the self-assessment relative to drought. The CSU Extension ABM Team has a dedicated website containing materials to help producers manage for all areas of risk in their operation. Visit https://abm.extension.colostate.edu to see more resources relative to risk management.

Drought Strategies

Risk Management

The resiliency self-assessment tool developed by the CSU Extension Agriculture and Business Management (ABM) Team is a set of statements and a self-ranking scale that producers can use to determine where to prioritize their efforts.

Once producers complete the self-assessment, they can find directly related resources on the ABM website to improve their risk management skills in the identified areas.

FINANCIAL RISK	TRUE	FALSE
1. I have a current business plan for my farm/ranch.		
2. I use software (such as Quickbooks) to keep financial records.		
3. I develop financial statements (balance sheet, income statement, statement of cash flows, and statement of owner's equity) from my farm/ranch records.		
4. I regularly analyze my financial statements and use the information to help make business decisions.		
5. I know the costs of production (i.e. develop enterprise budgets) for the enterprises on my farm/ranch.		
6. I compute the "key" financial ratios for my farm/ranch.		
I rate my overall resiliency to financial risk as: (1= my financial management and decision making skills are poor - - 10 = I know and understand the finances of my business and use the information to make business decisions)		

1	2	3	4	5	6	7	8	9	10

MARKETING RISK	TRUE	FALSE
1. I know the costs of production for the commodities I produce.		
2. I understand and track the local basis of the commodities I produce.		
3. I regularly pre-harvest price my commodities.		
4. I understand how to use futures and options markets to reduce price risk.		
5. As a cow/calf producer, I know how to use feeder cattle futures and options to cross-hedge my weaned calves.		
6. I understand how to utilize the forward pricing tools available through my local commodity buyers.		
7. I use a written marketing plan to manage price risk on my operation.		
I rate my overall resiliency to market risk as: (1= I do a poor job of marketing my commodities - - 10 = I am a master marketer)		

1	2	3	4	5	6	7	8	9	10

HUMAN RISK	TRUE	FALSE
1. The significant time pressures and long work hours of farming/ranching are not affecting my physical and emotional well-being.		
2. I eat and sleep regularly and dealing with family issues.		
3. I am concerned (dealing) with the health of a family member and/or aging parents.		
4. I am not overly concerned with debt.		
5. I am not experiencing stress nor having health issues due to the ever changing economic conditions of agriculture (changing costs and prices).		
6. I am taking care of my farm/ranch, machinery, and animals.		
7. I am paying my bills – including payroll taxes – in a timely manner.		
8. I have a written employee manual.		
9. I address employee issues in a timely/reasonable manner.		
I rate my overall resiliency to human risk as: (1= excessively concerned - - 10 = have few concerns and deal with issues and conflicts in a timely and reasonable manner)		

1	2	3	4	5	6	7	8	9	10

INSTITUTIONAL/LEGAL RISK	TRUE	FALSE
1. I know my rights and duties under contract law.		
2. I use written contracts and lease agreements.		
3. I regularly consult with an attorney to develop contracts and lease agreements.		
4. I have a written plan to reduce and manage environmental hazards.		
5. My family has regular family meetings to discuss mine and my spouse's final wishes and instructions, our estates, etc.		
6. I and my spouse have a retirement plan which states when we plan to retire, what we might do in retirement, and how we will pay for our retirement. We have discussed the plan with our family.		
7. I and my spouse have a plan to pay for any assisted living costs. We have discussed the plan with our family.		
8. I and my spouse have developed and implemented a plan for the succession of our business(es).		
I rate my overall resiliency to institutional/legal risk as: (1= have no written plans - - 10 = have regular family business meetings and all plans are written and being implemented)		

1	2	3	4	5	6	7	8	9	10

PRODUCTION RISK	TRUE	FALSE
1. I know the costs of production for each of my enterprises.		
2. I am a low cost producer.		
3. I have evaluated the riskiness of my current enterprises.		
4. I have evaluated the riskiness of potential enterprises and enterprise mixes for my farm/ranch.		
5. I develop and evaluate an annual production plan.		
6. I utilize crop/commodity insurance to manage production risk.		
I rate my overall resiliency to production risk as: (1= I do a poor job of managing my production risk - - 10 = I am great at managing my production risks.)		

1	2	3	4	5	6	7	8	9	10

Drought Strategies

Risk Management

Financial Risk

Definition

Financial risk is not having sufficient cash to meet expected obligations, generating lower than expected profits, and losing equity.

Key Considerations

Do you develop financial statements (balance sheet, income statement, statement of cash flows) from your farm/ranch records? Financial statements provide enormous amounts of information regarding an operations' revenue, expenses, profitability, debt load, and the ability to meet short and long-term financial obligations. When making day to day decisions, it's important to consult your financial statements, especially your cash flow. Understanding your available cash on hand can be very important to determining whether you can purchase additional feed or pasture to supplement your cows. When procuring an operating note to finance additional infrastructure, your financial statements will help you and your lender understand your debt load and ability to pay back the loan. Having a clear understanding of the financial standing of your business will allow you to make solid, informed decisions that will minimally impact your business financially. The CSU ABM Team has interactive spreadsheets available for each financial statement ready for you to use in your business. Access these tools at: https://abm.extension.colostate.edu/decision-tools/.

Marketing Risk

Definition

Marketing risk is defined as fluctuations in prices paid for inputs or received for products.

Key Considerations

Do you know the costs of production for the commodities you produce? Without knowing the true cost of inputs to produce goods, it is very difficult to price your product correctly to remain profitable.

Continued on next page

Drought Strategies

Risk Management

Marketing Risk, continued

Having a written marketing plan with identified triggers and selling price points will help you to properly market your commodities and remain profitable. This is especially important when marketing during a drought when you may have to sell animals at a time that was not planned. Knowing your input costs and a selling price baseline are critical for making informed, profitable decisions. For more information on strategic destocking that may impact marketing risk, see the Range and Livestock Strategies Section (pg.59)).

Human Risk

Definition

Human risk is the uncertainty attributed to the character, health, and behavior of the people involved in the business. The ever changing economic and weather conditions in the agricultural field can be serious stressors and have a major influence on a producer's mental health and well-being.

Key Considerations

You Don't Have to Go At it Alone

When managing stress and well being, the first thing that farmers and ranchers know is that you don't have to go at it alone. Working in agriculture is uniquely challenging. Many of the daily and seasonal stressors are out of your control. Taking care of yourself is the most important thing you can do for your operation, for your family, and for yourself. Staying connected to a person or community is the best and most important way you can– and will– make it through the challenging times. Though you are strong, we are always stronger together.

Recognize the Symptoms of Stress

It should be noted that not all stress is negative. Some stress makes us work harder, focus better, be more productive, and be more effective. However, unaddressed chronic stress can wear down both your body and mind.

Continued on next page

Drought Strategies

Risk Management

Recognize the Symptoms of Stress, continued

The American Institute of Stress that offers a comprehensive list of symptoms associated with chronic stress (See Appendix 5). When left unaddressed, these symptoms can continue to worsen and may lead to serious mental and physical illness. Not only can this impact your ability to do your job and run your operation, but it will also impact your relationships and the people who you love.

Many Ways to Release Stress

New research shows [43] that physical activity or exercise are the most effective ways to move stress through your system. If you don't enjoy walking, running, or bike riding, below are five additional evidence-based strategies for releasing stress:

- **Creativity.**
  - Make something! Do you like to knit, paint, sing, write, or widdle wood? Whatever creative endeavor speaks to you, do it.
- **Laughing.**
  - Especially when you can laugh together with someone, laughter is a way to release and express all of the emotions we keep inside. It is difficult to laugh and feel stress at the same time.
- **Crying.**
  - Crying is one of our body's mechanisms for releasing stress. It is natural and healthy for everybody to cry every now and then.
- **Physical affection.**
  - This can come from a romantic partner, or just from someone you feel safe with to give you a long, strong hug (about 20 seconds). Even time with a loving pet can be beneficial. Physical affection helps your body release trust and bonding hormones, like oxytocin, which can chase away the sense of danger held in your body. As our hormones shift, our heart rate slows and our body and mind begin to feel safe.
- **Deep breathing.**
  - Slowing down your breath is the quickest and most approachable way to help regulate your system during stressful moments. Find a breathing tool that resonates with you. Box breathing is a popular method that was developed by the marines.

Continued on next page

Crisis Intervention & Resources

Colorado Crisis Services - 1-844-493-8255 / Text "TALK" to 38255 https://coloradocrisisservices.org_
Professionals that can discuss and refer you to other services are available 24/7 365 days a year.

Resources for Farmers – Farm Aid - 1-800-FARM-AID (1-800-327-6243). https://www.farmaid.org/our-work/resources-for-farmers/
Agriculture specific hotline available Monday through Friday from 7am – 8pm MT.

CAAMHP for Health - https://www.caamhpforhealth.org
CAAMHP provides members of our agricultural and rural communities with six free sessions to an ag friendly, licensed behavioral health professional. It's anonymous and in many cases, can be accessed remotely.

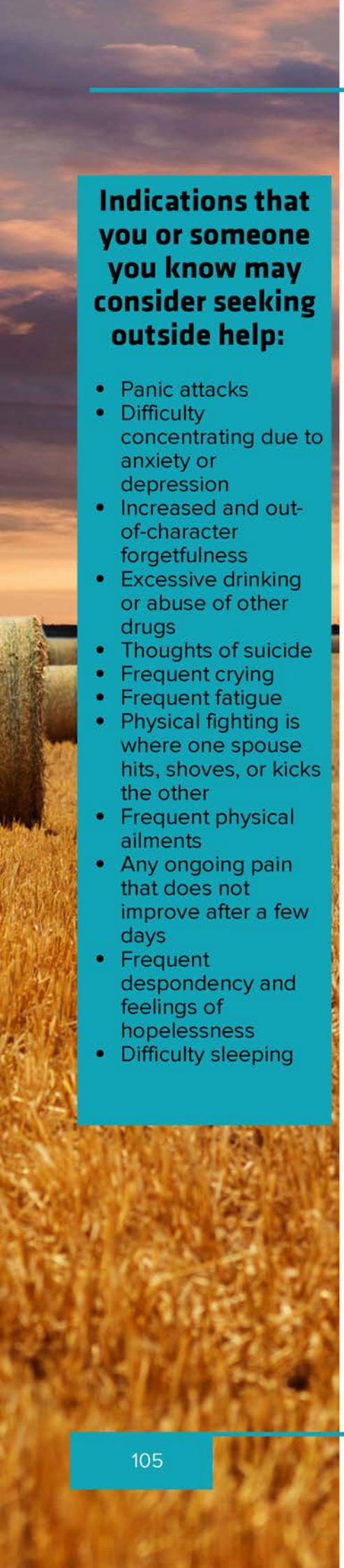
AgWell.org - https://agwell.org/wellbeing/
Colorado-based program providing state-wide resources and training opportunities.

988-National Suicide hotline - Available 24/7, 365 days a year

Excellent Resource for Farm stress management: Farm Stress Handout https://www.farmaid.org/wp-content/uploads/2021/12/FRN_guide-farm_stress_and_emotional_well-being_vol12.pdf

Drought Strategies

Risk Management



Indications that you or someone you know may consider seeking outside help:

- Panic attacks
- Difficulty concentrating due to anxiety or depression
- Increased and out-of-character forgetfulness
- Excessive drinking or abuse of other drugs
- Thoughts of suicide
- Frequent crying
- Frequent fatigue
- Physical fighting is where one spouse hits, shoves, or kicks the other
- Frequent physical ailments
- Any ongoing pain that does not improve after a few days
- Frequent despondency and feelings of hopelessness
- Difficulty sleeping

Many Ways to Release Stress, continued

Talk About It!

In addition to the strategies above, the importance of talking about your stress and worries with someone else cannot be overstated. Knowing that you are not alone and speaking the things that are bothering you out loud with a person you trust can be comforting and healing. This can be hard, and it takes courage. Be sure to communicate whether you want this person to help you with your stresses or if you just want them to listen. Making this clear can be helpful in allowing them to best support you.

Stressful times often accompany having to make difficult decisions. When you are able, avoid making impulsive decisions. In order to make good, well-informed decisions under stress, seek outside input. It is also helpful to give yourself space and time to consider your options and to allow yourself to get into a calm state of mind and body before you make lasting– and possibly permanent– decisions regarding your operation.

Reach Out for Help

Sometimes the stress becomes more than you can handle on your own, even with the support of friends and loved ones. The best thing you can do for yourself and those you care about is to find a professional to talk with. Scheduling an appointment to see your primary care provider or a therapist can help provide answers and support for symptoms you may be experiencing.

If you or someone you know would benefit from talking to a professional, CAAMHP for Health provides six free sessions with a counselor who understands the unique nature of agricultural stressors and challenges (See Appendix 5). This is available for anyone, including family members and couples involved in agriculture in Colorado.

Drought Strategies

Risk Management

Legal Risk

Definition

Legal risk is those things that change the "rules of the game". These are outside influences on the business.

Key Considerations

Legal Risk - Tax Implications

Do you understand or consult/employ an accountant to file your taxes as an agricultural producer? Much of the West is experiencing severe drought conditions and has been declared a disaster area by the Secretary of Agriculture. Many producers may be making decisions about selling their livestock because of these conditions. There are special tax provisions pertaining to the sale of livestock due to adverse weather conditions. Personal and business losses may be deductible due to disasters (i.e. fire, flood, hurricane, tornado). There are also tax related resources for COVID-19.

There are two sections of the Internal Revenue Code (IRC) that attempt to cushion producers from the tax liabilities as a consequences of adverse weather-related livestock sales. Under the first provision, livestock held for draft, breeding, or dairy purposes and sold due to adverse weather are provided a two-year reinvestment period. This replacement period can be extended if weather conditions persist for more than three years. The second provision applies to all livestock (other than poultry). It allows cash-based taxpayers whose primary trade or business is farming to defer receipt from sales in excess of normal practices due to weather-related conditions in a federally declared disaster area. Both sections of the IRC apply only to those sales that are in excess of "normal sales" for the producer. The two tax provisions for weather-related sales of livestock have slightly different requirements, so producers should evaluate their circumstances and seek appropriate professional advice. Producers may find the fact sheet "Weather Related Sales of Livestock", available on ruraltax.org. a helpful resource.

Continued on next page.

Drought Strategies

Risk Management

Legal Risk- Tax Implications, continued

The dollar value of property losses due to fires, floods, tornadoes, earthquakes, lightning, freezes, etc. can be substantial. Federal income tax regulations often provide relief by allowing deductions for losses of business-use property. The passage of the Tax Cuts and Jobs Act of 2017 resulted in significant modifications to the deductibility of losses involving personal-use property. In order to deduct a loss for personal-use property, the area in which the loss occurred must be declared a federal disaster area. A farm operator can deduct casualty losses that occur in the business of farming. For a loss to be deductible, a taxpayer must show proof that a casualty occurred. A record must be kept containing a description of the casualty (fire, tornado, etc.) and when it occurred, plus proof that the loss was a direct result of the event. Proof of loss includes photos and a letter from a neutral party indicating loss. In addition, the taxpayer must have ownership of, or be liable for, the damage to the property. If the property was insured, information about reimbursement possibilities for all or part of the loss must also be provided.

The Internal Revenue Code is quite complicated. Producers realizing additional income from livestock sales or personal property losses due to weather related conditions, such as drought or fire, should seek professional counsel from a skilled accountant before making any management decisions. Additionally, producers can educate themselves by visiting https://www.ruraltax.org. This web site is managed by the National Farm Income Tax Extension Committee (NFITEC) – a group of tax experts and farm management professionals at land grant universities across the United States. They develop and deliver tax related education to farmers and ranchers. The group collaborates with the Internal Revenue Service to prepare the annual Farmer's Tax Guide (Publication 225). The NFITEC is the only group of this type which meets annually with the IRS.

Continued on next page

Drought Strategies

Risk Management

Legal Risk

Legal Risk - Estate and Succession Planning

Have you (and your spouse) developed and implemented a plan for the succession of your business? Passing your business on to the next generation can be hard, especially taking into account the ongoing drought and weather-related concerns. An ideal farm succession plan will not only ensure the longevity and the future of the business, but also help you reach your financial goals and live comfortably during retirement.

Strategically planning the succession of an agricultural operation requires a lot of time. It would be wise to consult your lawyer, accountant, financial planner, and any other service professional you employ regularly to help you plan properly. It is important to involve your identified successor in the day to day decision making and discuss all drought plans and strategies with them in depth. When passing over the business, it's important for the successor to have a solid understanding and insight of the operation to ensure its success as the new key decision maker and risk bearer. For a full guide on creating an estate and succession plan, visit https://extension.colostate.edu/docs/abm/A-Lasting-Legacy-Workbook-Full.pdf to view A Lasting Legacy Workbook developed by Extension professionals. The development of A Lasting Legacy course was motivated by the need of an easy-to-use process to help families pass on a true legacy to younger generations.

Legal Risk - Leasing

Do you use written contracts and lease agreements and do you regularly consult with an attorney to develop contracts and lease agreements? Leasing additional pasture and cropland can be a great way to mitigate drought - however, it's important that you properly develop and write lease agreements to avoid conflicts between parties. Whether you are leasing animals or land, it is important that the agreement is fair for both parties involved.

Continued on next page.

Drought Strategies

Risk Management

Legal Risk - Leasing, continued

Having a written, lawyer reviewed contract will help take some of the stress out of leasing and give you one last thing to worry about during drought conditions. In some instances, it can be beneficial to look at lease-to-own arrangements when there is a generational shift happening in the operation. The CSU Extension ABM Team also has information available regarding all types of leases and their pros and cons: https://abm.extension.colostate.edu/full-resource-index/#financial.

Production Risk

Definition

Production Risk is fluctuations in yields (quantity and/or quality).

Key Considerations

Partial Budgeting

Partial Budgeting is a planning and decision making framework used to compare the costs and benefits of alternatives faced by a farm business. It focuses only on the changes in income and expenses that would result from implementing a specific alternative. For example, if a producer expects reduced water from irrigation, partial budgeting would allow a comparison between planting an annual crop into a marginal alfalfa versus retaining the alfalfa with reduced production. Or, partial budgeting could be used to evaluate the cost-efficacy of applying nitrogen to dryland wheat given drought scenarios and anticipated prices. Partial budgeting allows you to get a better handle on how a decision will affect the profitability of the enterprise, and ultimately the profitability of the farm itself. However, the value of a partial budget analysis is highly dependent upon the quality of the information used in the analysis.

Continued on next page

Drought Strategies

Risk Management

Production Risk and Partial Budgets, continued

Partial budgets are based on the principle that small business changes have effects in one or more of the following areas.

- Increase in income
- Reduction or elimination of costs
- Increase in costs
- Reduction or elimination of income

The net impact of the above effects will be the positive financial changes minus the negative financial changes. A positive net indicates that farm income will increase due to the change, while a negative net indicates the change will reduce farm income.

1. State the proposed change.

It is important to have a clear understanding of exactly what alternative is being analyzed. It may be helpful to analyze several changes and compare results. Remember, you can only analyze one alternative at a time. Let's suppose that you are looking at purchasing instead of raising your own replacement heifers as a way to free up some pasture for grazing during drought.

2. List the increases in income

Identify any possible means of generating new revenue streams or increasing existing streams. What will your raised heifer calf sell for since you will no longer be retaining her for your herd? How many lbs will they be at sale and what is the market price of calves?

3. List the reduced costs.

In this step, begin by identifying general areas where the choice might lower expenses. Once all general areas are identified for the specific alternative, you can plug numbers into the partial budget. Some of the costs for developing the heifers will no longer be incurred. Some examples are feed, health, and labor costs.

Continued on next page.

Drought Strategies

Risk Management

Production Risk and Partial Budgets, continued

4. List the increases in costs.

Once again, start by identifying all of the general areas in which costs will be increased. The choice to purchase replacement heifers has one obvious new cost: the expense for purchasing her for your herd. Be sure to investigate all the ways you may incur additional costs.

5. List the reduced income.

Will revenues be decreased or eliminated as a result of choosing a particular alternative? The most common forms of reduced income would be reductions in product sales due to the change. Sometimes accurately estimating this factor can be difficult, so be sure to double check your calculations and consider all potential reductions.

6. Summarize the net effects.

Once you have identified the individual positive (steps 2 and 3) and negative (steps 4 and 5) aspects of the alternative, these should be aggregated to determine a total cost and total benefit of the alternative. The net benefit of the alternative is found by subtracting total costs from total benefits (the Partial Budgeting tool does this for you automatically). If the net benefit is positive, then that alternative may have some economic advantages. However, if the net benefit is negative, the business would be better off staying with the current situation or analyzing a different alternative. Keep in mind that partial budgeting does not replace your own judgement in making decisions. For example, many producers do not purchase replacement hefeirs due to susceptibility of contracting brisket disease if they operate at a high elevation. This cannot be accounted for in a partial budget.

Continued on next page

Drought Strategies

Risk Management

Production Risk and Partial Budgets, continued

7. Consider non-economic and other factors.

Non-economic considerations must be taken into account when considering an alternative. Such considerations may include the social aspects of having less labor on the farm, increased/decreased leisure time, the need for increased or specialized knowledge, and safety and/or ease of use of equipment. Note that these are generally focused on quality of life measures, which are difficult to quantify.

It can be beneficial to use “best-case" and “worst-case" numbers to establish a range for the partial budget analysis. This is especially true for drought, when the forage or water supplies will be uncertain during the spring. For example, if you have enough water, alfalfa may be a more profitable crop, but if you do not, dry beans may be the better alternative. Or, nitrogen will increase production in dryland wheat, but without moisture it may be an additional cost that doesn’t result in an increase to income. While you can’t know all the drought scenarios, the fewer the soft or uncertain numbers you use for the potential increases, added costs, etc.,, the better. The more soft numbers included in the analysis, the less trustworthy the results of the analysis will be. This is why a good partial budget analysis must be founded upon good records, which provide many hard numbers.

In addition to the Partial Budgeting Tool, the CSU ABM Team have decision tools available that will help you determine the viability of a specific alternative (listed in the sidebar).

Some of these, such as Buy Hay vs Sell Cows are more specific to the decision at hand. Each of the decision tools is pre loaded with a scenario that is relative to an average producer in the state of Colorado. The tools also take into account more complex issues and decisions regarding the scenario, such as futures prices for cattle and feed for the next five years. These tools can be used in place of traditional partial budgeting to make it easier, or traditional partial budgeting can still be used to evaluate alternatives.

Additional Decision Tools available from the CSU Ag & Business Management Team (See Appx. 5)

- Buying Hay vs. Selling Cows
- Strategies for your Cattle Herd During Drought
- Matching Cow Size to Available Forage
- Leasing Beef Cattle
- What can you Afford to Pay for a Cow?
- Buying vs. Raising Replacement Heifers
- Estimating Costs and Returns for Yearling Cattle
- Calculating Your Cow Carrying Costs (Knowing your Cost of Production)
- Detailed Financial Statements (Balance Sheet, Income Statement, Statement of Cash Flows)
- So many more!

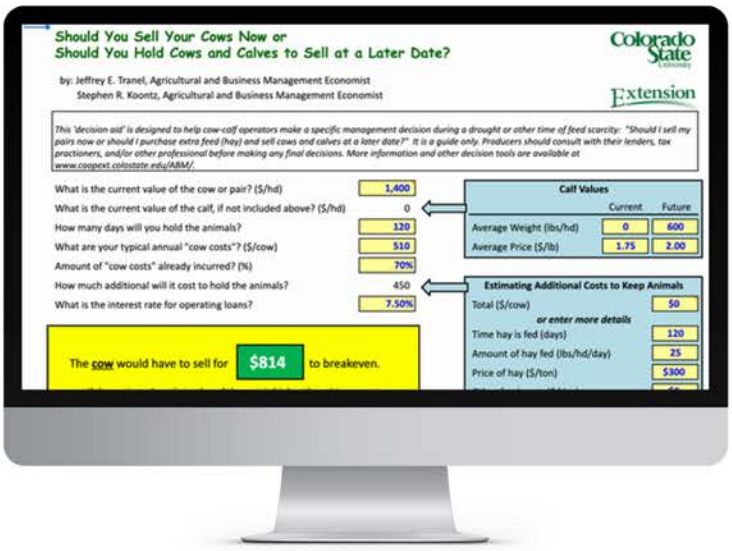
Drought Strategies

Risk Management

Insurance

Insurance can be an important tool to buffer the impact of weather variability, including drought. Two main programs exist for livestock operations on rangelands, the Non-Insured Agricultural Products program or NAP, and Pasture, Rangeland, Forage Insurance or PRF. NAP is available through the Farm Service Agency. PRF is offered by USDA Risk Management Agency (RMA) and is available through companies such as AgRisk Advisors. For both programs, a producer needs to opt in by a certain date, usually early November. With the base level of coverage in the NAP program, there must be a 50% loss on rangelands attributed to the entire county for producers to get a payment, but producers can opt to buy more coverage. Since programs and deadlines change, the best course of action is to get in touch with the Farm Service Agency.

The Risk Management Agency provides a decision support tool to help producers determine appropriate coverage under Pasture, Rangeland, Forage Insurance (PRF). Additionally, Colorado State University and Utah State University have fact sheets (See Appendix 5).



CSU Extension's Agriculture & Business Management website is a wealth of information for risk management, including the Decision Tools described above. Available at: https://abm.extension.colostate.edu

Appendices

In this Section

Appendix 1: Drought Plan Examples

Here are some sample trigger dates and actions from rancher drought plans. Example plans are available at the National Drought Mitigation Center and University of Nebraska's Managing Drought Risk on the Ranch website (See Appendix 5).

Bar X Ranch

:: Central Arizona ::

NDMC NATIONAL DROUGHT MITIGATION CENTER
UNIVERSITY OF NEBRASKA

Introduction

Mike and Diane Hemovich own Bar X Ranch, a 55,000-acre cattle operation that relies primarily on Tonto National Forest lands for grazing. They use Angus bulls and Hereford cows to produce black baldy calves, which are sold as yearlings.

Ranch inventory

- **Precipitation:** Average of 22 inches per year, about half of which falls during summer monsoon season.
- **Range:** 14 pastures with a north-south orientation. Rolling hills of pinyon pine, juniper, and gramma grasses in the south, and ponderosa pines and various grasses in the north. Elevation ranges from 5,000 to 7,000 feet.
- **Additional feed sources:** Mineral and protein blocks, but no additional hay or forage.

Strategies for preparing for drought

- **Short- and long-term planning:** Hemovich's long term plan focuses on drought and ensures multiple water sources and adequate water storage with wells and trick tanks. A trick tank captures precipitation which is stored in a covered tank to minimize evaporation and maintain water quality. In his short-term plan, Hemovich identifies the immediate actions he will take in response to drought. *"...we know where we're going to get out of that pasture should [it] run out of drinking water for the cattle."*
- **Rotational grazing:** Cattle are moved through pastures during the year and from year to year. In one year, Hemovich grazes cattle on the east side of his ranch moving from south to north, and in the next, he migrates cattle south on the west side of the ranch.

Critical dates and target conditions

- **Jan. 1:** Public lands ranchers work with their federal land management agency to develop the annual operating instructions (AOI) that dictate how an allotment will be grazed and managed. Hemovich compiles vegetation and precipitation data from the previous year and meets with a Forest Service range specialist to agree on AOI terms.
- **May 1:** Hemovich checks the 14 rain gauges on the ranch to determine winter cumulative precipitation from Nov. 1 to May 1. The rain gauge is a clear plastic pipe glued to a yardstick that is easy to read from horseback or an all-terrain vehicle. The precipitation readings are entered into MyRAINge Log (myrain-gelog.arizona.edu).
- **Sept. 15:** In mid-September, Hemovich spends about 5 days

1

monitoring vegetation production and composition which informs the grazing rotation schedule.

- **Nov. 1:** Hemovich checks the rain gauges again to determine cumulative summer precipitation (May 1 to Nov. 1) and adds the readings to MyRAINge Log.

Monitoring drought

- Hemovich uses the U.S. Drought Monitor (droughtmonitor.unl.edu) and the Standardized Precipitation Index (SPI) to monitor drought, in addition to data from the pasture rain gauges. *"I'm looking at the SPI because that gives me a good view as to what's happening locally but it's also the data that the Forest Service uses. If that SPI gets down to -1, they are going to be thinking of making some decisions on their part about my cattle."* He also monitors vegetation conditions such as ground cover and species frequency. Additionally, Hemovich relies on personal experience to track drought. During a drought in 2018, Hemovich determined that although his range looked healthy, it was lacking sufficient biomass to support his cattle.

Strategies during drought

- **Change rotation schedule:** Rotate cattle more frequently, which gives the grass time to recuperate, even with limited rainfall.
- **Build water infrastructure:** Each pasture has multiple sources of water including dirt tanks, trick tanks, pipelines, and storage. *"We've worked for 15 years on this ranch, and we've never had to haul water."*
- **Low stocking rates and culling:** While his grazing permit allows for more than 500 cattle, Hemovich stocks about 250 to lessen the impact on pastures. If necessary, he culls older or less productive cows.

Strategies for recovering from drought

- **Build redundancy:** *"...for every pasture that I use, I want another one in reserve."* Most pastures receive at least a full year of rest, allowing for plant regrowth to occur when drought conditions ease.

Lessons learned during drought

- **Be proactive:** *"You have to get ahead of the drought before the drought comes if you're going to successfully survive that drought."*
- **Plan for the hard times:** *"Don't ranch right to the edge. Don't push the envelope."*

Some general recommendations

- **Build partnerships.** Collaborating with local organizations and agencies can increase the feasibility of various ranch projects for drought planning and rangeland integrity. *"We could not afford...all of these infrastructure projects by ourselves. We've worked with Arizona Game and Fish because every water project we build helps the wildlife. The Arizona Department of Energy helped us change a lot of our wells from fossil fuel and generators to solar power [too]."*

Read the full case study at:

drought.unl.edu/ranchplan/WriteaPlan/SampleDroughtPlans.aspx

2

Drought Plan Examples, Continued

Example Drought Plan: Alexander Ranch in South Central Kansas

April 1

- End of the winter dormant season and the beginning of the growing season for warm-season grasses
- Less than 4" of moisture during the winter dormant season (killing frost or Nov 1 till April 1)
  - No prescribed burns should be conducted.
  - Plan to increase the length of rest periods earlier than usual.

June 15

- About half of the forage is produced by June 15
- 75%(15.75") of the annual average rainfall is received between Nov 1 & June 15
- If the rainfall is 80% (12.60") of the 75% (15.75") then the stocking rate should be decreased 30% by weight. (Finish culling herd C)
- If the rainfall is 60%(6.30") of the 75%(15.75") then the stocking rate should be decreased 40-50% by weight (Cull herd B deep)
- The 3 weeks following June 15th is very critical. By July 15 the destocking should be completed.
- Rest periods should be as long as possible by June 1 if any indicator of a drought is present.
- Graze periods should be as long as possible to allow the other paddocks to rest for as long as possible.

Example Drought Plan: Shamrock Ranch, SW Nebraska

April 1

- "We get a lot of moisture in March, so I really monitor March, and my first critical date is April 1st."

May-June

- "Two-thirds of our grass growth is here by mid-June. Our big moisture months are April, May, and June. If you know you're dry [in] April and May, you've already lost 2/3 of your growth."
- "When its dry, you'd better start depopulating something. You'd better get those cows out of there that haven't calved. You better get a cow that has a bad bag and you had to help her, you better get her and her calf out of there. Sell some of those pairs. You'd better get your stockers moving."
- Destock custom grazers
- "...Every custom grazer knew that when I pulled the plug, they had to go. I gave them a month's notice, then I gave them three weeks' notice that the cattle had to go."
- Stick to the plan, Don't second guess
- "It's all that planning and understanding so that you don't have to think about it when you are in the depths of the emotion." - Shamrock Ranch, SW Nebraska

https://drought.unl.edu/ranchplan/WriteaPlan/SampleDroughtPlans.aspx

Appendix 2

Colorado Climate

Colorado sits in an awkward 'middle child' location: not really SW, not really Southern Plains, but not Northern Plains either. Plus, we have the high elevation west slope, mountains and the plains to the east. The Pacific Ocean temperatures both along the equator and in the north have an impact on our weather patterns. And, according to some studies, so does the North Atlantic Ocean. Because of where Colorado is in North America, that impact varies depending on where you are in the state [44].

Awareness of ocean temperature cycles can prove useful when thinking about precipitation and potential grass growth. There are two separate warm & cold cycles in the Pacific Ocean that impact Colorado weather. It appears that the North Atlantic Ocean may also play a role. The El Niño-Southern Oscillation (ENSO) cycle along the Equator is the better known of the three. But the Pacific Decadal Oscillation (PDO) in the North Pacific can reduce or increase the El Niño/La Niña impact. And the North Atlantic (Atlantic Multi-decadal Oscillation (AMO)) may have a hand in the Pacific cycles as well.

El Niño-Southern Oscillation (ENSO)

The El Niño-Southern Oscillation (ENSO) refers to sea surface temperatures along the Equator in the Pacific Ocean, generally east of the International Date Line. These shifts tend to occur on 2-7 year cycles, often with 'neutral conditions during the summer. El Niño and La Niña refer to the ocean temperature, warm vs cold. But which one is which, and what does it mean for Colorado?

Warm phases are called El Niño. Just as warm water in a bathtub steams up the mirror, water vapor escapes into the air when sea temperatures are warm. This flow of vapor feeds the winter Subtropical Jet Stream and generally keeps it flowing across the southern U.S. It's not surprising then that El Niño (warm bathtub) is strongly correlated to wetter conditions in the southwest and central plains areas of the U.S. Examples of recent El Niño events include the winter of 2015-2016 (which was a very strong El Niño) and the moderately strong El Niño winters of 2002-2003 and 2009-2010.

Cold phases are referred to as La Niña. Just as an ice bath does not steam up the mirrors, a cold sea puts less vapor into the air. Less vapor tends to turn the Subtropical Jet stream north over the Pacific Ocean and to join the Polar Jet Stream.

Appendix 2

Colorado Climate

El Niño-Southern Oscillation (ENSO), continued

Not surprisingly, La Niña (cold bathtub) is correlated to dry conditions in the southwest and central plains of the U.S. Recent strong La Niña's occurred in the winter of 2007-2008 and 2010-2011 while 2011-2012, 2020-2021, and 2021-2022 were considered moderate events. A typical La Niña will develop in late summer or fall, peak in the winter, then weaken in spring.

The El Niño/La Niña cycle most commonly provides insight into potential conditions the following winter at a longer lead time (often up to 6 months). This is because of the somewhat regular swings in the last summer & fall ocean temperatures and resulting winter precipitation. On the other hand, when the El Niño Southern Oscillation near the equator is 'neutral', local precipitation patterns drive the forage system more than ocean conditions.

Evaluate ENSO's Status or ENSO Monitoring (See Appendix 5)

Pacific Decadal Oscillation

The Pacific Decadal Oscillation (PDO) refers to sea surface temperature changes in the North Pacific Ocean. These fluctuations between warm and cold phases generally run on a 10–30-year cycle. Just as on the equator, warmer water evaporates more readily than cooler water. More evaporation puts more water into the jet stream and tends to yield more reliable rainfall on the eastern Plains. On the other hand, cold phase impacts on rainfall are less reliable and more variable. For instance, the North Pacific Ocean was in a cold phase from 1999-2013. During that time, eastern Colorado saw notably dry years in 2002, 2006 and 2012. There were also some pretty wet years, for example 2009 and 2010, which illustrates the high variability. A cold phase began again in 2020.

Evaluate the Pacific Decadal Oscillatoi's Status - https://www.ncdc.noaa.gov/teleconnections/pdo/

Appendix 2

Colorado Climate

El Niño and the North Pacific Decadal Oscillation Together

The influence of El Niño Southern Oscillation sea-surface temperature changes along the equator (El Niño/La Niña) on Colorado weather are much more reliable than North Pacific (Pacific Decadal Oscillation) sea temperatures. A great example is the 1930's (i.e., the Dust Bowl period). Even though the North Pacific was generally warm, which should mean more water vapor in the air, the equatorial waters were cool to neutral. This cool to neutral condition 'overrode' the warm North Pacific influence, and we know the result.

Our understanding of PDO and its influence on Colorado weather is constantly changing. The ENSO signal, though it yields mixed and somewhat inconsistent results, is the best we have to work with right now [45].

Atlantic Multi-Decadal Oscillation (AMO)

Just like the Pacific Ocean temperatures change, the Atlantic Multi-decadal Oscillation (AMO) is natural variability occurring in the North Atlantic Ocean. The Atlantic has historically had a longer cycle, running 60-80 years (a cold phase lasted from 1870 to the mid-1920's). More recently, it was in a cold phase from the mid-1960's to 2000, and has been warm since then.

To date, little research has been done in extensive pasture settings for climate interactions with beef production in Western Colorado. One study found that when a warm phase of the Atlantic (Atlantic Multidecadal Oscillation (AMO)) aligned with cold ENSO and PDO (the triple whammie!) there was a high drought risk western Colorado. Other work using Global Climate Models concluded that a warm Atlantic lead to decreased summer precipitation in the Western U.S. and Mexico.

Evaluate the Atlantic Multi-Decadal Oscillation - https://tropical.colostate.edu/archive_amo.html

Appendix 3

Toolbox

Drought Planning Resources

- National Drought Mitigation Center - Drought Plan Resources :
  - https://drought.unl.edu/scenarioguide/processes/foundation.aspx#definescope

- Writing a Drought Plan UNL:
  - https://drought.unl.edu/ranchplan/WriteaPlan.aspx

- Guide to Co-Developing Drought Preparation Plans for Livestock Grazing on Southwest National Forests:
  - https://cals.arizona.edu/droughtandgrazing/sites/cals.arizona.edu.droughtandgrazing/files/Hawkes%20et%20al%202018%20Guide%20to%20Co-developing%20Drought%20Preparation%20az1764.pdf

- An Easy-to-Use System for Developing a Drought Management Contingency Plan. 2017.:
  - https://cals.arizona.edu/droughtandgrazing/sites/cals.arizona.edu.droughtandgrazing/files/Tolleson%202017%20An%20Easy%20to%20Use%20System%20for%20Developing%20a%20Drought%20Management%20Contingency%20Plan.pdf

Climate and Weather Resources

- Intermountain West Climate Dashboard - Western Water Assessment:
  - https://wwa.colorado.edu/resources/intermountain-west-climate-dashboard

- Current U.S. Drought Monitor Conditions:
  - https://www.drought.gov/states/colorado

- Colorado Basin-Wide Interactive Snotel Graphs:
  - https://www.nrcs.usda.gov/wps/portal/nrcs/detail/co/snow/products/?cid=nrcseprd1432263

- Severe storm prediction information can be found at NOAA's Storm Prediction Center:
  - https://www.spc.noaa.gov/products/

- High Plains Regional Climate Center Decision Dashboard:
  - https://hprcc.unl.edu/tribal-dashboards/dashboard.php

- Colorado Basin Forecast for in-depth streamflow and reservoir information can be found here:
  - https://www.cbrfc.noaa.gov/lmap/lmap.php

- Colorado Climate Center :
  - https://climate.colostate.edu

- Root Zone Soil Moisture Percentile Maps:
  - https://nasagrace.unl.edu

Appendix 3

Toolbox

- The Climate at a Glance https://www.ncei.noaa.gov/access/monitoring/climate-at-a-glance/city/time-series:
  - https://www.ncei.noaa.gov/access/monitoring/climate-at-a-glance/city/time-series

Range and Livestock Resources

- Rangeland Management Before, During and After Drought :
  - https://cals.arizona.edu/droughtandgrazing/sites/cals.arizona.edu.droughtandgrazing/files/Howery%202016%20Rangeland%20Management%20Before%20After%20and%20During%20Drought.pdf

- Early Warning for Stocking Decisions in Eastern Colorado – 3.115:
  - https://extension.colostate.edu/topic-areas/agriculture/early-warning-for-stocking-decisions-in-eastern-colorado-3-115/

- Skillful Grazing Management on Semiarid Rangelands:
  - https://extensionpublications.unl.edu/assets/pdf/ec162.pdf

- Drought Decision Support Tool for Ranchers:
  - https://ucanr.edu/sites/Siskiyou_County_Coop_Extension/files/362154.pdf?mc_cid=7f528867b9&mc_eid=9338860fd4

- Ranch Drought Monitoring Dashboard:
  - https://drought.unl.edu/ranchplan/monitor.aspx

- Eastern Plains: Grass-Cast:
  - https://grasscast.unl.edu
  -
- Nitrate Toxicity in Montana Forages:
  - https://apps.msuextension.org/montguide/guide.html?sku=MT200205AG

Risk Management Resources

- Resiliency Self-Assessment
  - https://abm.extension.colostate.edu/wp-content/uploads/sites/61/2020/10/Resiliency-Rack-Card.pdf

Crops and Cropping Systems

- Water Tracking Tool
  - http://droughtadvisors.org/%20resources

Webinars

- A comprehensive list of webinars is at:
  - http://droughtadvisors.org

Appendix 4
Worksheets

In this Section

- Appendix 4: Blank Worksheets

WORKSHEET #1

Drought Inventory

Consideration	Notes
General Consideratoins • How have previous drought years impacted your farm/ranch. • Were there any opportunities in past droughts that you took advantage of, or that you missed? • What did you manage well in past droughts?	
Weather & Climate • The historic frequency of drought • Average regional precipitation and timing • The range of annual precipitation amounts • Critical growth periods for crops, rangeland forage or hay • Future forecasts and expectations for your region	
Water Resources • Well capacity and ability to pump • Flow rate or storage capacity (tanks or earthen structures) • Water quality • Irrigation water availability • Probability of administrative calls on water or water deficits	
Herd Resources (if applicable) • Number and class of livestock • Value of animals, ranked by class and individual identification	

Worksheet adapted from: Managing Drought Risk on the Ranch: A Planning Guide for Great Plains Ranchers. The National Drought Mitigation Center, the University of Nebraska at Lincoln, South Dakota State University and Texas A&M Kingsville, 2014.

Category	Inventory
Financial Resources Consider how drought impacts: • Your business plan • The cost of production for each of your enterprises, • The riskiness of potential enterprises. • Marketing alternatives	
Human & Personnel Resources • Family member's interests and abilities • Resources for coping with stress in drought	
Soil Characteristics • Water holding capacity • Infiltration rate • Fertility • Soil moisture requirement in inches at critical periods	
Range & Forage Resources • Total average carrying capacity and forage demand by livestock • Average drought reductions in carrying capacity • Critical dates for forage production • Other feed supplies	
Crops (if applicable) • Input availability and costs (seed, fuel, fertilizer) • Dates where additional water or other inputs will not increase yield or create a return on investment • The 'salvage' point - harvesting or use the crop for something else rather than as intended	

WORKSHEET #2

Goals for Drought Prep & Response

Think back to the first step of this planning process and the assessment of your operation. Consider what you have and where you've been. Where are you trying to go with your operation to lessen the impact of drought? How do goals to lessen the impact of drought help you achieve your overall management goals for the operation? Goals should be specific, and attainable, and ideally include a timeline for accomplishment. We've included three examples to demonstrate what a goal might look like for a ranching and crop growing operation.

Goal	Goal Description

Worksheet adapted from: Guide to Co-Developing Drought Preparation Plans for Livestock Grazing on Southwest National Forests by Hawkes et al., 2018. Full handbook at: https://cals.arizona.edu/droughtandgrazing/

WORKSHEET #3

Trigger Dates

What to Monitor and When	Target Condition	Adaptive Action

WORKSHEET #4, Long-term Example

Identifying Issues & Strategies

Issues with Drought Preparation	**Possible Strategies** *What are potential strategies to this specific issue?*	**Farm/Ranch Goal Addressed** *How will addressing this issue enable you to reach your operation's goals?*	**Priority** *What's the feasibility and impact of the strategy?*	**Potential Partners** *Given the cost or scale, do you need additional partners?*

Worksheet adapted from: Guide to Co-Developing Drought Preparation Plans for Livestock Grazing on Southwest National Forests by Hawkes et al., 2018. Full handbook at: https://cals.arizona.edu/droughtandgrazing/

WORKSHEET #5, Short-term Example

Response Strategies to Deal with Current Conditions

	What are you watching for?	**Scenarios** *Available Rangeland forage/ water supply*	Scenario likelihood as of (date)...	Mgmt. Strategies

Worksheet adapted from: An Easy to Use System for Developing a Drought Management Contingency Plan by D, Tolleson. 2017. Fact sheet available at: https://cals.arizona.edu/droughtandgrazing/

WORKSHEET #6, Scenarios

Drought Scenarios

Scenario #1:
What if... we experience a winter season drought with only 50% average precipitation for 3 consecutive years

- What will we do?
- What flexibility do we have?
- How could we increase preparedness for this possible scenario?
- How do strategies developed in Worksheet #4 perform?

Scenario #2:
What if... receiving 20% of our historical irrigation water allocation becomes normal, occurring 5 out of every 10 years

- What will we do?
- What flexibility do we have?
- How could we increase preparedness for this possible scenario?
- How do strategies developed in Worksheet #4 perform?

Scenario #3:
What if... spring conditions are moderate/ dry, but a early-onset monsoon provides rain to maintain ditch levels and favorable conditions for rangeland forage.

- What will we do?
- What flexibility do we have?
- How could we increase preparedness for this possible scenario?
- How do strategies developed in Worksheet #4 perform?

Worksheet adapted from: Guide to Co-Developing Drought Preparation Plans for Livestock Grazing on Southwest National Forests by Hawkes et al., 2018. Full handbook at: https://cals.arizona.edu/droughtandgrazing/

WORKSHEET #7, Long-term Strategies

Prioritizing Strategies

This worksheet provides a framework for connecting strategies, the timeline, goals, prioritization, and finally, documenting progress. As with all worksheets in this handbook, it can be used in conjunction with others, or separately.

Basic Details of Strategy *Prioritize the top 5 actions you will take based on the above brainstorm in Worksheet #4.*	**Timeline**	**Goal Addressed**	**Priority**	**Done?** *What and Year*

Worksheet adapted from: Guide to Co-Developing Drought Preparation Plans for Livestock Grazing on Southwest National Forests by Hawkes et al., 2018. Full handbook at: https://cals.arizona.edu/droughtandgrazing/

WORKSHEET #8

Drought Plan Template

A drought plan can be as simple as a 1-2 page document that includes, goals, a basic inventory, strategies, and critical dates. Use this template to bring it all together.

Goal(s) for Drought Management (max 3):

Inventory:

- **Average Precipitation and Variability:**
- **Other:**

Strategies for Increasing Drought Preparedness and Timeline for Completion (max 4):

Critical Decision-making Dates and Target Conditions:

Strategies for Managing During Drought (max 4):

Worksheet adapted from: Guide to Co-Developing Drought Preparation Plans for Livestock Grazing on Southwest National Forests by Hawkes et al., 2018. Full handbook at: https://cals.arizona.edu/droughtandgrazing/

Appendix 5

Resource List

In order of appearance:

- Managing Drought Risk on the Ranch:
  - https://drought.unl.edu/ranchplan/

- Guide to Co-Developing Drought Preparation Plans for Livestock Grazing on Southwest National Forests:
  - https://cals.arizona.edu/droughtandgrazing/sites/cals.arizona.edu.droughtandgrazing/files/Hawkes%20et%20al%202018%20Guide%20to%20Co-developing%20Drought%20Preparation%20az1764.pdf

- National Drought Mitigation Center's Drought Management Resources:
  - https://drought.unl.edu/ranchplan/Overview/WhyPlan.aspx

- CoAgMet:
  - https://coagmet.colostate.edu/maps.html

- Colorado Climate Center:
  - https://climate.colostate.edu/normals_stn_select.html

- Drought Plan Examples.:
  - https://drought.unl.edu/ranchplan/WriteaPlan/SampleDroughtPlans/SouthernColorado-WelchRanch.aspx

- National Drought Mitigation Center's Drought Plan Examples.
  - https://drought.unl.edu/ranchplan/WriteaPlan/SampleDroughtPlans.aspx

- Collaborative Adaptive Rangeland Management experiment:
  - https://www.ars.usda.gov/plains-area/fort-collins-co/center-for-agricultural-resources-research/rangeland-resources-systems-research/docs/range/adaptive-grazing-management/research/

- Decision tree on ENSO / PDO Phase:
  - https://extension.colostate.edu/topic-areas/agriculture/early-warning-for-stocking-decisions-in-eastern-colorado-3-115/

- The National Drought Mitigation Center (Hemovich approach):
  - https://drought.unl.edu/ranchplan/WriteaPlan/SampleDroughtPlans/CentralArizona-BarXRanch.aspx

- Climate Toolbox:
  - https://climatetoolbox.org/tool/future-climate-dashboard

- NRCS:
  - http://www.co.usda.nrcs.gov

- DARCA (Ditch and Reservoir Company Alliance) Funding Guide:
  - https://www.irrigationresourcehub.org/pdf-guide

Appendix 5

Resource List Continued

In order of appearance:

- NRCS:
  - https://www.nrcs.usda.gov/wps/portal/nrcs/site/co/home/
- Bird Conservancy of the Rockies:
  - https://www.birdconservancy.org/what-we-do/stewardship/stewardship-contacts/
- Colorado Elevation Info:
  - http://climate.colostate.edu/climate_long.html
- The Colorado Climate Center, Station Normals:
  - http://climate.colostate.edu/new_station_normals.html
- Seasonal Precipitation or Temperature Outlook:
  - https://www.cpc.ncep.noaa.gov/products/predictions/30day/
- Drought Outlook:
  - https://www.cpc.ncep.noaa.gov/products/expert_assessment/sdo_summary.php
- Seasonal Precipitation Outlook:
  - https://www.cpc.ncep.noaa.gov/products/predictions/30day/
- Long Term Precipitation Outlooks Forecast:
  - https://www.cpc.ncep.noaa.gov
- GrassCast:
  - https://grasscast.unl.edu
- Colorado Climate Center, Temperature Change:
  - https://climate.colostate.edu/co_cag/temp_trends.html
- NASA GRACE Map:
  - https://nasagrace.unl.edu
- Bureau of Reclamation:
  - https://www.usbr.gov/uc/water/basin/
- Risk Management Agency Website:
  - https://webapp.rma.usda.gov/apps/actuarialinformationbrowser/CropCriteria.aspx
- Rangeland Analysis Platform:
  - https://rangelands.app
- Determining Stocking Rate:
  - https://digitalcommons.usu.edu/cgi/viewcontent.cgi?referer=&httpsredir=1&article=1992&context=extension_histall

Appendix 5

Resource List Continued

In order of appearance:

- Ecological Site Descriptions:
  - https://edit.jornada.nmsu.edu/catalogs/esd
- CSU Extension App:
  - https://rangemanagement.extension.colostate.edu/stocking-rate/\
- Web Soil Survey Data:
  - https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm
- University of Arizona Guide to Planning and NEPA:
  - https://cals.arizona.edu/droughtandgrazing/guides
- CSU Carrying Capacity App:
  - https://csurange.shinyapps.io/RangeCC/
- CSU Ag Business Strategies for Cattle During Drought Tool:
  - https://abm.extension.colostate.edu/decision-tools/
- Alternative Feeds for Cattle During Drought:
  - https://extension.colostate.edu/topic-areas/agriculture/alternative-feeds-for-cattle-during-drought-1-626/
- Nitrate Poisoning:
  - http://extension.colostate.edu/topic-areas/agriculture/nitrate-poisoning-1-610/
- Prussic Acid Poisoning in Livestock:
  - http://extension.colostate.edu/topic-areas/agriculture/prussic-acid-poisoning-1-612/
- Sheep Feeds and Management During Drought:
  - https://extension.colostate.edu/topic-areas/agriculture/sheep-feeds-and-management-guidelines-during-drought-1-633/
- CSU Veterinary Diagnostic Labs
  - http://csu-cvmbs.colostate.edu/vdl/Pages/default.aspx
- CDPHE Algal Bloom Info:
  - https://cdphe.colorado.gov/toxic-algae
- Livestock Water Quality:
  - https://www.ndsu.edu/agriculture/extension/publications/livestock-water-quality
- FSA Qualifying Counties:
  - https://www.fsa.usda.gov/programs-and-services/disaster-assistance-program/livestock-forage/index
- National Drought Mitigation Center- Priorities After Drought:
  - https://drought.unl.edu/ranchplan/AfterDrought/ManagementPrioritiesAfterDrought.aspx

Appendix 5

Resource List Continued

In order of appearance:

- Caring for Livestock Before Disaster:
  - https://extension.colostate.edu/topic-areas/agriculture/caring-for-livestock-before-disaster-1-814/
- Caring for Livestock During Disaster:
  - https://extension.colostate.edu/topic-areas/agriculture/caring-for-livestock-during-disaster-1-815/
- Caring for Livestock After Disaster:
  - https://extension.colostate.edu/topic-areas/agriculture/caring-for-livestock-after-disaster-1-816/
- Water Irrigation Scheduler for Efficient Application (WISE):
  - http://wise.colostate.edu
- American Institute of Stress:
  - https://www.stress.org/stress-effects#:~:text=Symptoms%20of%20chronic%20stress%20include%3A%201%20irritability,2%20anxiety%203%20depression%204%20headaches%205%20insomnia
- CAAMHP for Health:
  - https://www.caamhpforhealth.org
- CSU Ag Business Decision Tools:
  - https://abm.extension.colostate.edu/decision-tools/
- Risk Management Agency Decision Support Tool:
  - https://prodwebnlb.rma.usda.gov/apps/prf
- CSU Drought Fact Sheet:
  - https://extension.colostate.edu/docs/pubs/drought/drought-str
- USU Drought Fact Sheet:
  - https://digitalcommons.usu.edu/cgi/viewcontent.cgi article=3031&context=extension_curall
- Managing Drought Risk on the Ranch Overview:
  - https://drought.unl.edu/ranchplan/Overview.aspx
- ENSO Status:
  - https://www.pmel.noaa.gov/elnino/status
- ENSO Monitoring:
  - https://www.ncei.noaa.gov/access/monitoring/enso/soi

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