Climate Change Resiliency in Colorado: Grazing System BMPs

Introduction

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Concentrations of carbon dioxide in the atmosphere are projected to continue rising. Elevated levels of greenhouse gases like CO2 can lead to environmental impacts such as increased temperatures, varied patterns of precipitation, and more extreme weather events. These environmental changes can cause changes in vegetation composition & diversity, water availability, and the presence of weedy or invasive species. All of these factors can have serious implications for livestock and forage quality & yield (Augustine et al., 2018). Grazing capacity, irrigation water, and winter feed availability can be reduced leading to negative impacts on calf weaning weights, reproductive rates, rangeland condition, and ultimately profitability. In the face of climate change, it is important as producers to be prepared for severe circumstances to be able to recover quickly with minimal impact on their agricultural enterprises.

The following best management practices are strategic, tactical, and operational recommendations based on current research that is applicable to the climate and ecosystems present in Colorado. However, it is recognized that rangeland systems across Colorado are ecologically diverse and multifunctional, and not all practices will be applicable in every situation. These are general technical guidelines to provide information on how producers could potentially improve resilience against variable climate and remain adaptable in the face of adverse conditions.

Adaptability is a term often mentioned with rangeland resiliency and is discussed in the following pages. Although this document is largely a list of research based BMPs, it is recognized that being flexible and adaptable in the face of an uncertain future requires this concept to go beyond day to day grazing management decisions. The basis of adaptive ranch management includes not only a concept of managing cattle for ecological sustainability but also economical and mental adaptability. Adaptive management includes large social and economic pieces. Forming community networks for information sharing and support, best and worse-case scenario financial planning, and many other strategies fall under being wholly adaptable as an entire ranch enterprise.

Climatic uncertainty in the form of drought, intense rains, and wind is a concern many scientists, extension agents, and other related parties have for current and future agricultural entities. Many resources and people are available through the network of Colorado State University and Extension for more advice, assistance, and questions regarding these matters visit https://extension.colostate.edu/. Lastly, this document is a continuous work in progress, with modifications made when required.

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Strategic/Whole Ranch Planning

Adaptive Grazing Management

- Adopt adaptive management practices for grazing and the enterprise as a whole.
    - Decisions are evaluated in a continuous loop. Goals and objectives are set, a complete inventory of resources are recorded, rangeland or pastures are monitored, and management decisions are then adjusted based on findings to move closer to set goals and objectives. This is a tool that provides flexibility and will likely be needed in the face of an uncertain future (Derner, 2015; Derner et al., 2018; Ellenwood et al., 2012; Kachergis et al., 2014; Sprinkle, 2018).
    - Overall flexibility and adaptability of an enterprise is important to have alternate plans for variable climate.
    - Multiple studies that suggest grazing practices that stimulate greater forage productivity, reduce invasive weeds, and increase grass species can promote carbon stores (Conant et al., 2009; Ellenwood et al., 2012; Follett and Reed, 2010; Fynn et al., 2010).
    - Properly managed rangeland has been estimated to have the potential to offset 3.3% of carbon dioxide emissions (Ellenwood et al., 2012; Fynn et al., 2010). However, heterogeneity makes it difficult to properly measure/monitor carbon in rangeland (Failey and Dilling, 2010).
    - Adaptive grazing strategies can support species diversity which is advantageous under drought conditions.
        - Peak growing seasons vary among species taking advantage of different temperatures and providing a more heterogenous and consistent forage base (location dependent).
        - Heterogenous root morphologies of different species can take advantage of moisture at varying depths.
        - Diversity generally correlates to less exposed soil leading to greater ground cover, greater structural soil stability, less erosion, and greater moisture holding capacity. (Howery, n.d.)
        - Greater rangeland diversity help combat toxic/invasive plant growth.
        - Above ground diversity helps create below ground diversity of microbial communities. Plant roots exude various sugars, amino acids, hormones, and other compounds that are utilized by microbes, insects, and other invertebrates (Pasture Soils from the Ground Up, Lecture, LRGA, Chad Cheyney, Extension Educator).
            - Improved microbial diversity aids in the breakdown of livestock manure contributing to a more efficient nutrient cycle (Condron et al., 2010). Physical and hydrological cycles can also improve through healthy biological communities.
    - Manure from grazing increases nutrient loading.
    - Grazing can decrease woody vegetation in certain ecological settings.

- Adaptive grazing can improve over-grazed or degraded rangelands that often amplify the effects of drought.
    - When palatable plants are weakened, toxic plants can remain green becoming a more likely chosen option for livestock (Hart and Carpenter, n.d.).
    - Bare spaces void of ideal species can create habitat for invasive or undesirable species often displacing native plants (Nania et al., 2014).

- Overgrazing may lead to decreased soil organic matter, water holding capacity, and soil organic carbon (Conant and Paustian, 2002).
- Riparian areas often get heavily utilized due to the moisture and green forage that is retained there. Heavy utilization of riparian areas can lead to erosion of stream banks.
    - With more sporadic and extreme precipitation events, weakened riparian areas will see a negative impact on bank stability and erosion (Derner et al., 2018).

Adaptive Rangeland Management of Livestock Grazing, Disturbance, and Climatic Variation research project: https://www.ars.usda.gov/research/project/?accnNo=424156
USDA Northern Plains Regional Climate Hub Assessment of Climate Change Vulnerability and Adaptation and Mitigation Strategies: https://www.climatehubs.oce.usda.gov/sites/default/files/NorthernPlains_Vulnerability_Assessment_2015.pdf

Key Components of Adaptive Grazing

Adaptive grazing is a goal-based method that encourages managers to make a plan, implement it, and assess whether the actions were successful or need to be changed. This is a continuous loop that allows producers to constantly hone in on management tactics that further reach their goals and objectives for their individual land and ecosystem.

Intensity

- Balance animal units (AU's) to match forage availability (Ogle and Brazee, 2009).

- Cover can increase precipitation infiltration, slow down erosion and lessen raindrop impact.

- Use 1-3 month weather predictions to adjust stocking rates on rangeland (Kachergis et al., 2014)

- Set a target grazing utilization that is physiologically aligned with the present species to maintain a productive forage stand and avoid overgrazing.
    - A generally rule for utilization is to graze 50% of aboveground biomass. Beyond 50%, multiple studies have shown root production in many grasses decrease. In addition, less leaf area is available for photosynthesis which directly impacts regrowth potential (Pearson et al., 2011).
        - At 50% biomass removal, roots will continue to growth. At 70% utilization caused 50% of the roots to stop growing for 17 days which reduces nutrient absorption. At 90% utilization of the plant, nearly all roots stopped growing for 17 days (Burritt and Reid, 2012; Fick, 2013).
        - The standard grazing rule of "take half, leave half' or 50% utilization of forage may have a significant impact in N cycling. In one study, the moderate grazing treatment increased the supply of mineral N for plants when compared with the response observed in not grazed and high intensity grazing treatments (Shariff et al., 1994).

- Shift to a moderate level of use of forage resources to create drought resiliency.
    - Under drought conditions, heavy grazing can lead to plant stress, slowed regrowth, plant kill off, and increased likelihood of weedy plant invasion. It can also impact growth in future growing seasons (Hart and Carpenter, n.d.).
    - Plants grazed to moderate residual heights (lightly – moderately) will recover quicker than plants that were stressed with heavy use for multiple years prior to a drought event. (Mosley, 2016)
        - http://www.msuextension.org/magazine/assets/docs/GrazingDecisions.pdf
    - Plants that are only moderately grazed can still uptake moisture when the soil only contains 1% moisture. Heavily grazed plants will reach permanent wilting point when there is still 6-8% moisture (Howery, n.d.)
        - https://cals.arizona.edu/droughtandgrazing/sites/cals.arizona.edu.droughtandgrazing/files/Howery%202016%20Rangeland%20Management%20Before%20After%20and%20During%20Drought.pdf

    - 50% utilization leaves residual forage behind which retains moisture from precipitation. Residual vegetation can also aid water infiltrate through the soil profile by reducing evaporative losses.

Frequency

- Employ some type of deferred grazing to allow for proper rest and regrowth of forage.
    - Repeated grazing events that occur too frequently can damage plants on rangeland or irrigated pasture. (Dawson et al., 2000; Trlica, n.d.).
    - Rest/rotation methods allow time for pastures ahead in the rotation to accumulate feedstocks or “grass banks” and to provide time for rest and regrowth of already grazed areas (Kachergis et al., 2014).
        - Shorter grazing periods (less than 1 month for rangelands) allow more control over the distribution of livestock and allow pasture regrowth as well as provide the opportunity for stockpiling (Kachergis et al., 2014).
        - In an irrigated MiG system, grazing period of just a few days is recommended to avoid grazing the re-growth. Irrigated, cool-season perennial grasses can begin to regrow within 3-5 days. Grazing this regrowth can weaken plants.
- Subdivide grazing land to create greater animal distribution and increased forage utilization.
    - This can be done by physical fencing, using herding practices, or strategically placing water and mineral.

Timing

- Rotate the time at which a pasture or area of land is grazed each year.
    - This gives different types of plant species a chance to complete reproductive cycles and set seed.
        - Cool season species grow early in the season and set seed while warm season grasses set seed much later (Trlica, n.d.). By rotating spring and fall grazing, these species have the opportunity to set seed every other year to improve forage stands.
    - Avoids grazing the same area during boot stage each year (Burritt and Reid, 2012).
        - In dry environments, grazing at boot stage can be detrimental because the growing point can be removed. This causes the plant to go through the process of re-growing from axillary buds which is a slow process requiring water and nutrients. This is not ideal in a situation where water and time are limiting factors.
    - During drought years, pastures that were grazed in the late spring and early summer receive the most stress. This is because regrowth occurs at a time of least moisture causing stress and poor regrowth.
        - Following drought years, the pastures that were grazed during late spring should be grazed during dormant season as to not stress the same plants multiple years in a row (Mosley, 2016).
            - http://www.msuextension.org/magazine/assets/docs/GrazingDecisions.pdf

- Move livestock quickly early in the season to take advantage of spring moisture and forage that is available.

Stocking Rates: Stock and Monitor

- Establish initial stocking rates by using a previously established stocking rate as a historical baseline, then monitor, assess, and adjust to meet set goals. Generalized stocking rates published by other organizations can be vague and overarching. Set stocking rates and set rest periods make a rigid system not resilient to climatic changes. All adaptations are local and no single approach works in all locations across Colorado's landscape (Joyce and Marshall, 2017).
    - If no baseline stocking rate exists, Natural Resources Conservation Service (NRCS) Web Soil Survey can generate productivity estimates of the area's soil series to use as a starting point.
    - The Rangeland Production Monitoring Service (RPMS) developed in Colorado is a GIS database that estimates forage amounts on rangeland in real time and future predictions. More information can be found at: https://www.fs.fed.us/rmrs/projects/development-rangeland-production-monitoring-service-could-improve-rangeland-management
    - Stocking rates can also be estimated by hoop/clipping sampling and calculations explained in a technical report by the NRCS found at the link below (Ogle and Brazee, 2009).
    - https://www.nrcs.usda.gov/Internet/FSE_PLANTMATERIALS/publications/idpmstn9390.pdf
    - Stock conservatively. Although there are studies that predict greater production in rangelands with climate change, this is not the case for all areas of Colorado (Mccollum et al., 2017; Wyndham et al., 2018). Having a lower stocking density is important to ensure demand does not exceed forage supply. This is particularly true during periods of drought.

- Adjust stocking rates throughout the growing season.
    - Stocking rates are temporally based on averages collected at a point in time. That makes that stocking rate only correct for that time period.
    - Speed of grass growth, cattle nutritional demand, weather patterns, and many other factors are changing throughout the year. It's imperative to monitor and have a working knowledge of forage resources over time to account for these changes in a grazing management plan.
    - Every ranch has a different microecosystem that if learned can lead to greater efficiency and resilience in the face of extreme conditions. Many ranchers that were interviewed in one study discussed the need to "assess, and continually reassess their rangeland based on production, weather, and livestock needs (Knapp and Fernandez-Gimenez, 2009)."
    - A case-study example of adjusting stocking rates throughout the season is the Rancho Largo Cattle Company in Southeastern Colorado. The case study can be found at: https://journals.uair.arizona.edu/index.php/rangelands/article/view/19606/19239

- Monitor water sources (wells, springs and ponds) at a daily, weekly or monthly interval.

- Create a plan for long and short term monitoring to learn ecological trends of a piece of land as well as the scales of variability that exist in soil and topography. This is useful for identifying where problem areas lie or where resources might exist during times of drought.
  - Short-term monitoring
    - Within the year (forage utilization/production)
    - This type of monitoring can help understand how certain areas of grazing land respond to certain climatic conditions (temp/precip)
  - Long-term monitoring
    - Over years (plant species, ground cover, climate)
    - One study found that long-term monitoring discovered decreased C3 grasses over rangeland area on the Colorado Plateau (Munson et al., 2011). With increasing aridity, this area predicts an increase in grass loss. Species change alters forage productivity which would require a reassessment of stocking rates and shifts in grazing seasons (Nania et al., 2014).
  - Evaluate monitoring data and use this information in future decision making on an on-going basis.
    - Information from collected data can help create a detailed inventory of expected available forage in different areas at different points in time allowing for informed decision making in irregular climatic conditions (Sprinkle, 2018).
  - Colorado Resource Monitoring Initiative & Monitoring on Public Lands was created by stakeholders to standardize monitoring on public lands. Colorado Rangeland Monitoring Guide can be found at coloradocattle.org/coloradoresourcemonitoringinitiative ("Colorado Rangeland Monitoring Guide," 2014)
  - Grass-Cast: An Experimental Grassland Productivity Forecast for livestock producers by Colorado State University that provides total biomass production at the county level for the duration of the growing season (Peck et al., 2019). (http://grasscast.agsci.colostate.edu/resources/Grass-Cast%20flyer_May142018.pdf)
  - Forage monitoring methods
    - USFS Utilization gauges (Sprinkle, 2018)
    - Balance techniques for rangeland (Sprinkle, 2018)
    - Grazing stick or clipping method for irrigated pastures (Sprinkle, 2018)
    - Grass balancing method for estimating forage height for achieving specific utilization levels (Stam, 2014)
    - Range hoop method (Ogle and Brazee, 2009)
  - Monitoring Phone Apps
    - LandPKS (free) (landpotential.org/landpks.html)
    - PastureMap (paid)
    - GrassSnap (free)
    - "GrazeOK" is an app for Android or iPhone to allow fast estimations of stocking density based on average canopy height measurements (Great Plains Grazing, 2018)
      - https://greatplainsgrazing.org/decision-support-tools

- “Canopeo” is an app for Android or iPhone that quantifies percent canopy cover of live green vegetation by taking a photo with the mobile device. This may be difficult to use in rangeland situations.
- Remote sensing: the use of large scale photographs to detect noxious weeds, soil, and plant cover using freely available satellite imagery (Landsat, AVHRR, MODIS) (Hunt et al., 2003).

Drought Planning, Preparing, and Monitoring

- Create a strategic drought contingency plan that provides management flexibility and the ability to respond quickly and effectively. Strategies should be developed for preparing, responding, and recovering from drought. (Derner et al., 2018; Olsen et al., 1954)
  - Take inventory of forage and range resources, identify target conditions, and monitor resources.
  - Southeastern Colorado Drought Vulnerability Assessment (USDA SW Climate Hub, NRCS, Jornada Arid Land Research Program) examines potential sensitivity of a site, ranch, or region to drought scenarios. It also gives an idea of what adaptive capacity is available in response to a drought based on ecological attributes (soil, common species, etc) (Wyndham et al., 2018).

- Increase flexibility by making business decisions ahead of time that can reduce the impacts of drought (Kachergis et al., 2014).
  - Growing a larger operation in terms of acreage. More land resources means access to more heterogenous forage resources that could be of use during drought.
  - Having yearling livestock can allow for a more flexible stocking rates. This may not be advantageous in all scenarios.
    - According to an economic study, having yearlings as part of the enterprise as compared to strictly calf-calf increased average annual net income by 14% with conservative stocking rates and nearly 66% with flexible/adaptive grazing (Torell et al., 2010). However, this is also more of a financial risk.
  - Shorter grazing periods can allow for stockpiling and rest periods.
  - Reduce stocking density and/or adjust stocking rate with weather predictions.

- Track and monitor dryness and drought across the country.
  - U.S. National Drought Mitigation Center has drought tracking across the United States as well as example drought management plans for ranches in the west.
    - https://droughtmonitor.unl.edu
  - Use seasonal weather predictions to adjust stocking rate (Derner, 2015)
  - Winter season predictions have become more accurate than summer precipitation. This can be an important source of moisture for operations that rely heavily on snow melt (Hawkes, 2018).
    - https://cals.arizona.edu/droughtandgrazing/sites/cals.arizona.edu.droughtandgrazing/files/Hawkes%20et%20al%202018%20Guide%20to%20Co-developing%20Drought%20Preparation%20az1764.pdf

- Utilize decision making tools to weigh enterprise options during times of drought.
  - Colorado State University has two management decision tools available at http://wr.colostate.edu/ABM/ -> Full Resource Index -> Decision Tools
    - “Buy Hay or Sell Cows” and “Strategies for Cattle Herd During Drought” (Colorado State Extension, Ag and Business Management Department)

- Downloadable guide for “Managing Drought Risk on the Ranch” (National Drought Mitigation Center, 2013)
    - https://drought.unl.edu/ranchplan/overview.aspx

Enterprise Changes

- Modify livestock enterprise structure to match forage availability with demand.
  - Shift from a cow-calf enterprise to a mixed cow-calf and stocker/yearling enterprise to provide flexibility (Derner et al., 2018).
    - This allows produce to sustain genetics with a smaller numbers of breeding cows by eliminating the need to liquidate during drought.
    - According to an economic study, having yearlings as part of the enterprise as compared to strictly calf-calf increased average annual net income by 14% with conservative stocking rates and nearly 66% with flexible/adaptive grazing (Torell et al., 2010).
  - Adjust to a later calving season (April-June) to match livestock's nutritional needs to forage availability.
    - This can increase cows' body condition prior to breeding and saves costs on feeding hay to fall calves.

- Utilize multi-species grazing to increase carrying capacity, rangeland plant utilization, economic returns, and overall flexibility in the face of climate change (Derner et al., 2018; Launchbaugh, 2016).
  - 24% greater carrying capacity grazing sheep and cattle than just cattle alone in a study in Colorado.
    - This can be landscape dependent. Most benefit would come from grass/shrub landscapes.
  - Different animals to market at different times of the year which improves cash flow. Diversifying reduces financial risks.
  - Greater weight gains and production up to 9-10% greater than single species grazing systems.

- Diversify grazing lands portfolio.
  - Utilize a mix of different grazing lands to spread risk (Hawkes, 2018).
    - Privately owned pasture
    - Public land grazing allotments (BLM, Forest Service, etc)
    - Lease other private pasture
    - Irrigated pasture
    - Guide to co-developing drought preparation plans for livestock grazing: https://cals.arizona.edu/droughtandgrazing/sites/cals.arizona.edu.droughtandgrazing/files/Hawkes%20et%20al%202018%20Guide%20to%20Co-developing%20Drought%20Preparation%20az1764.pdf

Tactical Methods

Prescribed Fire and Patch-Burning

Using fire as a tool in Colorado is extremely dependent on ecosystem type and historical fire regime. Contact local resources to determine if fire is a viable option for site-specific systems.

- Utilize prescribed fire or patch burning during non-drought years to stimulate above and belowground biomass grass while increasing diversity and heterogeneity (Augustine and Derner, 2014; Derek Scasta, n.d.; Scasta et al., 2016)
  - During drought years, patch-burning was documented to reduce cattle gains (Derek Scasta, n.d.).
  - Key considerations of prescribed burning should include (Derek Scasta, n.d.)…
    - What is the historical fire regime? Less precipitation usually equates to a long fire return interval (Weir et al., 2013).What size area should be burnt? What present wildlife habitat and plant species are sensitive to fire?
  - Stock at a moderate rate pre and post burn. If too heavily grazed, patch burns will not carry a fire (Weir et al., 2013).
  - A proper fire regime can improve plant growth which can lead to greater amounts of sequestered carbon. However, too frequent fires can create the opposite scenario and lose CO2 (Follett and Reed, 2010; Rice and Reed, 2007).

- Use patch-burning to mitigate invasive species spread and parasite loads on rangeland.
  - Climate change is causing invasive species to expand their range and encroaching on rangelands reducing the amount of available forage for cattle production and sometimes causing toxicities to livestock.
  - Patch-burn grazing can slow the reproduction and spread of invasive or toxic weeds and reduce costs associated with other weed management strategies such as herbicide (Scasta et al., 2016).
  - Like invasive plant species, climate change may contribute to a more abundance of some parasites. Fire can help control parasite loads on rangeland. (Derner et al., 2018).

- Employ patch-burns to increase livestock distribution.
  - One study found that in semi-arid rangeland that was patch-burned, cattle selected riparian areas five times less compared to a traditionally managed system (Scasta et al., 2016).
    - This is extremely dependent on ecosystem type and historical fire regime

- Use prescribed fire to increase forage quality.
  - Burn during the grazing season provide to high quality forage in the fall months helping to extend the growing season and reduce input costs (Augustine and Derner, 2014).

◦ Standing dead biomass in above-average precipitation years can suppress cattle weight. Burning could have a positive impact in this scenario by removing low quality material and encouraging vegetative regrowth (Augustine and Derner, 2014).

Managing Invasive/Toxic Plant Species

- Utilize proper grazing practices that have flexible stocking rates and improve livestock grazing distribution. This promotes species diversity and discourages heavy grazing in particular areas.
  - Impacts of climate change allow hardier species that can be toxic or invasive to expand their range.
  - If undesirable or toxic plants exist in pastures, drought can exacerbate these issues. This is especially true when rangelands are overgrazed or in poor conditions.
  - Weeds often can handle environmental stresses better than forage species allowing them to take advantage of stressful climatic conditions.

- Make controlling toxic species a priority objective (mechanically, chemically, or biologically).
  - Cost-sharing funds may be available through the local NRCS Conservation District, Habitat Partners Program (Colorado Parks and Wildlife), or the Colorado Partners for Fish and Wildlife Program.
  - “Toxic Crops for Livestock” is an app for Android or iPhone that lists plants that have been evaluated for safety in regards to metabolic or toxicity issues for multiple livestock species.

- Monitor livestock when heavy rains occur after an extended period of drought.
  - A flush of toxic plants can occur causing toxicities to livestock.
- Monitor livestock during a drought for toxicities because non-toxic plants can become toxic under severe environmental stresses such as wilting (Hart and Carpenter, n.d.).

- Supplement with protein, vitamin A, and phosphorus
  - Vitamin A and phosphorus deficiencies become common during droughts and often cause animals to alter grazing behavior which can lead to consumption of toxic plants (Foster et al., 2015; Hart and Carpenter, n.d.).
  - Livestock have an internal ability to detoxify certain amounts of phytotoxins from plants. Adequate protein levels can improve the nutrional status of the animal which can aid the rumen in detoxifying and tolerance of the phytotoxin the animal has consumed.
  - Protein supplementation has also been shown to reduce methane production (Cole, 2018).

- Adopt proper grazing management to avoid over-grazing that can lead to the present of fire regime altering invasive species.
  - Cheatgrass, a common invasive annual grass, can thrive and establish in disturbed areas. This species creates increased amounts of fine fuel load that is highly flammable and can alter fire frequencies further (“Cheatgrass and Wildfire,” 2012; Diamond et al., 2009; Nader et al., 2007).
    - Cascading effects can include erosion and water quality issues.
    - https://extension.colostate.edu/docs/pubs/natres/06310.pdf

◦ Multiple studies have shown that grazing during specific phenological phases (especially in the fall) can reduce Cheatgrass biomass over multiple years (Diamond et al., 2009; Foster et al., 2015).

Reduce forage demand

- Stock at 90% of the average long-term carrying capacity to prepare for drought.
  - Having a greater forage buffer can avoid having to sell cattle when prices are low. (Hanson et al., 1993; Howery, n.d.)
    - https://cals.arizona.edu/droughtandgrazing/sites/cals.arizona.edu.droughtandgrazing/files/Howery%202016%20Rangeland%20Management%20Before%20After%20and%20During%20Drought.pdf

- Vary stocking rate for forage supply
  - Use weather predictions to adjust stocking rates.
  - Include yearling livestock to reduce forage requirements and intake.

- Diversify livestock enterprises (yearlings, other species)

- Reduce cattle numbers early in the drought cycle.
  - Delaying this decision making can lead to exhaustion of forage inventory and declining markets leading to lower overall income (particularly if the drought is widespread) (Gill and Pinchak, n.d.)
  - Sell breeding stock.
  - Weaning calves early is a common practice that is resorted to when forage supply is getting scare. However, culling spring calves under six months of age does not significantly decrease herd forage demand. In addition, these animals tend to have little market value in wide-spread drought situations (Gill and Pinchak, n.d.).
    - http://varietytesting.tamu.edu/files/forages/drought/Destocking%20Strategies%20During%20Drought.pdf

- The exception to this is if early weaning is being used to improve cow conditions.

- Move cattle to a dry lot and supplement with grain and hay.
  - It is recommended to feed a 1:2 or 1:3 ratio of grain to hay to “stretch” supplies. However, never exceed 0.4% of an animals body weight if their rumen is accustomed to a forage diet. (LeValley, 2009)

Increase forage supply

- Purchase or reserve backup feed early because hay and feed prices can spike during widespread drought.
  - Feed hay in strategic locations to improve soil fertility and organic matter. If applied in bare areas of soil, hay applied can be trampled in by cattle hooves. Nutrients that the hay removed from the soil when harvested can be decomposed and added to the soil.
    - It's important to note that hay can harbor weed seeds that could establish where cattle are being hayed. If possible, be selective in purchasing quality hay.
  - Consider alternative feed sources such as cottonseed, wheat middlings, soybean hulls, and sorghum-sudan (LeValley, 2009)

- Utilize stockpiled forage when pastures are becoming low on forage availability.

- Rent additional pasture/move to another location

- Consider working with local crop farmers to graze crop residues (Ward Laboratories, 2018).

- If possible, delay grazing in the late spring during and after an extended drought to avoid plant stress by supplementing with hay.
  - Depending on conditions (i.e. wet spring), this may not be necessary. Monitoring will be required to decide if this is the best route of action.

- Stocking rates may need to be reduced in the following years after a drought depending on condition of pastures.

- Match feed quality with animals with the greatest nutrient requirements (LeValley, 2009).
  - Saving higher quality feeds for pre and post calving cows

Windrows/Swathing

- Utilize windrow grazing to reduce associated labor and input costs of baling, storing, and feeding hay which can be beneficial if dry climatic conditions impact yields during the growing season.
  - This eliminates the cost of hauling and spreading manure back onto fields from concentrated winter feeding areas. (Surber, 2003)
  - Nearly all organic matter added to a system is derived from plant material directly or indirectly in the form of detritus, soluble exudates, or in a digested form such as animal manure (Condron et al., 2010). This method returns organic matter and nutrients to the soil which is something that hay production lacks.
    - https://extension.usu.edu/rangelands/ou-files/Swath_Grazing.pdf

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- Employ windrow grazing to provide a hay quality equivalent feed source to livestock.
  - Drier climate retains greater forage quality in windrows.
  - A study by Nebraska Extension showed that windrows maintained about the same crude protein levels throughout the fall and winter as baled hay while standing forage lost a substantial amount of quality (Berger et al., 2006).
  - Drier climate retains greater forage quality in windrows.
  - Controlled strip grazing is an effective method for using this strategy.

Stockpiled Forage

- Stockpile forage to extend the grazing season.
    - Warmer winter temperatures are predicted with climate change which could elongate the grazing season (Ahraf et al., 2014).

- Utilize warm season grasses for forage stockpiling in irrigated scenarios.
    - C4 species are high yielding and more water and nitrogen use efficient than cool-season grasses (LeValley, 2009). They will grow during the hot, dry months of the summer generally when drought impacts are most prevalent. (Kachergis et al., 2014; Nania et al., 2014; Tradeoffs in ecosystem services using warm-season grasses in managed pastures, 2009)
        - Pearl millet – warm season annual grass that is commonly used as an "emergency forage" because of its drought tolerance, high energy and protein, and low fiber and lignin (Golden et al., 2016). This species is drought-tolerant because of its extensive root system. It is also a safe choice because this plant does not contain prussic acid, eliminating the worry for prussic acid poisoning when the plant is stressed.

- Plant forage specifically for the purposes of stockpiling for later use or set aside areas of pasture/ rangeland to accumulate a 'forage bank.'

Operational Strategies

Irrigated Pasture

- Incorporate irrigated pasture into an enterprise as a forage safety net during dry years and for an abundance of high quality feed during non-drought years.
  - Forage on an irrigated pasture can be grazed, stockpiled, hayed, or a combination of the three depending on the circumstance.
  - According to multiple studies, rangeland quality is predicted to decrease making irrigated pasture or planted crops an option for improving livestock nutrition (Derner et al., 2018; Mccollum et al., 2017).

- Establish cool-season perennial species if irrigation is not a limiting factor. If water is limiting, warm season species can planted as an alternative.
  - Warm season species have a greater water use efficiency than cool-season species.
  - Annual forages are another option for irrigated pasture (cool and warm season).

- Employ management-intensive grazing (MiG) practices for optimal forage utilization and efficiency in an irrigated pasture system. Management practices, such as MiG, that often improve forage biomass and overall productivity.
  - The amount of organic matter added to a system is influenced largely by its level of productivity. Improved, perennial, irrigated pastures that are intensively-managed have the greatest ability to sequester carbon compared to other pasture systems (Conant et al., 2009). Cultivation in soils can cause carbon losses of 30-50% while pasture can act as a carbon sink (Kucharik et al., 2001).
  - Thriving perennial pasture species with increased productivity have healthy, actively growing and sloughing root systems. Root and root exudates contribute 60-80% to soil organic matter (Chiavegato et al., 2015; Condron et al., 2010).
    - The total carbon fixed through photosynthesis, soluble root exudates make up 10-40% which drives microbial processes in the rhizosphere important for decomposition (Condron et al., 2010)
  - Sequestering carbon not only decreases atmospheric carbon dioxide but increases soil quality. Higher carbon content in soils reduce crusting, increase water holding capacity, improves soil structure, and fosters more microbial activity.

- Improve soil quality with irrigated pasture.
  - Irrigated, productive systems often have greater microbial activity which can lead to greater soil aggregate formation.
  - Soil aggregate formation can improve water infiltration which is advantageous in an irrigated system.

Wet Meadow Restoration

- Utilize low-tech methods for wet meadow restoration to increase forage productivity and enhance ranch resiliency during periods of drought.
    - Increased vertical and lateral hydrologic connectivity can lead to vegetation resilience to climatic variability.
    - Wet meadow restoration (using Zeedyk structures) resulted in 24% increase in vegetation productivity in a case study in the Upper Gunnison Basin (Silverman et. al., 2018).

Annual Forages/Cover Crops

- Use annual forages/cover crops as a low input emergency forage during drought conditions.
  - Cover crops combined with no-till practices can help retain spring and fall moisture from evaporation.
  - Over the long-term, cover crops can add organic matter to the soil which can lead to greater retention of moisture (Golden et al., 2016; USDA-NRCS, 2013). Greater soil organic matter has a host of benefits for a production system:
    - Improves physical structure (water infiltration, porosity, aeration)
    - Stimulates soil biology (increase in microbial activity which can lead to greater nutrient availability)
      - http://www.extension.uidaho.edu/publishing/pdf/BUL/BUL901.pdf

- Plant annual cover crop to fit into specific windows of time in which they take advantage of seasonal moisture or any other opportunity to lessen the pressure on other grazing resources (range, etc).

- Utilize management-intensive or strip grazing to obtain the greatest efficiency with cover crops.
  - This method only allots a given amount of area and forage for a certain period of time before allowing access to a new section allowing cattle to be more efficient with less waste.

- Use cover crops as a high quality feed source, to extend the grazing season, or as winter feed.
  - Quality and energy can be very high in annual crops. If possible, graze only a few days a week or in combination with low quality pastures (Farney, 2018).
  - Winter hardy crops can be grazed multiple times, even late into the fall and early winter.
  - Cover crops can be preserved and stored for winter feeding.
  - Select species based on growth time, water requirements, and season length.
    - Low relative water use cover crops: Barley, Phacelia, Field pea, Lentil, Lupin, Berseem clover, medic, chickpea, amaranth, pearl millet, and foxtail millet (Golden et al., 2016)

- Use cereal crops as an alternative to a traditional hay crop during times of drought due to their drought resistance.
  - They are also known for their ability to improve soil tilth and scavenge for nutrients.
  - Many varieties of barley and wheat can be grown in dryland conditions for hay or grazing.

- Plant additional spring, summer, and fall forage that can be grazed, hayed, or ensiled (LeValley, 2009).
  - Spring: Small grains planted previously in the fall
  - Summer: Drought tolerant warm season grasses
  - Fall: During the summer, small grains and brassicas can be planted for additional fall grazing.

Genetics

- Select genetics for animals that fit their unique environments.
  - Utilize cattle that meet the climatic and environmental conditions of the specific location.
  - This can be a long term commitment but can help create more efficient cows and improve post weaning traits.
  - Cull for moderate sized animals. Aggressive selection for growth has created a gradual increase in cow size which requires greater inputs for maintenance and growth (Lalman et al., 2018).
  - Cull open cows and keep only early-born heifers
  - Select cattle that utilize upland rangeland. This can increase better distribution in pastures creating greater forage utilization avoiding overutilization of riparian area (Burritt, 2012; Derner et al., 2018).
  - Select animals with moderately colored coats to combat heat issues. Light colored cattle can become damaged from UV light and black cattle absorb a lot of heat increasing the chances of overheating.
    - https://animalagclimatechange.org/2019/protecting-livestock-from-uv-damage/

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