UPPER SNAKE RIVER TRIBES FOUNDATION

Climate Change Adaptation Strategies for Rangeland Managers

A Literature Review

adaptation international

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1. Executive Summary

Rangelands are complex, intricate, interconnected, and dynamic socio-ecological systems comprised of humans, livestock, and natural wildlife. They are an integral part of the region's economy and provide valuable income to both tribal and non-tribal ranchers and communities.

The climate of the Upper Snake River Watershed, and the Great Basin as a whole, is changing. While variable across the region, for the Upper Snake River Watershed, projections indicate that there will be a significant long-term decrease in snowpack, an increase in the variability of precipitation events, and an increase in temperatures across all seasons. These changes are altering rangelands and challenging ranching operations across the region. This paper provides a literature review of relevant rangeland management and water resource strategies that ranchers and rangeland managers are using to respond to the changing climate conditions. While not comprehensive, this review summarizes some of the most salient current research and actions on managing rangeland systems in a changing climate. The summary is organized around three main themes:

1) ***Grazing –*** By diversifying the variety, age, species, genetic source, and breed of livestock, rangeland managers can invest in cattle that have an increased tolerance to drought, heat, and parasites in order to improve the resilience of their rangeland operation. Key actions include varying stock, constructing exclosures, and using rotational grazing.

2) ***Rangeland -*** Natural plant diversity across rangelands minimize the risk of catastrophic events (wildfire, disease, and pests) and improve consistency of livestock production. Key actions include: improving landscape connectivity; integrating rangeland and cropland; and removing invasive species while enhancing planting of native grasses and forbs.

3) ***Water Resources -*** Healthy ecosystems support many essential services including: enhancing biodiversity; enhancing healthy soil and water quality; encouraging pollinator habitat; controlling erosion; providing essential water services for rangeland production; sequestering carbon; and reducing the susceptibility to climate change. Key actions include creation of beaver dam analogues, expanding water storage, and supplemental watering.

Table 1: Summary of grazing, rangeland management, and water resource management-focused action areas that can be used to improve or enhance the resilience of rangeland operations to changing climate conditions.

Focus	Action Area	Description
Grazing		
Stock	Type of Stock	Diversifying the variety, age, species, genetic source, and breed of livestock
	Stock Rates	Adaptive stocking rate strategies (flexible, seasonal, etc.)
	Stock Density	Determining stocking density based on rangeland quality
	Stock Protection	Daytime shelters and shading
Timing	Matching Turn-out Dates with Greening	Updating lease agreement to match turn-out dates with green-up to ensure nutrient availability for cattle
	Rest Rotations	Controlling pasture recovery periods
	Water Points and Salt Licks	Using watering points and salt licks to control livestock distribution across the landscape
	Exclosures	Creating exclosures to protect sensitive habitats and manage stock distributions
	Targeted Grazing	Using specific livestock at specific times to target invasive species
Rangeland Management		
Conservation Strategies	Improve Landscape Connectivity	Reducing landscape fragmentation
	Mix Rangeland and Cropland	Integrating livestock into cropland operations to reduce feed cost, provide additional forage, and eliminate manure concentration areas
	Improve Soil Health	Improving soil health across the landscape (e.g. providing ground cover of plants or residue in specific areas)
	Support & Improve Native Grasses	Minimizing invasive grass species and planting native grass seed
Restoration Strategies	Upland Restoration	Restoring and improving the health of native grasses and trees in upland areas
	Fire	Utilizing prescribed fire to improve adaptability to a changing fire regime
	Invasive Species Management	Eradicating invasive species (e.g. Juniper, cheatgrass) and supporting native grass and tree species growth
Water Resource Management		
Conservation Strategies	Preparing for Drought	Using resources and partnerships to prepare for drought
	Limit Grazing Pressure in Riparian Areas	Reducing stocking rates, density, or utilizing exclosures to reduce grazing pressure in riparian areas
Restoration Strategies	Riparian Restoration	Improving and restoring riparian habitat using various methods to enhance rangeland health and resilience
	In-stream Habitat Restoration	Redistributing large woody debris or boulders to improve stream complexity and lower velocity
	Habitat Connectivity	Reconnecting isolated watershed stream habitats
	Road Improvement	Using good road design, engineering, and maintenance to reduce impacts on watersheds
	Water Storage	Improving water storage and distribution capabilities to preserve water resources and improve livestock access

Adapting to a changing climate will mean more than just modifying approaches to stocking, enhancing and restoring rangelands, or providing diverse and redundant systems for providing and managing water. It will require embracing some amount of uncertainty, and for rangeland managers to be willing to continue to be creative and flexible to make the most of the highly variable and dynamic environmental and socio-economic systems on a seasonal, annual, and even decadal basis. It will also require policy frameworks that enhance the ability of ranchers, and the cattle they manage, to respond to these changes in productive ways. In some cases, it may even mean abandoning certain grazing parcels or allotments that may become unsuitable for ranching.

Regardless of the extent of the challenge, rangeland managers are creative, adaptable, and innovative people and they have a proven ability to prepare for and adjust to changing conditions. Yet, the extent and rate of change is likely to go beyond what they have experienced in the past. Climate change is just one of many factors that rangeland managers will have to balance in their quest to continue to be both profitable and sustainable. ***Utilizing holistic approaches that value both the economic success of a ranching operation and the long-term health and resilience of the landscape and wildlife will ensure that rangelands remain an important part of the social, economic, and cultural fabric of the Upper Snake River Watershed for decades to come.***

2. Introduction and Context

2.1 Geographic and Technical Scope

This project focuses primarily on the Upper Snake River Watershed of Idaho, Nevada, and Oregon. However, the literature review of relevant rangeland management and water resource strategies includes practices outside of the watershed and, where appropriate, includes the Great Basin and the broader Pacific Northwest region. While not comprehensive, this literature review summarizes some of the most salient current research and actions on managing rangeland systems in a changing climate. The first section of this literature review establishes the foundation of this work including: the significance of rangelands in the region (Section 2.2); how climate change is projected to affect the Upper Snake River Watershed (Section 2.3); and, principles for action (Section 2.4). Next, promising climate change adaptation actions are grouped into three primary sections: grazing (Section 3); rangeland management (Section 4); and, water resource management (Section 5). Each of the three sections contain specific case studies to help highlight individual adaptation strategies in action. In addition, specific planning tools, resources, and networks are provided that can help rangeland managers access the information that they need to inform their decision-making (Section 6).

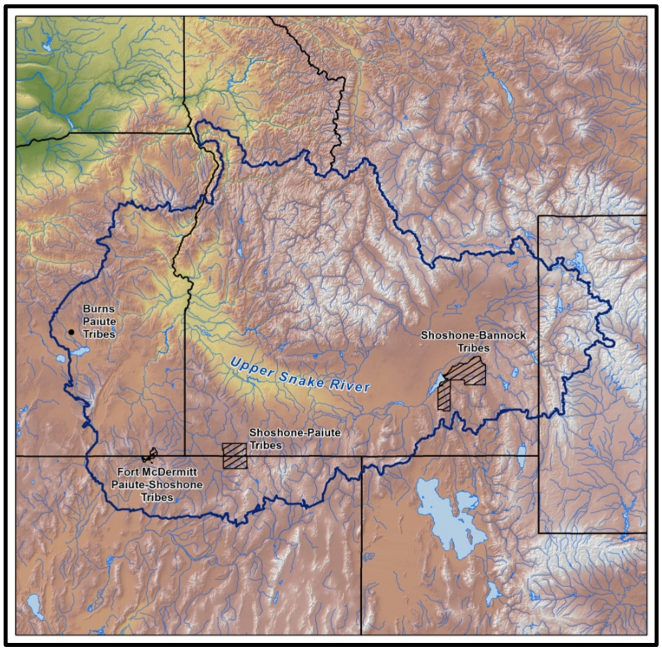

Figure 1: The Upper Snake River Watershed project area for this review - an area of more than 97,000 square miles.

2.2 The Cultural, Economic, and Ecological Significance of Rangelands

The Upper Snake River Watershed is ancestral territory for the Burns Paiute Tribe, Fort McDermitt Paiute-Shoshone Tribe, Shoshone-Bannock Tribes of the Fort Hall Reservation, and Shoshone-Paiute Tribes of the Duck Valley Reservation, the four-member tribes of the Upper Snake River Tribes Foundation (USRT). The Pacific Northwest (WA, OR, ID) includes about 26 million acres of rangeland and pasture land (Figure 2) and is home to over 1.3 million head of beef cattle (Niebergs et al., 2018).

The Upper Snake River Watershed region has one of the highest concentrations of cattle per square kilometer outside of the Great Plains and California's central valley (Figure 3[1]). Over the last few decades, cattle (and the sagebrush steppe rangelands that they rely on) have become an integral part of the region's economy and provide valuable income to Tribal governments, as well as tribal and non-tribal ranchers. Rangelands are an essential component of the cultural, social, economic, and ecologic make-up of this region.

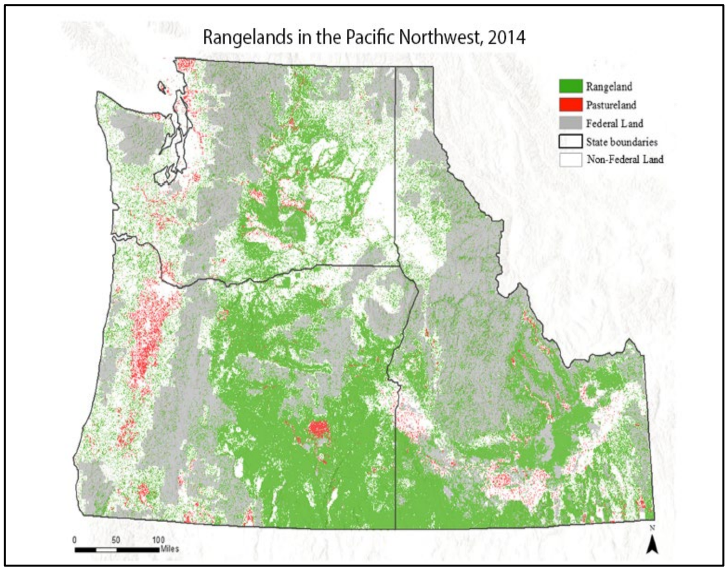

Figure 2: Grazing lands in the Pacific Northwest, 2014 (Niebergs et al., 2018).

There is also a growing understanding that **rangelands are complex social-ecological systems** (Brunson, 2012; Derner et al., 2016; Briske (ed), 2017) and should be managed as "*adaptive social–ecological systems [that] provision multiple ecosystem services to benefit human well-being*" (Briske (ed), 2017, pg. 19). Rangelands serve an essential role in carbon sequestration, provide cultural value, enhance biodiversity, and provide food, fuel, and fiber (Briske (ed), 2017; Provenza, 2008). Rangelands are also extremely diverse, often characterized by differences in topography, soil type, historical management practices, water availability, and more (Derner et al., 2016). More broadly, rangelands encompass 30% of the Earth's land area, and in the conterminous United States, make up nearly 35% of the overall land area (268 million hectares) (Augustine et al., 2018; Briske (ed), 2017; Reeves, 2016). The Society of Range Management defines rangelands as "*land on which the indigenous vegetation (climax or natural potential) is predominantly grasses, grass-like plants, forbs, or shrubs and is managed as a natural ecosystem. If plants are introduced, they are managed similarly; rangeland includes natural grasslands, savannas, shrublands, many deserts, tundras, alpine communities, marshes and meadows*" (Society for Range Management, 1998). As such, rangelands are part of a larger agroecosystem that encompasses more than the land on which livestock graze on.

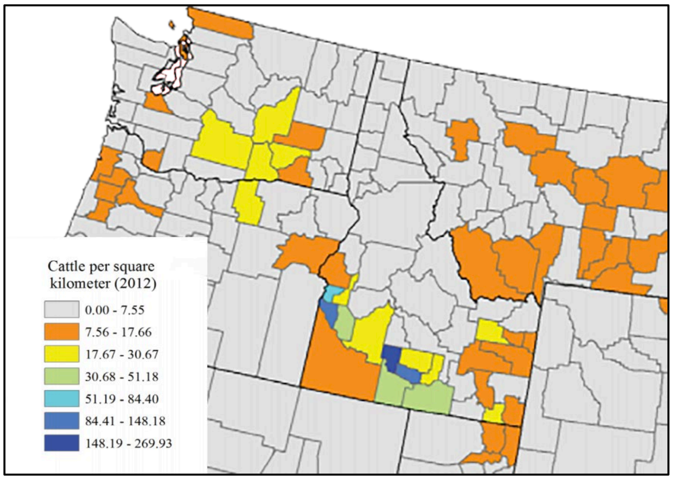

Figure 3: Density of cattle per square kilometer, 2012.

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[1] https://www.fs.fed.us/rm/pubs/rmrs_gtr343.pdf

Rangelands are influenced by both biophysical and socioeconomic drivers (Joyce et al., 2013). In addition, historic rangeland management practices have important implications for the ecology of rangelands (Bouwes et al., 2016). For example, historic overgrazing in the Upper Snake River Watershed and the Great Basin has led to degradation of water resources, soil structure, and plant communities, often leading to social conflict and litigation regarding habitat for fish species protected under the Endangered Species Act (Charnley et al., 2018). Increased temperatures, reduced snowpack, and variable precipitation due to climate change are projected to cause further damage to rangeland systems (Reeves & Bagne 2016).

2.3 Climate Change, Rangelands, and the Upper Snake River Watershed

On-going changes in the Upper Snake River Watershed and Great Basin are part of a larger trend of changing climate conditions for the region, the nation, and the world (USGCRP, 2017). Climate change impacts rangeland ecosystems in complex ways (Izaurralde et al., 2011). The projected increase in temperatures, variability in precipitation, elevated levels of atmospheric carbon dioxide (CO_2), and decrease in snow pack will have varying affect within the Upper Snake River Watershed and Great Basin dependent on topography, site-specific plant community composition, water availability, presence of invasive species, historical and current land use, and aspect. These site-specific impacts are difficult to predict and not yet fully understood. In order for rangeland managers to successfully adapt to these changes, it is important to consider the entire geographic scope and scale of the system. According to the recent climate change vulnerability assessment conducted by USRT:

> *"The climate around the Upper Snake River is changing. USRT member tribes have already noticed shifts in species and habitats driven by increasing temperatures and changing precipitation patterns. Such changes in temperature and precipitation have resulted in drying sagebrush steppe habitat, extended wildfire seasons, less winter precipitation falling as snow, earlier spring run-off, low summer river flows, higher water temperatures, reduced flow from springs/seeps, proliferation of invasive weeds, and the decreasing productivity of rangelands"* (Petersen et al., 2017, pg. 1).

Temperature and Precipitation

Global average temperatures have increased 1.8° Fahrenheit (F) since 1901, 16 of the warmest years on record have occurred since 2000, and extreme heat events are projected to become more common (USGCRP, 2017). For the Upper Snake River Watershed, temperatures are projected to increase across all seasons. While precipitation may increase in many seasons, some areas will experience lower soil moisture levels due to higher temperatures and increased evaporation and evapotranspiration (though the projections aren't consistent across the region and the Upper Snake River plains may have slightly higher soil moisture levels). Increases in atmospheric concentrations of CO_2 and in precipitation may result in higher Net Primary Production (NPP) for forage, yet an increase in temperature has uncertain consequences (Izaurralde et al., 2011). Increasing summer temperatures and more frequent extreme heat events can lead to an increase in heat stress for cattle, often resulting in reduced performance due to lower food intake (Petersen et al., 2017).

The climate projections were downscaled and analyzed by the Oregon Climate Change Research Institute as part of the climate change vulnerability assessment and are specific to the Upper Snake River Watershed. Average annual temperatures across the region could increase by as much as 6.5° Fahrenheit by the 2050s and 10.9° Fahrenheit by the 2080s. Depictions of the projected changes by season for the 2050s is shown below in (Figure 4).

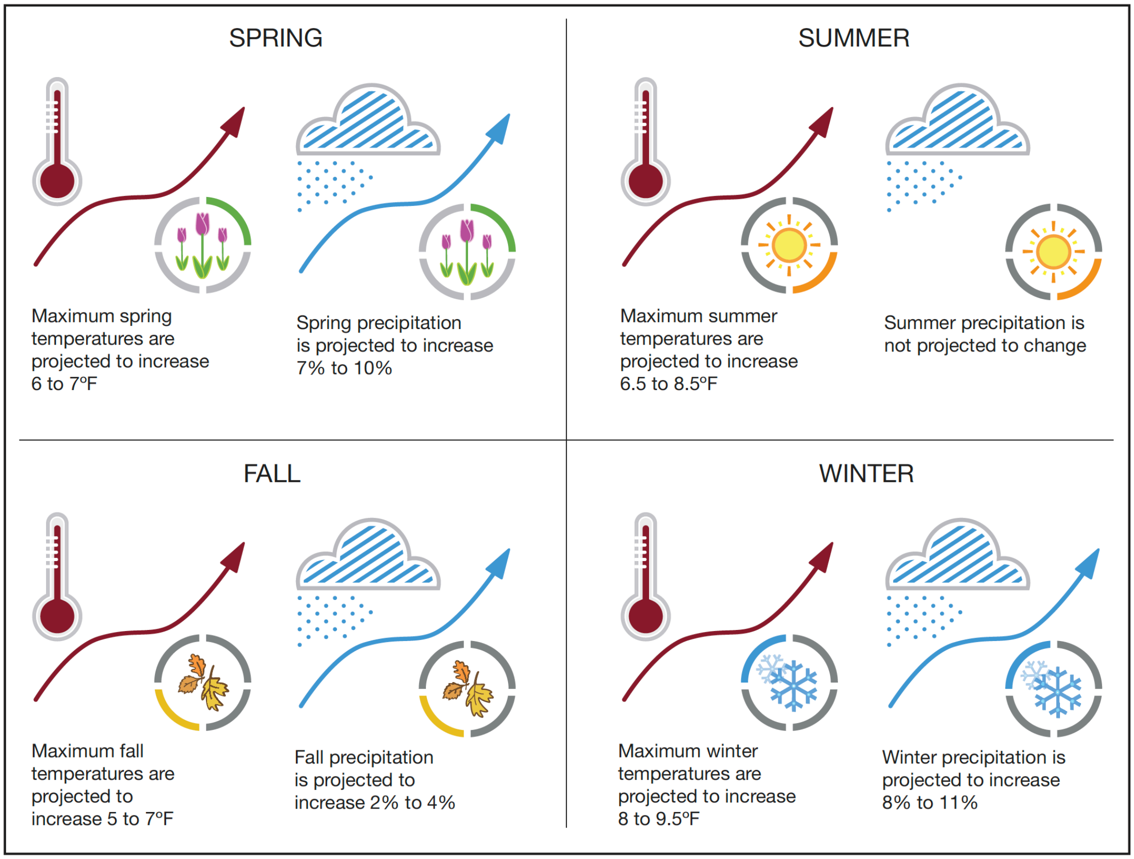

Figure 4: Seasonal temperature and precipitation projections for the 2050s (2040-2069) in the South subdomain (around the river plain) of the Upper Snake River Watershed. Temperature increases and percent precipitation change are relative to modeled historical averages from 1950-2005. The range of values represent the average of the lower climate scenario model projections (RCP 4.5) and the average of the higher climate scenario model projections (RCP 8.5) across all models.

Invasive Species and Plant Composition

Dry and drought conditions are projected to increase in the Upper Snake River Watershed and the Great Basin, leading to a decrease in the timing, quality, and quantity of forage (Neibergs et al., 2018; Petersen et al., 2017). It may also result in the migration of essential rangeland plant communities to higher elevations, or in a change in plant composition due to soil moisture variability (Petersen et al., 2017; Briske (ed), 2017). Native perennial grasses are being out-competed by invasive annual grasses (such as cheatgrass and medusahead) that can thrive in drier conditions, resulting in degraded wildlife habitat and a decrease in biodiversity (Davies et al, 2015). The prevalence of these species on rangelands may also have deleterious impacts on the ability of cattle stocks to obtain vital nutrition, resulting in a decrease in leasing revenue for ranchers.

Fire

Historically, fire has been a natural ecosystem process without regular or uniform distribution that is correlated with warm/dry periods, and dependent on fuels, weather/climate patterns, and ignitions (Scasta et al., 2016). Over the last three decades, the frequency, severity, seasonality, and size of wildfires has increased in the Western United States (Scasta et al., 2016, CCSR Chapter 8, 2017, Perryman et al, 2018). Climate projections show that wildfire risk will continue to increase at least through the middle of the century due to longer and more intense drought conditions, hotter temperatures, and lower relative humidity (Scasta et al., 2016).

In the Pacific Northwest, wildfire events are projected to start earlier, finish later, and occur more often due to increases in spring precipitation (leading to increases in plant growth and thus more fuel for fires), and warmer-drier summers (higher risk conditions for burning) (Niebergs et al., 2018). For sagebrush shrublands, fire has had a variable presence, often dictated by the climate and the abundance and continuity of fuels (Brooks et al., 2011). Fire frequency has been greater in areas with higher productivity sage brush and in periods of increased precipitation (Brooks et al., 2011). According to a recent study, a reduction in grazing livestock on rangelands in the Pacific Northwest region over the last few decades has increased fuel loads and the risk of wildfire (Scasta et al., 2016). In general, wildfire results in the loss and degradation of habitat, lower air quality, property damage, higher firefighting cost, and more health risk (Stavros et al., 2014). Fire on rangelands specifically in the Upper Snake River Watershed and the Great Basin (Figure 5)- has the potential to harm people and livestock, damage or destroy property, and burn forage and rangeland affecting agro-ecosystems (Scasta et al., 2016). It also may require rangeland managers to provide supplemental feed, rebuild fencing, consider alternative grazing options, and in some cases, relocate cattle to other regions.

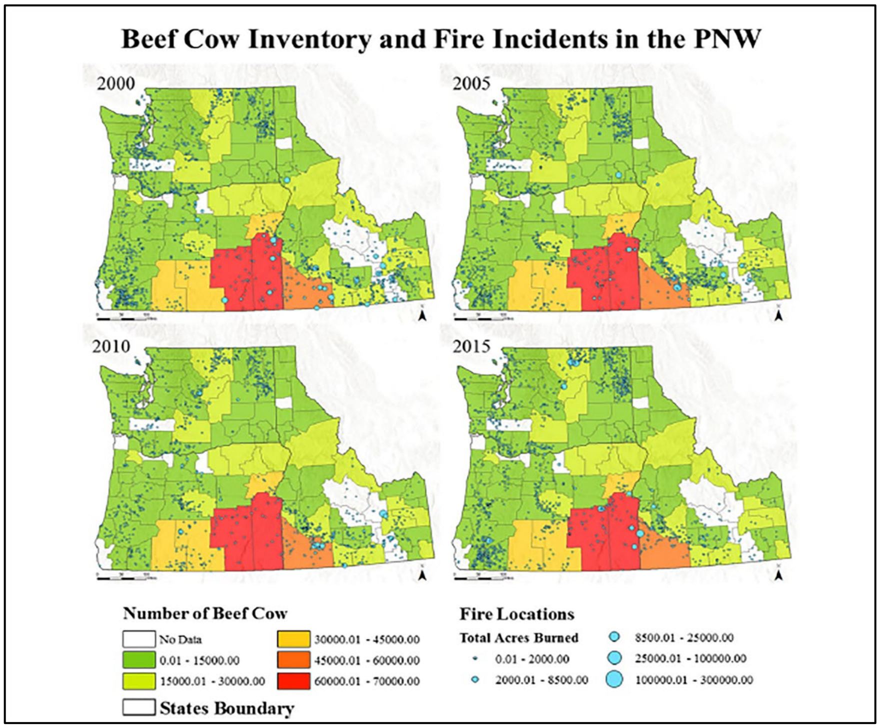

Figure 5: Beef cow inventory and fire incidents in the Pacific Northwest (Niebergs et al., 2018).

The Costs of a Changing Climate

The impacts of changing climate conditions for rangeland managers go beyond warming temperatures, shifting precipitation patterns, invasive species, and fire risk. Climate change will likely increase production costs for rangeland managers by: increasing watering costs, requiring supplemental feeding measures, and requiring the reduction of livestock numbers during the summer (*May et al., 2018).* Financial considerations for rangeland managers are also influenced by global food consumption and production alterations, international trade agreements, and the ability of rangeland managers to adapt (Gowda et al., 2018). As a whole, the industry plays a vital role in supplying food to millions of people globally and will continue to be important as human populations increase and further exacerbate challenges in global food security (Rivera-Ferre, 2016). Specifically, the livestock sector supplies between 13-17% of calories and between 28-33% of protein globally (Rivera-Ferre, 2016). It is important that these drivers are taken into consideration when rangeland managers are making decisions about their current and future operations.

Generally speaking, the rangeland and agricultural sectors are increasingly vulnerable to the impacts of climate change. These combined challenges of responding to degradation of rangelands and climate change make clear the need for a systematic assessment of actions that ranchers, rangeland managers, and tribal staff members can use to prepare for the future and continue to support or enhance the rangelands across the region. These rangelands are vital to sustaining the ranchers and the economy while also protecting important natural and cultural resources. Resilience-thinking can help address some of these challenges, yet rangeland managers need better information, more supportive institutions, and more accessible tools in order to understand and incorporate best practices into their management (Brunson, 2012). Section 2.4 will establish how rangeland managers can begin to incorporate resilience concepts into their own operations.

2.4 Principles for Action

Characteristics of a Resilient System

Not only are there many ways to define resilience, but there are many different approaches to enhancing the resilience of a system. Because rangelands are dynamic socio-ecological systems that involve both ecosystem and managed human components, it can be insightful to think about the system in this context. The Arup and Rockefeller Foundation's seven common characteristics of a resilient system (below) have been adapted for the purposes of this document:

- ***Flexible*** – Rangeland managers and operations have the ability to change or respond to external pressures like market fluctuations or drought conditions.
- ***Inclusive*** – Rangeland operations are designed to value and incorporate all aspects of the system including thinking across systems, fostering knowledge sharing, cultivating partnerships, and utilizing valuable resources.
- ***Integrated*** – Rangeland managers work across geographic scales and resource silos in order to most effectively manage their operations and adapt to changing conditions.

- ***Redundant*** – Rangeland operations contain back-up systems or alternatives to efficiently respond to disruptions like drought.
- ***Reflective*** – Rangeland managers are constantly evolving and learning from experiences to best manage their resources.
- ***Resourceful*** – Rangeland managers have the ability to rapidly find alternative solutions to challenges and maintain the key functionality of their operations.
- ***Robust*** **–** Rangeland operations should be designed in anticipation of potential failures and limit cascading impacts from a changing climate.

Historically, rangeland managers are resourceful and adaptive people due to the complexity and variability of the systems they manage. In order to avoid severe economic, ecologic, and livelihood impacts due to projected changes in the climate, rangeland managers are encouraged to continue to be proactive in their planning and to implement best practices for resilience. This also includes incorporating practices that support holistic management of their operations that account for rangeland production, ecological health, and the sustainability of their operations.

Holistic Supportive Management

To improve the sustainability of natural resources, *"…managers need not only better or more complete ecological data, but also a clear understanding of where, when, and how resources are used and who gets to use them, and how and why use varies over time and across the landscape*" (Briske (ed), 2017, pg. 265). Much of this information can be obtained using the social ecological systems framework (Briske (ed), 2017). Rangeland managers can draw on credible, relevant, and up-to-date science in order to inform their decision-making (Roberts, Personal Communication, 2018). There is also a growing recognition among ranchers that rangeland managers should take into consideration entire ecosystems and the changes that they are undergoing in order to effectively build rangeland and operation resilience (Briske (ed), 2017).

Supporting the health and conservation of rangelands can improve water quality, as well as enhance plant communities, biodiversity, and soil health. In semi-arid ecosystems, livestock have the ability to function as ecosystem engineers. Studies indicate that ranchers can use an array of tools such as location-specific supplemental feed, patch burning, water, and herding in order to reduce ecosystem degradation due to grazing as well as improve vegetation heterogeneity for native bird species (Derner, 2009). Yet, further study is required in order to understand the scale in which this can occur as well as the potential economic and practical drawbacks for doing so.

Incorporating Traditional Knowledges

Incorporating traditional and local knowledges is fundamental to understanding and managing for resilient rangelands. This is, of course, particularly true for tribally-run and managed landscapes. It can help promote collaboration, improve adaptation planning, and support individual and tribal interests (Tribal Adaptation Guidebook, 2018). These knowledges can also enhance understanding of observed changes and the development of effective response options.

Traditional Knowledges (TKs)—complex and multifaceted Indigenous knowledge systems encompassing many aspects of traditional practices and cultural information.

Traditional Ecological Knowledge (TEK)—complex and multifaceted Indigenous knowledge systems based in Traditional Knowledges that are often direct application and utilization of Traditional Knowledges having to do with ecology, ecosystems, or the environment.

Traditional Knowledges encompasses a wide variety of overarching traditional practices that are foundational bases for traditional culture. Traditional Knowledges may include, but is not limited to: storytelling, seasonality, phenology, identification of cultural items, patterns, or traditions, and genealogy. Traditional Ecological Knowledge is the application of the specific area of Traditional Knowledges and Indigenous Science that relates to the environment and ecology, including botanical knowledge, medicinal application (collection and/or administration), hunting, fishing, gathering, processing of material(s), caretaking (such as burning, coppicing, thinning), astronomy, phenology, ecological markers, species markers, and weather and climate knowledge.[12]

Figure 6: Definition of Traditional Knowledges from the Tribal Adaptation Guidebook, 2018.

Traditional Knowledges (TKs) (Figure 6) represent multi-generational ways of knowing and are clearly present in all of the USRT member tribes. It is up to each individual tribe and knowledge holders to determine if it is appropriate to share TKs as part of any ranching or rangeland management project and how those TKs will be shared and with whom. The *Guidelines for Considering Traditional Knowledges (TKs) in Climate Change Initiatives*[2] and the *Tribal Climate Adaptation Guidebook*[3] (2018) provide an extensive amount of information on the best practices, risks, and approaches to consider when choosing if and when to incorporate or share TKs in a specific project.

The National Climate Assessment (2018) indicates that indigenous peoples and tribes are considered "frontline communities" in the Northwest, communities that are on the front lines of climate change and experience the first, and often worst, effects (May et al., 2018). Indigenous peoples face unique and disproportionate impacts from climate change (e.g. loss of culturally significant foods and medicines) and are more vulnerable to its impacts than other populations (Buford, 2018; Woodward et al., 1998).

Embedding Monitoring, Evaluation, and Data into Management

Many ranchers have a long history working on rangelands and know how best to manage those lands for the health of their cattle and the sustainability of their operations. With rapidly changing conditions, the use of data-driven management approaches and effective monitoring becomes increasingly important (McCollum, et al., 2017). Thus, it is critical that with the implementation of adaptation actions, ranchers, land managers, and others invest in monitoring (in situ, periodic surveys, or remote sensing) to track the success of these actions and make appropriate adjustments over time.

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[2] https://climatetkw.wordpress.com/
[3] http://www.occri.net/projects/tribal-climate-adaptation-guidebook/

One of the most relevant and important techniques for rangeland managers is the utilization of a threat-based land management framework to classify and monitor the state of ecological health of a rangeland ecosystem. This framework assists rangeland managers in assessing the state of certain attributes of the rangelands they utilize (e.g. prevalence of invasive species) and develop effective management tools for addressing and monitoring those attributes. More information can be found using the Northern Great Basin Threat Based Land Management Guide developed by the Nature Conservancy, Oregon State University, the USDA, and the US Fish and Wildlife Service. Tools and resources such as the USFS Rangeland Production Monitoring Service can provide data on the historic average and trends in productivity for an area at the parcel or allotment level. These data can be used to inform the selection of actions (tailoring stocking rates and timing…etc.) or combined with a Livestock Early Warning System (used in sub-Saharan Africa and being explored for application in the Northwest), or a Community Based Observer Network (CBON) (see poster – Hogrefe & Gosnell, PNW Climate Conference 2018) to refine or share information and make short term (weekly or seasonal) projections about rangeland quality that can inform adaptive management approaches to managing rangeland. Emerging social networks and data/information sharing platforms (such as agclimate.net) provide an opportunity for researchers and ranchers in the region to share information and promising resilience practices.

3. Grazing Strategies

3.1 Introduction

Climate change will affect the productivity of rangeland and the carrying capacities of pastures through changes in precipitation patterns as well as increases in invasive species, temperature, and fire frequency (Neibergs et al., 2018; Yorgey, 2018). Historically, grazing has had an important relationship with fire, invasive species, watershed health, and biodiversity across the sagebrush steppe for centuries and climate change is impacting the way in which rangeland managers must account for the intersectionalities.

Elevated concentrations of carbon dioxide (CO_2) have been shown to increase the rate at which plants in an ecosystem produce useful chemical energy, also known as Net Primary Production (NPP) (Izaurralde et al., 2011, Yorgey, 2018). NPP is a good indicator for the productivity of a rangeland system - the higher the value, the more productive that land is for cattle. The growing season for pasturelands and rangelands in the Upper Snake River Watershed and Great Basin is expected to lengthen with increasing global temperatures, yet, the impacts of climate change on pasturelands and rangelands are not yet fully understood. Regionally, specific factors such as air temperatures and precipitation will affect NPP, thus, NPP levels are expected to fluctuate spatially and temporally, and will require producers to implement complex and dynamic approaches to grazing management to ensure maximum productivity (Yorgey, 2018; Izaurralde et al., 2011). In general, NPP is anticipated to increase in the Pacific Northwest by mid-century due to rising global temperatures, yet some areas may see NPP decrease (Yorgey, 2018). Implementing effective adaptive grazing strategies at the regional, site, or producer-specific level will be essential for minimizing economic, ecologic, and social risks associated with climate change.

In order to effectively adapt to a changing climate, rangeland managers are required to consider long-term and short-term biophysical, social, and economic factors (Derner et al., 2017). Managers must consider the extent to which alternative actions are necessary and determine if incremental adaptation measures (small changes over time, such as altering the timing and length of a grazing regime) or transformational adaptation measures (often large changes made over a short amount of time, such as shifting to an entirely new breed of cattle) are appropriate (Derner et al., 2017).

Promising adaptive grazing strategies focus on two key approaches: 1) adjusting the specific stock being used, and 2) shifting the timing and distribution of the stock while grazing. The following sections identify tools, tactics, and approaches to adaptive stocking methods (Section 4.2) and timing-distribution methods (Section 4.3) necessary for supporting productive grazing management. In addition, Section 4.4 highlights case studies that highlight two of these adaptive strategies in action.

Table 2: Summary of grazing-focused action areas that can be used to improve or enhance the resilience of rangeland operations to changing climate conditions.

Focus	Action Area	Description	Key Citations
Stock	Type of Stock	Diversifying the variety, age, species, genetic source, and breed of livestock	Derner et al., 2015; Janowiak et al., 2016,
	Stock Rates	Adaptive stocking rate strategies (flexible, conservative, seasonal…etc.)	Joyce et al, 2013; Augustine et al., 2018
	Stock Density	Determining stocking density based on rangeland quality requirements	USDA, 2016
	Stock Protection	Daytime shelters and shading	Derner et al., 2017
Timing	Matching Turn-out Dates with Greening	Updating lease agreement to match turn-out dates with green-up to ensure nutrient availability for cattle	Launchbaugh et al, 2006; Derner et al., 2017; Provenza et al., 2007; Provenza & Villalba, 2010
	Rest Rotations	Controlling pasture recovery periods	Boltz, 2017
	Water Points and Salt Licks	Using watering points and salt licks to control livestock distribution across the landscape	Ganskopp 2001; Fensham & Fairfax, 2008
	Exclosures	Creating exclosures to protect sensitive habitats and manage stock distributions	EPA, 2018; Mosley et al., 1997
	Targeted Grazing	Using specific livestock at specific times to target invasive species	Launchbaugh et al., 2006

3.2 Stock

Making changes to the type of cattle that are utilizing the rangeland is one way to enhance resilience. Strategies for better adapting to a changing climate include: diversifying the type, age, species, genetic source, and breed of stock; altering stock rates to better adapt to projected or real-time changes in the climate or forage quality; altering the density in which stock are utilizing rangelands; and, developing infrastructure that reduces exposure to excess heat or drought.

Type of Stock

Diversifying the variety, age, species, genetic source, and breed of livestock so that they have an increased tolerance to drought, heat, and parasites may, in turn, improve resilience of a rangeland system (Derner et al., 2015). In addition, altering the timing of animal reproduction in order to match maximum feed productivity and suitable temperatures may be key to adapting to climate change (Howden, 2007; Derner, 2015).

The 2017 USRT vulnerability assessment indicates that significant changes are already occurring that are negatively affecting stock:

> *"Increasing summer temperatures, more extreme heat events, and the potential for increases in pathogens and parasites are climate change-related factors that directly influence cattle's physiological health. High temperatures (particularly heat events that occur in spring and early summer when cattle are less acclimated to heat) can increase the risk of heat stress. Heat stress results in higher respiration rates, increasing body temperature, reduced food intake, and reduced performance (Nienabar et al., 2007; Baumgard, 2012). Mortality can occur with more severe heat events, such as those that last three or more days (Nienabar et al., 2007). Cattle at higher risk of heat stress include: newly arrived cattle that may have already been stressed by weaning, processing, or transportation; finished or nearly finished cattle, especially heifers; cattle that have been sick in the past and may have some preexisting lung damage; black or very dark-hided cattle; heavy bred cows that will calve sometime during the summer; older cows; and cattle which may be thin due to inadequate nutrition (Blezinger, 2004)*" (Petersen et al., 2017, pg. 64).

Although few studies have been completed that define cattle breeds ideal for large temperature fluctuations or higher summer temperatures, heat tolerant breeds such as Brahman, Criollo, Santa Gertrudis, Senepol, Tuli, and a variation of crosses are likely suited for these conditions (Derner et al., 2017). A corollary to this approach is to move cattle breeds that have low tolerance to drought and heat to locations that are expected to provide ample resources in the future (Janowiak et al., 2016; Derner et al., 2017). Attributes that determine cattle's sensitivity to heat include breed, coat thickness, and color. Yet, further research is needed in order to best quantify livestock's' susceptibility to heat stress based on their biological make-up (Derner et al., 2017). By diversifying the age of cattle (integrating cow-calves and yearlings) producers can reduce their susceptibility to the impacts of climate change. Utilizing cattle at different stages of production facilitates diversity in an operation. In addition, genetic variation can help lineages better survive in or adapt to specific local environments (Provenza, 2008). Shifting to different breeds of cattle can be a costly transition. Ranchers could consider making this transition over time instead of investing in new breeds all at once in order to reduce the financial costs of the transition.

Stock Rates

Stock rate is the number of animals on a given area of land over a certain period of time (USDA, 2016). The decision to stock or de-stock livestock numbers based on changes in the climate can have drastic and long-term financial and ecological implications for producers (Scasta et al., 2016). Adaptive stocking rate strategies include utilizing flexible stocking rates (adjusting the number of livestock based on pasture feed availability) and conservative stocking rates (stocking a smaller number of livestock to ensure adequate feed and maximum productivity) (Joyce et al., 2013). Projected increases in atmospheric concentrations of CO_2 and increased temperatures due to climate change will likely increase forage production, while at the same time decrease forage quality, and lead to declines in weight gain per animal. This may lead rangeland managers to increase stocking rates in order to achieve the same total mass gain per unit area of their operation (Augustine et al., 2018).

In general, water demand for cattle increases in the summer months due to higher temperatures. Because maximum temperatures are projected to rise in every season in the Upper Snake River Watershed, overall water demand is likely to increase. It is important for stocking rates to be managed according to seasonal water and forage demand (Scasta et al., 2016).

Generally, stocking rates are determined by AMUs (Animal Month Units) which are agreed upon and formalized in lease contracts for public land. For U.S. Forest Service lands, the leasing cost is determined by the total AMUs for the land and the ranchers are required to pay that price regardless of the number of cattle placed on the landscape. For the Bureau of Land Management (BLM), rangeland managers are required to pay a price per AMU and a limit is set on the number of livestock used (Kesling, Personal Communication, 2018). Managers that use less than the AMU limit, are required to pay only what they used in that particular season. Yet, there is an economic incentive to use the maximum stocking rates, and it is challenging to make adjustments to established stocking rates to accommodate drought scenarios. Thus, in situations focused on short-term gains, there is a strong economic incentive to maximize the stock density on the landscape even to the potential detriment of the landscape (Hudson, Personal Communication, 2018). Public land AMU's are generally priced in a way that allow rangeland managers to prioritize long-term decision making over short-term financial gain for their operations (Hagle, Personal Communication, 2018). In addition, many rangeland managers view their grazing allotments as an extension of their own property, resulting in decision-making that reflects a long-term approach to stewardship and their investment (Hagle, Personal Communication, 2018).

In some cases, federal grazing programs are making adjustments to their approach. For example, the BLM implemented 11 demonstration projects across six states with more flexible turn-out dates and overall grazing management to adapt to changes in forage availability, wildfire, and drought (BLM, 2018). With outcome-based grazing methods, the goal is to improve the ecological, economic, social, and production outcomes for rangeland managers in order to ensure sustainable rangeland practices.

Stock Density

Stock density is the number of animals grazing on a specific unit of area at a single point in time (USDA, 2016) - usually expressed in pounds of animal per acre. Stock density can affect the health of a rangeland and must be taken into consideration when planning and managing stock rotations. Increasing stock density can reduce livestock grazing selectivity and can improve the uniformity in which a pasture is grazed. Yet, without proper monitoring and rotation increasing stock density can raise the risk of overgrazing, decrease animal performance, and damage pastureland and rangeland ecosystems (USDA, 2016). Fencing (temporary or permanent) can aid producers in managing stock density on any particular pasture.

Alternative grazing methods advocated for by Alan Savory suggest that intensive livestock grazing with large numbers of stock concentrated in a particular area can combat climate change and desertification (the transformation of grassland and forest into desert). Savory started to garner attention for these ideas with the release of his 2013 TED Talk[4]. His most controversial claims suggest that two thirds of the worlds lands are turning into deserts, that degraded lands can be restored by using livestock when mimicking 'natural grazing' of wild herbivores (large herds of animals like wildebeest that move across vast areas), and that the carbon storage potential of pastures that use 'holistic grazing' will reduce atmospheric carbon dioxide levels to below pre-industrial levels within a few decades (Nordberg, 2016). Yet, wide-ranging criticism from practitioner and scientific communities globally suggest that the "narrowly focused and widely challenged" methods developed by Alan Savory are unfounded, oversimplify rangelands as ecosystems, detract from rangeland practices that are rooted in credible science, and "*weaken efforts to promote rangeland restoration and carbon sequestration*" (Briske et al., 2013, pg. 74; Nordberg, 2016). In short, critics suggest that his methods are not backed up by substantial peer-reviewed scientific evidence.

Stock Protection

Extreme heat events result in heat stress among livestock. This is particularly true in the Northwest and was observed during 2015. Projections indicate that by mid-century, extreme heat events may exceed 60 days per year (Yorgey, 2018). According to the USDA, "*livestock respond to changes in temperature by altering their core body temperature, metabolic rates, or behavior, all of which can lead to increased stress and disrupt their growth, production, or reproduction*" (Janowiak et al., 2016, pg. 25). Although this is not typically a tenable solution for large rangeland operations, providing shelter for livestock can help cattle better regulate their temperatures in order to decrease the impacts of heat stress.

Heat stress risk is much more prominent for confined livestock than grazing livestock. An outdoor-confined animal's microclimate is defined by pen location, slope, and surface maintenance (Derner et al., 2017). Generally speaking, pens in the northern hemisphere that face the south, south-west, and west produce much more solar radiant heat than the other directions (Derner et al., 2017). By altering the orientation and slope of confined livestock pens, rangeland managers can reduce the risk and potential impacts of heat stress. Additional adaptation measures that can reduce the risk of heat stress include utilizing stir fans, improving insulation, providing tunnel ventilation, installing sprinkler cooling or high-pressure misting, and providing evaporative cooling pads (Derner et al., 2017). In some cases, investing the resources into shifting containment facilities or pens to a geographic location that best suits the herd's needs may be necessary (Derner et al., 2017).

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[4] https://www.ted.com/talks/allan_savory_how_to_green_the_world_s_deserts_and_reverse_climate_change?language=en

Additional tactics can help limit heat stress including diversifying livestock production systems. For example, utilizing outdoor-confined cattle, indoor-confined cattle, and rangelands can help create redundancies in a rangeland operation that ensure resilience (Derner et al., 2017). In addition, due to the high water-holding capacity of manure, precipitation events in confined areas may result in more standing water and increased humidity on hot days (Derner et al., 2017). By reducing the amount of manure and improving runoff in confined spaces during extreme precipitation events, rangeland managers are better able to regulate temperatures for their livestock.

Generally, windbreaks have a deleterious effect on confined cattle during warm or hot days due to a decrease in reductive animal cooling (Derner et al., 2017). Access to shade (where possible) and night-time cooling may be important tools for limiting the risk of heat stress in cattle (Petersen et al., 2017).

3.3 Timing – Distribution

Altering the timing and distribution of cattle on rangelands to account for shifts in seasonality due to climate change is an effective adaptive grazing practice and should be coupled with long-term and seasonal climate projections (Janowiak, 2016). In addition, shifting the distribution of cattle on the rangelands can alleviate pressure on grazing resources. Livestock generally graze selectively (choosing the most desired grass species to graze first) and deplete forage resources around riparian areas before utilizing any other forage (Hodder & Low 1976; USDA, 2016). Distributing livestock between upland and riparian zones can minimize impact to riparian zone vegetation (Roni et al., 2002).

Variability of climatic patterns could result in earlier forage availability in the spring, and increase grazing in the fall months. In the summer months, ranchers may need to rely on supplemental feeding, increasing the cost for production. In the near future, it may not be feasible to finish cattle in feedlots due to the rising grain prices (Provenza et al., 2008). In addition, rangeland managers may consider altering the timing of their calving season in order to align with maximum forage quality potential (WSU CAHNRS, 2016; McCollum, 2017). As precipitation patterns become more variable, ranchers may be required to move cattle to new grazing allotments, or to areas with stockpiled forage, requiring additional grazing leases or smaller herd sizes (Niebergs et al., 2018). In order to protect rangelands from overgrazing, managers may decide to move cattle from rangelands prior to the permit lease end date. It is important to consider the full extent of financial and logistical constraints prior to implementing major operational changes.

Utilizing current long-term and seasonal climate projections for the Upper Snake River Watershed and appropriate monitoring tools can help managers more accurately determine appropriate timing and distribution for livestock on their pastures. In addition, if real-time datasets like the Rangeland Production Monitoring System (see Section 6 - Planning Tools) indicates that water will be limited and temperatures will be elevated during the coming months, rangeland managers can prepare by distributing cattle into areas with better water availability and more shelter in order to reduce the risk of heat stress. In addition, altering the timing of animal reproduction in order to match maximum feed productivity and suitable temperatures may be key to adapting to climate change (Howden, 2007; Derner, 2015).

Additional tactics include using feeder banks and resting pastures for more than a year to better provide more forage during dry periods (Janowiak et al., 2016).

Tools that improve timing and distribution of livestock are site-specific and generally a combination of tools, tactics, and approaches will be required to best fit a rangeland manager's needs. The following section includes adaptive grazing strategies that are based on stock timing and distribution including: matching turn-on dates with rangeland greening; utilizing rest rotations; using water points, salt licks, and exclosures; and, using targeted grazing methods.

Matching Turnout Dates with Greening

With warmer spring temperatures, rangelands are greening earlier. This can create a mismatch between the contracted turnout dates and the ideal time for cattle to be released onto the pasture to consume the maximum nutrients and do the least amount of damage to the rangelands. This issue can be exacerbated with the spread of invasive species, such as cheatgrass, generally one of the first grass species to green (and the first to die out). Forage with low nutritional quality, like that of cheatgrass and other invasive grass species, can limit the ability of cattle to gain weight and must be managed accordingly. For example, targeted grazing based on plant phenology has been shown to effectively manage invasive species, reduce fire risk, and shift the composition of plant species on a rangeland (Launchbaugh et al., 2006). Also known as 'prescribed grazing' or 'managed herbivory', targeted grazing utilizes specific livestock at a targeted time and place to manage for specific invasive species and achieve desirable ecological outcomes.

While it is possible to utilize supplements (like nitrogen supplements or protein blocks) to offset low forage quality, that increases the cost of production (Derner et al., 2017). Cattle consume a variety of plants (if available) to find the right mix of nutrients and even address medical issues. Natural rangeland habitats that have a mix of native grasses and forbs. Healthy shrub-steppe commonly contain 50+ species in a given area (Hudson, Personal Communication, Nov. 27, 2018) and this diversity supports the health of the animals that graze in these areas (Provenza et al., 2007; Provenza & Villalba, 2010) especially as compared to damaged or degraded systems with less diversity. Bunch grasses should achieve a certain level of growth before turnout date, otherwise healthy shrub steppe can be damaged by early spring grazing (Hagle, Personal Communication, 2018).

Rest Rotations

Rest rotations are effective mechanisms for controlling pasture recovery periods and studies indicate that it can be effective in reducing pest cycles and weeds (Boltz, 2017). According to the U.S. Department of Agriculture (USDA), cattle rotation should be continued in the winter months and should be used in parallel with supplemental nutrients and health monitoring. In addition, bale grazing – also known as swath grazing or rake-bunch - can reduce both grazing costs and time (Boltz, 2017). Studies indicate that utilizing grass or fodder banks (areas specific to the production of high-quality, nutrient-rich grass for livestock feed) in parallel with resting pastures for a year, or more, not only help provide forage for livestock during dry periods but minimizes a pastures vulnerability to long-term negative impacts from drought and encourages pasture regeneration (Janowiak et al., 2016).

Water Points and Salt Blocks

Watering points and salt blocks are effective tools for controlling livestock distribution on a pasture. While watering points are generally considered more effective (Ganskopp 2001), salt and protein blocks have more flexibility for rotation (Hagle, Personal Communication, 2018). This is especially true of water remote pastures (areas more than 3.75 miles from any watering points) (Fensham & Fairfax, 2008). In areas that are overused or in water remote areas, strategic de-stocking in parallel with the use of water points (a distribution location for water for livestock) are instrumental in facilitating effective rangeland management and maximum productivity (Fensham & Fairfax, 2008). By altering the location of water points, ranchers can rehabilitate rangelands, minimize overgrazing, and facilitate more uniform distribution of livestock. It can also help previously degraded areas to recover from overuse.

Exclosures

Properly utilizing exclosures (barriers used to exclude animals from specific locations) can be an extremely effective in managing where cattle graze. Limiting defoliation from grazing has shown to revitalize riparian communities, result in erosion control, and enhance soil recruitment (the accumulation of high-quality soils). Studies in mountain range allotments show that riparian forage accounts for about 20% of all forage available to cattle, but around 80% of their diet when unrestricted (Kauffman et al., 1983). Such heavy reliance on riparian forage can quickly lead to ecosystem damage. Fencing riparian areas can enhance the regeneration of stream and spring habitat.

Fencing can also help manage non-point source pollution (natural and human made pollutants that deposits into lakes, streams, coastal areas, or wetlands from a variety of areas and can include fertilizers, salt, livestock waste, insecticides, herbicides, oil, grease, and other toxic chemicals), particularly during heavy rainfall events, as well as support the health of important riparian species (EPA, 2018). Non-point source pollution originates from cattle defecating directly into or near water systems. During run off events, this pollution can put excess phosphorus and nitrogen into the water supply (Mosley et al., 1997). Riparian zones serve as important buffer systems to fresh water and exclosures can help facilitate or enhance their ability to provide this water quality protection.

Utilizing exclosures is effective for controlling grazing distribution, yet, they can require significant financial resources, time, and energy to install and maintain. In addition, improperly placed exclosures can exacerbate grazing problems and can increase sediment, fecal, and nutrient inputs from cattle located near water (Mosley et al., 1997).

Targeted Grazing

Targeted grazing of invasive plant species and riparian vegetation can be an effective method for reducing fire risk, controlling and managing invasive species, and improving the ecological health of rangelands. Also known as 'prescribed grazing' or 'managed herbivory', targeted grazing utilizes specific livestock at a targeted time and place to manage for specific invasive species and achieve desirable ecological outcomes (Launchbaugh et al., 2006). For example, sheep and goats are effective at managing invasive species such as leafy spurge and spotted knapweed and spring cattle grazing can be an effective fire fuel management tool (Launchbaugh et al., 2006; Davies et al, 2017). Generally speaking, a minimum of three years of targeted grazing is required for noticeable changes and concomitant methods for eradicating invasive species are recommended (e.g. prescribed burns, herbicides, etc.) (Launchbaugh et al., 2006). Prescriptions for a targeted grazing regime should focus on a time when the target species are most vulnerable to grazing and most desirable to the grazing livestock being utilized. This specificity requires rangeland managers to develop a strong understanding of ecological dynamics and animal husbandry.

3.4 Case Studies

Adaptive grazing in Colorado. Located in Southeastern Colorado in the shortgrass steppe, the Rancho Largo Cattle Company successfully implemented adaptive grazing measures to improve economical, ecological, and resilience outcomes (Grissom, 2013). Specifically, rangeland managers altered the duration, seasonality, and frequency of grazing in order to recruit cool-season mid-grasses (Grissom, 2013). Recovery period measures specific to the desired plant species (Western wheatgrass) was key to their success. In addition, rangeland managers indicated that cool and warm season grass recruitment "*improved water cycling, extended the grazing season, and eventually increased sustainable stocking rates*" (Grissom, 2013, pg. 35).

Holistic management and summer calving in Eastern Washington. Maurice and Beth Robinette, managers of the Lazy J Ranch in Eastern Washington advocate for holistic management and its ability to maximize native grass productivity, decrease cost, and maximize water access in drought and variable precipitation conditions (WSU CAHNRS, 2016). For them, utilizing the process of plan, monitor, control, and re-plan is a foundation that helps minimize the risk of their stocks being affected by drought. Rather than setting aside a particular pasture for grazing at a later date (also known as a drought reserve pasture), they plan for extra days of grazing. This allows the Lazy J Ranch to avoid destocking all at once towards the end of the year when market prices may be at their lowest. They have also shifted their calving schedule to the summer and market their finished cattle at two years old. This shifts births to coincide with the peak production of the native grasses (calves are born in May and June) and provides more time for the calves to reach market weight. These changes have reduced supplemental feed that the ranchers need for their calves to reach market weight (WSU CAHNRS, 2016). Additional information on holistic management can be found in Section 2.4.

4. Rangeland Management Strategies

4.1 Introduction

Rangeland managers deal with a wide variety of challenges depending on their geographic location, production goals, and management style. Therefore, no single adaptation tool, approach, tactic, or strategy can be applied across the industry. The general strategies and actions described below will need to be reviewed and customized to meet the production, demand, and resilience needs of an individual tribe or ranching area (Janowiak et al., 2016). For USRT and its member tribes, managing rangeland in a changing climate is more than maximizing the number or weight of their stock. Equally important is maintaining and restoring natural ecosystems like riparian areas, wetlands, bottomlands, and floodplains, so that the habitats can foster and support a diversity of species and protect key ecosystem characteristics.

The following sections identify tools, tactics, and approaches to conservation (Section 4.2) and restoration (Section 4.3) strategies for effective rangeland management. In addition, Section 4.4 highlights specific cases of adaptive grazing strategies currently being utilized in the United States.

Table 3: Summary of rangeland-focused action areas that can be used to improve or enhance the resilience of rangeland operations to changing climate conditions.

Focus	Action Area	Description	Key Citations
Conservation Strategies	Improve Landscape Connectivity	Reducing landscape fragmentation	Janowiak, 2016; Galvin et al., 2008; Kariuki et al., 2018
	Mix Rangeland and Cropland	Integrating livestock into cropland operations to reduce feed cost, provide additional forage, and eliminate manure concentration areas	Joyce et al., 2016; Izaurralde et al., 2011
	Improve Soil Health	Improving soil health across the landscape (e.g. providing ground cover of plants or residue in specific areas)	Janowiak et al., 2016; Provenza, 2008; 25x25 Alliance Adaptation Work Group, 2013; Neibergs et al., 2018
	Support/Improve Native Grasses	Minimizing invasive grass species and planting native grass seed	Derner et al., 2017; Davies et al, 2015; Provenza, 2008; Davies et al, 2017
Restoration Strategies	Upland Restoration	Restoring and improving the health of native grasses and trees in upland areas	The Great Basin Native Plant Project, 2018
	Fire	Utilizing prescribed fire and RFPA's to improve adaptability to a changing fire regime.	Stasiewicz et al., 2017; Scasta et al., 2016; Derner, 2016; Perryman et al., 2018; Davies et al., 2015; Davies et al., 2016; Davies et al., 2017
	Invasive Species Management	Eradicating invasive species (e.g. Juniper, cheatgrass) and supporting native grass and tree species growth	DiTomaso, 2010; Chambers et al., 2008; Jones & Gregory 2008; Bates et al., 2005; Roundy et al., 2014; Floyd & Romme, 2012; Davies et al., 2015; Davies et al., 2010; Maestas et al., 2015; Davies et al, 2016; Perryman et al, 2018

4.2 Conservation Strategies

Historically, overgrazing of rangelands has led to the degradation of water resources, soil structure, and plant communities in the Pacific Northwest (Charnley et al., 2018). Thus, conserving the remaining high-quality and high-functioning rangelands across the region is a critical first step in supporting productive livestock operations. In addition, studies show that conserving biodiversity on landscapes aids in building landscape resilience to climate change (Janowiak et al., 2016). The following section features promising adaptive rangeland conservation strategies including: increasing landscape connectivity; utilizing rangeland and cropland for grazing; maintaining and supporting soil health; and supporting the growth of native grass species.

Improving Landscape Connectivity

Reducing landscape fragmentation on rangelands supports climate change adaptation by encouraging and utilizing "*a mosaic of habitats to support natural and facilitated migration of plants, animals, and other organisms across a landscape*" (Janowiak et al., 2016, pg. 27). Landscape connectivity can improve the resilience of rangelands to climate change by maintaining or improving ecosystem heterogeneity for vegetation and water resources (Galvin et al., 2008). Landscape connectivity also supports migrating species (plants, animals, and insects), pollinators, and provides landscape buffers essential for supporting variable habitats across natural ecosystems that promote biological diversity and reduce susceptibility to environmental stressors (Janowiak et al., 2016). Tools that aid in improving landscape connectivity include creating natural habitat corridors for migrating plant, animal, and insect species, as well as developing and maintaining effective partnerships with landscape-planning organizations that value landscape connectivity.

In addition, livestock grazing can help promote wildlife corridors and support biodiversity (Kariuki et al., 2018, pg. 2). Adaptation tactics include maintaining and promoting natural wildlife corridors through landscape-scale planning and partnerships that enhance connectivity (Janowiak et al., 2016, pg. 27).

Mixed Rangeland and Cropland

Integrating livestock into established cropland operations can increase access to additional livestock forage, reduce feed costs, eliminate manure concentration areas, and improve a farm's overall efficiency (Janowiak et al., 2016). These practices can be improved by planting and supporting the growth of drought and heat resistant species. In addition, mixed cropland and rangeland operations can improve rangeland resilience to higher levels of atmospheric CO_2, increasing temperatures, and variable precipitation patterns (Izaurralde et al., 2011). Further regional-specific research and a deeper understanding of the precipitation and temperature variations are needed in order to understand how utilizing a crop-livestock production system will help increase production for rangeland systems (Izaurralde et al., 2011).

Soil Health

Healthy soil is essential to functioning rangelands, can reduce production costs, and provide essential ecosystem services (Provenza, 2008). Soils support biological life and diversity, provide key functions in carbon sequestration (Janowiak et al., 2016), and important ecosystem services like "*water storage, water quality, and biological habitat for plants and animals*" (Neibergs et al., 2018, pg. 6).

Climate change affects soil health directly and indirectly by increasing nutrient loss, reducing water retention, and limiting filtration during extreme heat, drought, and heavy precipitation events (25x25 Alliance Adaptation Work Group, 2013). Reciprocally, soils affect the climate at short and long-term time scales depending on the soils depth and ability to retain moisture. For example, moisture from the top layer of soil can influence day to day weather, especially in drought conditions when deep-rooting plants' access and draw moisture into the atmosphere (25x25 Alliance Adaptation Work Group, 2013). However, the full scale at which soil affects the climate is not fully understood or modeled.

According to the 2016 USDA report on adaptation strategies for agriculture (Janowiak et al., 2016), climate change adaptation measures to improve or maintain soil health include:

- Avoiding or reducing tillage for planting, weed control, and other purposes by minimizing soil disturbance;
- Providing a ground cover of plants or residue (cover crop or mixes, compost, mulch, biochar, etc.) to reduce evaporation during extreme weather events, improve water-holding capacity and filtration, and reduce erosion;
- Diversifying the plant species used in crop rotations to improve soil conditions and limit the spread of invasive species;
- Avoiding planting during wet conditions to minimize field operation impacts to soil;
- Reducing vehicle traffic and other operations that are known to compact soil;
- Supporting grazing rest periods, managing efficient stocking densities, and reducing long and intense rotation periods;
- Utilizing windbreaks to minimize the impact on soil erosion; and
- Developing sub-surface drainage techniques.

Native Grasses

Natural plant diversity across rangelands minimizes the risk of catastrophic events (wildfire, disease, and pests) and improves consistency of livestock production (Provenza, 2008). In addition, perennial non-native grasses can also minimize the risk of wildfire. Native grasslands and shrub lands have been disappearing from the Western United States due to the introduction of invasive species, altered fire regimes, and overgrazing (Shock et al., 2015). In addition, studies indicate that increasing concentrations of atmospheric CO_2 and temperatures can reduce the quality, productivity, and species composition of native grasses in sagebrush steppe (Augustine et al., 2018). Livestock studies show that elevated concentrations of atmospheric CO_2 reduced forage protein content and digestibility (Augustine et al., 2018). In addition, supporting the health of native forb species is vital to maintaining biodiversity (Briske (ed), 2017). Atmospheric concentrations of CO_2 have surpassed 400 parts per million and projections suggest 600 ppm is realistic in the next 30-70 years under a "business as usual" scenario (Augustine et al., 2018). This has important implications for native grasses and livestock productivity. Although species dependent, increases in the atmospheric concentration of CO_2 generally favors invasive perennial grass species over native perennial grass species (Davies, Personal Communication, 2019). In addition, studies show that higher atmospheric concentrations of CO_2 will likely result in increased forage production, decreased forage quality, and less weight gain per animal (Augustine et al., 2018).

4.3 Restoration Strategies

According to the Society for Ecological Restoration International, "*ecological restoration is the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed*" (SERI, 2014, pg. 3). Healthy ecosystems are generally: resilient to natural disturbances; consist of indigenous species; contain characteristic species to that ecosystem; function normally for its stage of ecological development; function within a larger ecological landscape; have limited threats to ecosystem health; and are self-sustaining (SERI, 2014). Restoration of rangeland ecosystems may be particularly important in building resilience in degraded landscapes. Adaptive management of restoration tools and techniques require effective planning, monitoring, and evaluation (SERI, 2014).

The following section focuses on promising adaptive rangeland restoration strategies including: upland restoration methods; effective fire management strategies in rangeland management practices; and effective invasive species management.

Upland Restoration

Restoration of upland plant, shrub, and tree species can improve the health of rangeland ecosystems. Several organizations specialize in upland restoration, specifically with tribes. For example, the Great Basin Native Plant Project[5] spans nine states and is supported by over 30 different cooperating organizations. Through the support of the BLM Plant Conservation Program, the USFS Rocky Mountain Research Station, and the Intertribal Nursery Council, the Great Basin Native Plant Project seeks to increase the accessibility of "genetically appropriate" native plant seeds to land managers in order to restore and improve native grasses across the Great Basin (The Great Basin Native Plant Project, 2018). In addition, this project can help land managers better understand species variability in response to a changing climate, support the development of seeding technology and techniques that support native plant restoration, and support communication networks among land managers (The Great Basin Native Plant Project, 2018).

In addition, organizations like Trees, Water, and People and the Red Cloud Renewable Energy Center support the restoration of forests on tribal lands with native tree species (Trees, Water, and People, 2018). These applications can help provide shade for livestock, increase erosion control, improve water quality, increase carbon sequestration, improve habitat heterogeneity, and increase biodiversity on rangelands.

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[5] http://www.greatbasinnpp.org/

In the sagebrush steppe, healthy native forb, grass, and shrub species maintain biodiversity and combat invasive species (Briske (ed), 2017). This is especially true following a wildfire, and adaptive management literature encourages rangeland managers to use local seed mixes that prioritize native grass and forb species that are less sensitive to drought conditions, increasing summer temperatures, and more variable precipitation patterns (Davies et al 2015; Briske (ed), 2017). This often requires ranchers to have the budget, accurate adaptive species seeding information, and the adaptive capacity to try new seed mixes despite the risk for unsuccessful propagation (Briske (ed), 2017). Studies indicate that inter-seeding legume forbs - like Utah lotus (*Lotus utahensis Ottley*) - can help offset decreasing forage quality due to elevated atmospheric CO_2 levels, attract pollinators, improve sensitive bird species habitat, and enhance plant mixture composition diversity (Stettler et al., 2017; Augustine et al., 2018).

Fire

Rangeland managers are presented with a range of challenges in relationship to fire: a lack of resources; inadequate local and national policies; institutional barriers; a legacy of poor fire management; and the increased risk of fire danger due to climate change (Stasiewicz et al., 2017; Abrams et al., 2017). Not only does fire directly threaten livestock, property, and human life, it can significantly impact the economy of a ranch or community through loss of access to land (Stasiewicz et al., 2017).

Invasive annual grasses in the sagebrush steppe can be directly related to the increased mortality of bunchgrasses (Perryman et al, 2018). Although bunchgrasses evolved with fire over millennia, increases in fire frequency, intensity, and area burned due to an increase in invasive species has driven the down the abundance and survivability of un-grazed bunchgrasses (Perryman et al, 2018). In turn, this decreases the resilience of sagebrush steppe to invasive species and to wildfire.

Prescribed fire (or cultural fire) has historically been an important part of grassland and rangeland forage regeneration. Some studies indicate that patch burn management of small portions (25%) of rested pastures can help support species biodiversity, reduce density of invasive species, and improve forage availability for future seasons (Derner, 2016). The remaining 75% can act as a reservoir for forage reserves in the event of below average precipitation in the subsequent grazing season (Derner, 2016). Due to the severity, size, and seasonality shift in wildfire behavior, prescribed burns may become more difficult to implement, coordinate, and manage (Scasta et al., 2016).

Rangeland managers also use grazing strategies to manage fuels in the Great Basin. Studies show that pre-fire grazing by cattle can increase the resistance of sagebrush steppe to post-fire invasive species invasion, especially from cheatgrass (Davies et al, 2016). Studies indicate that fall and spring grazing strategies can be an effective fuel management strategy to reduce fire ignition and spread because they decrease fuel cover and height and increase fuel moisture (Davies et al, 2017). Although studies show that fire risk was reduced when using both fall and spring grazing fuel management strategies, spring grazing had 6x greater impact on reducing fire ignition and spread (Davies et al, 2017). In addition, winter grazing has been shown to reduce fire risk and severity when used correctly, particularly in areas where other fuel management strategies are not cost effective or practical (Davies et al, 2015). Some experts indicate that "intense dormant season grazing" in the fall and winter (as opposed to growing season grazing in the spring) can lead to a reduction in surface fuels and an increase in desired perennial species growth (Perryman et al, 2018). In turn, the establishment of desired perennial species can repress undesired invasive species. Supporting the growth of desired perennial species (like bunchgrasses) in the Great Basin may require a multi-layered and long-term approach including targeted grazing (Section 3.3), chemical control, and large-scale re-seeding efforts among others (Perryman et al, 2018).

Rangeland Fire Protection Associations (RFPA's) are partnerships developed to synthesize collaboration among communities and state and federal land managers to empower private citizens to help adapt to a changing fire regime on public lands (Stasiewicz et al., 2017; Abrams et al., 2017). RFPA's have existed in Idaho since 2012, and in Oregon since the 1960's, and can be effective mechanisms for addressing local and community-wide fire management challenges while utilizing state and federal networks and resources.

Invasive Species Management

As Anglo-Americans settled in the American West, they introduced non-native grass species. Not only did this change the historic fire regime, but it altered native rangeland habitat composition by initiating the growth of invasive species (Brooks et al., 2011). In addition, fire frequency and fire risk increased (Chambers et al., 2008). Repeat fires and changing climate conditions are converting more diversified woodlands and shrublands into homogenous landscapes dominated by invasive grasses (Neibergs et al., 2018). Non-native annual grasses such as medusahead (*Taeniatherum caput-medusa*), red brome (*Bromus madritensis*), wiregrass or North African grass (*Ventenata dubia*), and cheatgrass (*Bromus tectorum*) are prevalent across much of the Great Basin and Upper Snake River Watershed.

Effective invasive species management requires prevention, early detection and eradication, monitoring and assessment, containment of large infestations, coordination among stakeholders, a long-term commitment, adaptive management strategies, and integrated pest management (DiTomaso, 2010). Invasive species management objectives should account for the severity and size of the land area impacted, as well as the technical, physical, and financial resources land managers have available to them. Changing the composition of invasive species dominated rangelands back to rangelands composed of primarily native plant or perennial introduced species can be time-consuming, costly, and can yield variable results. For example, reestablishing native grass species on invasive species-dominated rangelands through seeding requires substantial financial resources due to a high failure rate (Davies et al, 2015). Yet, utilizing local seed sources may improve the rate of success (Davies et al, 2015). Despite controversy around introducing additional non-native species to rangelands, some studies show that seeding non-native perennial grass species around specific areas infiltrated by invasive species can be effective at reducing invasive species cover and density (Davies et al, 2010; Davies et al, 2015). Climate projections for the area show that increased risk for wildfire, more variability in precipitation, and increased summer temperatures could result in an influx of more invasive species on rangelands. In turn, this could decrease forage quality and quantity as well as enhance the risk of wildfire.

The following section will highlight information and resources on three of the primary invasive species concerns for the region: western juniper, cheatgrass, and medusahead.

Western Juniper

Over the last 150 years, overgrazing, fire suppression, and favorable climatic conditions have allowed juniper and pinyon pine to extend into non-traditional habitats in the Intermountain West (Maestas et al, 2015). In the Great Basin, this area has increased by ~625% (Maestas et al, 2015). The expansion of juniper in rangelands has important implications for the health of native grasses and water availability on the landscape. Juniper stands use a significant amount of water depending on the soil type and location. Juniper also accelerates the rate of evapotranspiration, the cyclical process of water entering the atmosphere by means of evaporation (generally from the soil) or transpiration (from vegetation).

Removal of juniper from upland areas can increase stream flow, recharge aquifers, increase soil water availability for native grass species, and increase herbaceous biomass (Jones & Gregory 2008; Bates et al., 2005; Roundy et al., 2014; Floyd & Romme, 2012). Control of invasive woodland species requires land managers to assess landscape scale impacts including wildlife habitat, management costs, land-use goals, and site conditions (Maestas et al, 2015). Juniper control strategies include prescribed fire, chainsaw cutting, mechanical shredding, or chaining. Reduction of juniper overgrowth with additional invasive species and post-treatment management has been shown to effectively increase native grasses and soil water recharge, both essential for productive rangelands (Floyd & Romme 2012). In many cases, reestablishment of perennial vegetation is required to curb the infiltration of invasive grass species following juniper removal (Davies et al, 2019). Recent studies show that broadcast seeding is effective at restoring perennial grass species and sage brush following fire in juniper-dominated sagebrush communities, yet further research is required to determine the optimal seeding rates and mixtures (Davies et al, 2019). In addition, juniper control methods can only be effective if subsequent generations of juniper are not allowed to reestablish at the same density or root depth.

Cheatgrass

Cheatgrass affects nearly 28% of all federal rangelands (23 million hectares) (Briske (ed), 2017). It was introduced in 1861, is the most pervasive invasive species in the United States, and generally affects areas that have been historically overgrazed or burned by wildfire. Not only does wildfire support the growth of cheatgrass, but cheatgrass can increase the size, duration, and spread of wildfire (Petersen et al., 2017). Fires fueled by cheatgrass can be more frequent and intense, in turn decreasing the ability of sagebrush and other native species to reestablish post fire. This process is part of a positive feedback loop that facilitates the spread of cheatgrass (Petersen et al., 2017). Yet, studies also show that pre-fire grazing by cattle can increase the resistance of sagebrush steppe to post-fire invasion by non-native species, especially cheatgrass (Davies et al, 2016). In general, cheatgrass (and medusahead) "*require standing dead litter or thatch to maintain their ability to establish and dominate perennial grasses*" (Perryman et al, 2018, pg. 3). Therefore, maintenance and reduction of standing dead litter and thatch can help reduce the invasion and dominance of cheatgrass in sagebrush steppe.

Seeding native grass species in cheatgrass-dominated areas is particularly challenging, yet studies show that reestablishing native plant communities can be successful when using "assisted succession", particularly in normal or below average precipitation years (Cox and Anderson, 2004). "Assisted succession" is a two-step restoration method that encourages the conversion of annual invasive species (like cheatgrass) to perennial plant species (like crested wheatgrass (*Agropyron cristatum*)) prior to seeding for native plant species (Cox and Anderson, 2004). It is important to note that many areas within the Great Basin already have been seeded to crested wheatgrass priming the way for native grass restoration with the right combination of seeding and seedbed preparation techniques. In general, drilling can be the most effective and consistent seeding technique in rangelands, yet it can be impractical over large areas of rough terrain, therefore broadcasting can be an effective alternative (Cox and Anderson, 2004).

Medusahead
Medusahead is a perennial invasive grass that exists on rangelands across much of the west. For rangelands, medusahead "degrades wildlife habitat, reduces forage production, and decreases biodiversity" (Davies et al, 2015). Some studies have shown that medusahead can reduce livestock forage production by up to 80% (Davies et al, 2015). Several studies show that in order for natural or perennial grass species to reestablish in rangelands, medusahead must first be successfully controlled (Davies et al, 2015). Methods to control medusahead include integrating control treatments and the use of prescribed burn followed by pre-emergent herbicide application. After controlling medusahead, seeding perennial grasses (like crested and Siberian wheatgrass) in tandem with prescribed burn techniques can allow the native grasses to more successfully out-compete medusahead in sagebrush dominated rangelands than simply seeding native perennial grasses (Davies et al, 2015).

4.4 Case Studies

Utilizing seasonal grazing to influence fire ignitability and spread in sagebrush steppe communities. This case study highlights the effects of fall (autumn) grazing, spring grazing, and no grazing on fire fuels, ignition, and spread in five different sagebrush steppe sites in Oregon (Davies et al, 2017). Although the study found that both fall and spring grazing reduced fire ignition and spread by decreasing fuel cover and height and increasing fuel moisture; spring grazing reduced fire ignition and spread significantly more than fall grazing strategies. This implies that grazing can be an effective fire fuel management strategy, and by utilizing spring grazing strategies, land managers can reduce fire risk in sagebrush steppe rangelands. In this case study, cattle grazing had no impact on shrubs in the sagebrush steppe. The authors are quick to point out that this study only considered differences in timing of one grazing event, and that impacts on fire reductions are dependent on many factors including "*defoliation level and frequency, herbivore type, grazing history, plant community and site characteristic, and interactions among these factors*" (Davies et al, 2017, pg. 488). Historically, cattle grazing has been shown to reduce the severity and temperature of fire when used properly. Yet, it can also have deleterious impacts on plant communities and watershed health when not used properly. Fuel management may only need to occur after "high herbaceous-production" years, therefore, it likely isn't necessary every year (Davies et al, 2017).

Utilizing upland restoration, sustainable grazing, riparian restoration, habitat connectivity, mixed land-use methods, and fire on the Zumwalt Prairie Reserve in Northeastern Oregon. Located in Northeastern Oregon, the Zumwalt Prairie reserve is a 30,065 acre reserve owned and managed by the Nature Conservancy (TNC) that provides healthy wildlife habitat, local economic benefits, and superb sustainable rangeland to a wide range of stakeholders (TNC, 2018). By actively mapping, managing, and monitoring invasive species (sulfur cinquefoil, meadow hawkweed, and common bugloss); promoting sustainable grazing practices (monitored and managed grazing to protect specific shrub and forage species); utilizing prescribed fire; and restoring sensitive riparian habitat; the reserve boasts viable rangeland; healthy plant, bird, and animal populations; and a sustainable harvest of elk and deer that fund local charities. Rangeland managers and scientists use remote sensing data from satellites to more appropriately and adaptively determine annual stocking rates and densities based on vegetation cover. This case-study highlights the importance of understanding and implementing a combination of rangeland management and grazing strategies to more effectively sustain rangeland productivity, maintain and improve biodiversity, and manage invasive species.

Revegetating medusahead-invaded sagebrush steppe. In southeastern Oregon, a study evaluated the viability of re-seeding introduced perennial vegetation (as opposed to native species) as a means of controlling the dominance and spread of medusahead in sagebrush rangelands (Davies et al, 2015). The spread of medusahead - an invasive species known for habitat degradation, reduced livestock productivity, and increased fire risk – will likely be exacerbated due to climate change in sagebrush dominant rangelands in the Great Basin. The authors chose study sites that ranged from 972-1052 meters above sea level, were separated by up to 30 km, were northeast, southwest, and west facing, and were relatively flat (< 12° slope). They chose climatic conditions that resembled typical Northern Great Basin conditions with average annual precipitation between 249-258mm. Despite controversy around the topic of seeding non-native species in an already invasive species dominated landscape, the authors found that re-seeding introduced perennial species can be more effective at reducing the dominance and spread of medusahead than re-seeding native species. The authors suggest that seeding introduced perennial bunchgrasses (like crested and Siberian wheatgrass) after a prescribed burn can be an effective method to revegetate sagebrush rangelands invaded by medusahead. In contrast, re-seeding native perennial plant species can have a low and variable success rate, resulting in the area being quickly revegetated by medusahead. Re-seeding native bunchgrass species can be expensive, time-consuming, and yield variable results. Re-seeding introduced perennial grass species can have important management implications for areas with limited resources and lack of access to technologies that are required to successfully seed for native bunchgrasses.

5. Water Management Strategies

5.1 Introduction

Water is essential to the productivity of rangelands. The Upper Snake River Watershed and Great Basin are expected to experience hotter and drier summers, wetter winters, increasing temperatures during all seasons, more variable precipitation events, decreased snowpack, and an increasing risk of wildfire (Petersen et al., 2017). Overall, studies indicate that this will increase water demand by cattle and ranching operations. In the short term, the adaptive capacity of the Pacific Northwest water system is likely to be high, yet projected long-term changes will require livestock producers to implement effective water conservation and restoration strategies (Hamlet, 2011). Climate projections indicate that there may be a ~10% reduction in annual flow for large river systems like the Columbia River (Mote et al., 2003). Generally speaking, the Pacific Northwest is not as vulnerable as other regions of the United States (like the Southwest) due to its extensive irrigation network, management support and funding, and ample hydrologic resources. Yet, effective and dynamic water management will be key to supporting healthy rangelands, production practices, and ecosystems (Hamlet, 2011).

The drought conditions in the region during 2015 tested agricultural systems and perhaps provided a prelude to the climate conditions of the future.

> *"Impacts from the 2015 "snow drought" were widespread, including irrigation shortages, agricultural losses, limited snow- and water-based recreation, drinking water quality concerns, hydropower shortages, and fish die-offs from impaired stream water quality. Many farmers received a reduced allocation of water, and irrigation water rights holders had their water shut off early; senior water rights holders had their water shut off early for the first time ever. For example, Treasure Valley farmers in eastern Oregon received only a third of their normal irrigation water because the Owyhee Reservoir received inadequate river inflows to fill the reservoir for the third year in a row"* (May et al., 2018 Box 24.7).

Water rights in the west can be a nuanced and contentious issue, especially during periods of limited water availability and drought. There are a variety of laws, regulations, and policies that can affect individual land-owner or rancher's ability to access and use water on their rangeland. While a detailed review of water rights - and how they affect the implementation of adaptation actions - is beyond the scope of this report, water rights and the constraints they can put on an individual rancher's ability to implement any of the following actions should be considered on an individual, site specific basis.

The following sections identify tools, tactics, strategies, and approaches to water conservation (Section 5.2), restoration (Section 5.3), and storage (Section 5.4), In addition, Section 5.5 highlights specific cases of adaptive water strategies currently being utilized in the United States and internationally.

Table 4: Summary of water management-focused action areas that can be used to improve or enhance the resilience of rangeland operations to changing climate conditions.

Focus	Action Area	Description	Key Citations
Conservation Strategies	Planning and Preparing for Drought	Using resources and partnerships to better prepare for drought	Kelley et al., 2016; Vose et al., 2016
	Reducing Grazing Pressure in Riparian Areas	Reducing stocking rates, density, or utilizing exclosures to reduce grazing pressure in riparian areas	Oles et al., 2011; Bellows, 2003
Restoration Strategies	Riparian Restoration	Improving and restoring riparian habitat using various methods to improve rangeland health and resilience	Armour et al., 2004; Davee et al., 2017; Pilliod et al., 2018; Bouwes et al., 2016; Pollock et al., 2014; Davee, Charnley, & Gosnell, 2017
	In-stream Habitat Restoration	Redistributing large woody debris or boulders to improve stream complexity and decrease velocity	Roni, 2002; Hough-Snee et al., 2016; Powers et al., 2018
	Habitat Connectivity	Reconnecting isolated watershed stream habitats to support healthy ecosystems	Roni, 2002
	Road Improvement	Using good road design, engineering, and maintenance to reduce impacts on watersheds	USDA, 2002; Roni, 2002
Water Storage	Subsurface Dams	Subsurface structures that trap water, limit evaporation, and increase filtration	Lasage et al., 2013; Ishida et al., 2011
	Sand Dams	Trapping and storing water from ephemeral streams in the pores of sand	Quilis et al., 2009; Aerts et al., 2007; Lasage et al., 2013
	Troughs	Providing water to cattle in confined bins away from riparian areas	Franklin et al., 2009; Willms et al., 2002
	Ground Water Recharge	Either natural or assisted recharge and replenishment of ground water	Taylor et al., 2012; Cui & Shao, 2005; Misra, 2014
	Supplemental Watering	Pumping and distributing water to cattle across rangeland to enhance efficient and productivity	Neibergs et al., 2018; Marsh, 2009; Gopal et al., 2013

5.2 Conservation Strategies

Adaptive water conservation strategies are essential for rangeland managers operating in the Great Basin and Upper Snake River Watersheds. Protecting and preserving high-quality watersheds is easier and generally more successful than to trying and recreate or restore degraded habitat (Roni, 2002). Healthy watershed ecosystems support many essential ecosystem services including: enhancing biodiversity, enhancing soil health, improving water quality, encouraging pollinator habitat, controlling erosion, providing essential water services for rangeland production, sequestering carbon, and reducing the susceptibility of individual ecosystem components to climate change (Janowiak, 2016). In order for watersheds to effectively capture, absorb, hold, and use water necessary for effective livestock production, riparian areas must be in good health (Bellows, 2003). Characteristics of a healthy riparian area include:

> *"... a thick growth of vegetation representing a diversity of grasses, forbs, shrubs, and trees, covers the streambanks and provides shade over the stream (except where streams cut through rocky terrain, land surrounding streambanks remains wet throughout most of the year); streambanks that are more vertical than flattened out; streamflow levels that vary only moderately throughout the year; stream water that is relatively clear but contains leaves, twigs, or logs from streambanks that create pools and other habitat for fish and other aquatic organisms; and a diversity of fish, aquatic life, mammals, and birds live in and around riparian areas"* (Bellows, 2003, pg. 5).

In order for watersheds to effectively capture, filter, and absorb water, rangeland managers should prioritize practices that support adequate vegetation ground cover (Bellows, 2003). This can include utilizing techniques such as conservation tillage, contour farming, cover cropping, agroforestry, and rotational grazing (Bellows, 2003). Overgrazing can decrease a watershed's ability to capture, hold, absorb, and utilize precipitation, especially in areas prone to drought. Sustainable water use is critical in arid and semi-arid regions like the Upper Snake River Watershed and Great Basin. Utilizing (but not over using) ground water resources in conjunction with surface water resources can help conserve and maximize water use efficiency (Cui & Shao, 2005). In turn, this can enhance ecological health and facilitate healthy cattle production. In addition, utilizing both channel and well irrigation diversifies water resource availability and can improve water use efficiency (Cui & Shao, 2005). Water use should be informed by the most recent and credible science available. In addition, it can be important to conserve wetlands and protect buffer strips, swales, and other landscape features because they can act as a buffer against hydrologic variability and increase infiltration after extreme precipitation events (Janowiak et al., 2016). The following section highlights promising adaptive water conservation strategies for planning and preparing for drought and reducing grazing pressure in riparian areas.

Planning and Preparing for Drought

Drought, as defined as "*a prolonged period of abnormally low rainfall that adversely affects vegetation growth and negatively impacts land managers, ranching enterprises, and pastoral systems* (Kelley et al., 2016, pg. 159), is projected to increasingly challenge rangeland management. Responses will require a diverse array of site and operation-specific strategies and approaches. For example, Figure 7 (below) showcases strategies that rangeland managers use in California to adapt to drought. Rangeland managers are challenged by: the complexity of drought; limited drought planning resources, predictors, and tools; policies that discourage proactive drought planning; and a lack of inter-generational knowledge transfer (Kelley et al., 2016). Planning for drought can include maintaining flexibility in rangeland management and use as well as diversifying livestock operations and types of land use (Vose et al., 2016). For more information on drought planning tools, see Section 6.

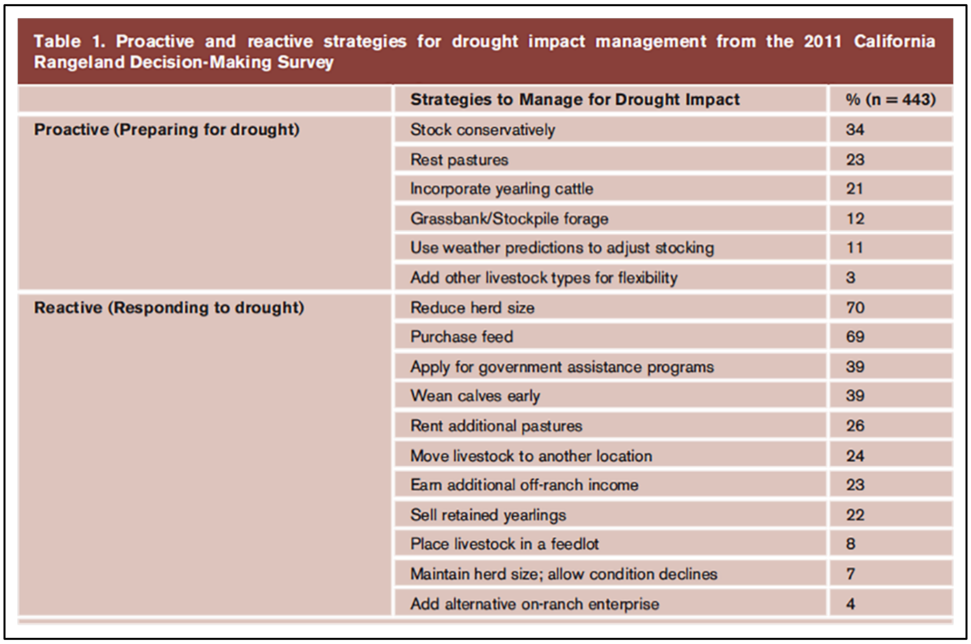

Table 1. Proactive and reactive strategies for drought impact management from the 2011 California Rangeland Decision-Making Survey

	Strategies to Manage for Drought Impact	% (n = 443)
Proactive (Preparing for drought)	Stock conservatively	34
	Rest pastures	23
	Incorporate yearling cattle	21
	Grassbank/Stockpile forage	12
	Use weather predictions to adjust stocking	11
	Add other livestock types for flexibility	3
Reactive (Responding to drought)	Reduce herd size	70
	Purchase feed	69
	Apply for government assistance programs	39
	Wean calves early	39
	Rent additional pastures	26
	Move livestock to another location	24
	Earn additional off-ranch income	23
	Sell retained yearlings	22
	Place livestock in a feedlot	8
	Maintain herd size; allow condition declines	7
	Add alternative on-ranch enterprise	4

Figure 7: Examples of drought adaptation strategies and the percentage of rangeland managers that utilized them in California (Macon et al., 2016).

Reducing Grazing Pressure in Riparian Areas

Riparian areas provide a large variety of ecosystem services and forage for grazing livestock. In the west, many ranchers rely on these areas for summer grazing of livestock. Detailed studies in California on a reduction in grazing pressure (reductions in livestock stocking rates on public lands and implementation of new grazing standards) found a better balance with riparian conservation and livestock production, particularly at the individual meadow scale (Oles et al., 2017). There are a number of other approaches that are more management intensive that can support the health of riparian areas. They include: reducing soil compaction (by limiting grazing when soil is wet or saturated, minimizing the length of grazing time, and discourage the formation of pathways; minimizing stream bank degradation (providing alternative sources of water and designate stream crossings); and reducing manure concentrations in or near streams (place mineral supplements and water tanks away from springs, seeps, or streams, and constructing ramps or bridges for crossing) (Bellows, 2003).

5.3 Restoration Strategies

Rangeland health can be directly correlated to watershed health. Many of the streams in the western United States are degraded due to a number of historical factors including: agriculture, timber harvest, mining, overgrazing, urban development, improper methods of water storage, hydroelectric dam construction, and the removal of beaver from natural ecosystems due to overhunting/trapping (Bouwes et al., 2016). These human activities have led to extensive stream incision, a process in which a stream becomes disconnected from the floodplain due to a rapid down-cutting of the stream bed (Bouwes et al., 2016; Pollock et al., 2014). Limited riparian vegetation can increase erosion and exacerbate channel incision. Incised channels have lower base flows due to the fact that very little water is captured and stored in ground water resources. Effective restoration starts with identifying restoration needs using a tool called a watershed assessment (Roni, 2002). In addition, effective restoration requires sufficient monitoring and adjusting strategies over an extended period of time.

The following section highlights promising adaptive watershed restoration strategies including: riparian zone restoration, in-stream habitat restoration, habitat connectivity, and road improvement.

Riparian Restoration

While only a small percentage of overall rangeland area, riparian areas are particularly important for dissipating stream energy, filtering sediment, retaining water, enhancing water quality, supporting biodiversity, and providing wildlife and fisheries habitat (USFS, 2016). The health of individual rivers, streams, springs, and seeps, are tied to the health and vitality of the riparian areas immediately surrounding them. Studies indicate that grazing is responsible for degrading around 50% of all riparian ecosystems on federal lands across the United States (Armour et al., 1994). Specifically, grazing can cause "*upland and streambank erosion, channel sedimentation and widening, increase stream temperatures, decrease water quality, and changes in the water table*" (Roni et al., 2002, pg. 8). Restoration of riparian corridors can take numerous forms including: active plant introduction, exotic and invasive species control, natural floodplain conversion, grazing and herbivory control, controlled floods, shifting dam operations, dam removal, and landform reconfiguration (Gonzalez et al., 2015). They also include popular stream restoration tools like the Zeedyk method, a method created by Bill Zeedyk that utilizes strategic wood and rock structures to help restore damaged streams back to a healthy flow (Maestas et al., 2018). In addition, promising adaptive methods for supporting riparian restoration include beaver reintroduction and/or creating artificial beaver dams (Pilliod et al., 2018; Pollock et al., 2014; Bouwes et al., 2016; Davee et al., 2017; Davee et al., 2017). The North Pacific Landscape Conservation Cooperative recently funded a multi-agency collaboration to create a guidebook for working with Beaver to restore streams and riparian corridors[6] (Pollock et al., 2017). There are economic, institutional, logistical, and social challenges involved with each method.

Diversifying forage crops and planting species that are resistant to higher peak flows and erosion pressure can help sustain and maintain riparian soil health and protect water quality. Restoration of riparian zones often require livestock exclusion or rest rotation (Roni et al., 2002). See Section 3.3 for more information on exclosures. Although developed over decades, riparian restoration strategies have not been comprehensively and effectively evaluated for success due to lack of funding and the lack of systematic and objective evaluation criteria (Gonzalez et al., 2015).

In-stream Habitat Restoration

Redistributing large woody debris and strategically placing boulders in streams can increase stream complexity, improve habitat heterogeneity, and slow water velocity (Hough-Snee et al., 2016). Large woody debris creates sinuosity (curvature and bends in a stream) and scour

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[6] https://www.climatehubs.oce.usda.gov/hubs/northwest/topic/incised-stream-restoration-western-us

pools resulting in vital habitat for fish (Roni et al., 2002). The amount of large woody debris in a stream is dependent on many different characteristics, including tree cover and mean annual precipitation (Hough-Snee et al., 2016). Additional instream fish habitat restoration approaches include placement of individual logs, log jams, brush bundles, boulders, rock-filled wire gabions, and spawning gravel (Roni, 2002). Restoring watershed ecosystems can bolster a stream's ability to retain and store water, improve water quality, improve the health of watershed ecosystems, and maximize rangeland ecosystem benefits that support productive rangelands.

In addition, 'Stage 0 restoration' techniques are changing the way stream and river restoration is being discussed and carried out. Studies are showing that single thread meandering channel streams do not accurately represent the conditions of many streams or rivers prior to human modification. Instead, conditions of streams in alluvial valleys - especially in the Pacific Northwest - were an anastomosing network of channels and wetlands that flooded often (Powers et al., 2018; Cluer & Thorne, 2013; USDA, 2018). The Stage 0 stream evolution model is enabling practitioners to achieve healthy habitats as well as maximize watershed ecosystem benefits.

Habitat Connectivity

Studies indicate that reconnecting isolated watershed stream habitats can be extremely successful and support healthy ecosystems (Roni et al., 2002). Isolated habitats include: off-channel freshwater areas; and stream sections isolated by artificial obstructions (like culverts) (Roni et al., 2002). Isolation can be caused by agriculture, transportation, and flood control activities. Reconnecting these off-channel habitats to the floodplain can improve water availability for livestock, groundwater recharge, ecosystem function, and biological productivity.

Road Improvement

Roads and parking lots negatively impact the ability of watersheds to absorb and filter water, nutrients, and contaminants from precipitation events (Bellows, 2003). Roads can increase sediment loads and alter in-stream hydrology (Roni et al, 2002). With good road design, engineering, and maintenance, these impacts can be reduced drastically. In some cases, road relocation or realignment can reduce or eliminate negative impacts in sensitive areas, restore or reconnect floodplains, reduce the risk of road failures, and improve habitat (USDA, 2002).

5.4 Water Storage

Local water storage is an important adaptation measure for rangeland managers (Lasage, 2007). It is especially important in the Upper Snake River Watershed and Great Basin in remote areas with highly variable precipitation patterns. For producers that are reliant on surface water from stock water ponds, changing climate conditions and droughts can negatively affect their operations. Adaptive management approaches to water storage from both groundwater and surface water sources are essential to reducing the vulnerability of communities to climate change (Taylor et al., 2012).

The following section highlights promising adaptive water storage approaches including utilizing: subsurface dams and sand dams; groundwater recharge systems; and supplemental water supplies.

Note: water resource management in western states can be a challenging and sometimes contentious issue. Each State has its own water laws and policies and it is important to consult with the State's water resource planning department before constructing new water storage alternatives drawing on or utilizing additional water resources. For more information contact the following:

- Idaho Department of Water Resources
- Nevada Division of Water Resources
- Oregon Water Resources Department
- Washington Department of Ecology.

Subsurface Dams

Subsurface dams have been shown to be effective adaption measures to improve water security (Lasage et al., 2013). These dynamic structures are used to increase water storage by arresting groundwater flow, thereby raising the water table. Subsurface dams are shown to decrease evaporation, improve long-term storage capacity, and increase filtration (Lasage et al., 2013). Subsurface dams can be constructed on a variety of scales in order to provide water for agriculture (Ishida et al., 2011). They can be constructed using various types of materials, including compacted clay, plastic sheeting, or corrugated iron (Onder & Yilmaz, 2005). Generally, subsurface dams are built in one stage. Subsurface dams require knowledge of the complex geology of the area to properly locate the site and can be difficult to situate so that the water can be extracted using gravity. This means that costly pumping equipment is generally required to access the water.

Sand Dams

Sand dams are constructed on ephemeral streams and are used to trap runoff by storing water in the pores of sand. Sand dams slow the flow of water runoff events by allowing higher flows to flow over the dam while capturing the remaining sediments (Quilis et al., 2009). Larger grain sediments build up behind the dam and create an artificial aquifer. Coarse gravel and sand can store up to 35% of their total volume as water, but, depending on the size of the dam, it can take years of runoff events to fill the dam (Lasage et al., 2007).

Storing water in sand has shown to yield lower evaporation levels (by 8-30%), and create longer storage capacity and better filtration than open reservoirs (Aerts et al., 2007). This longer release of water can be essential when precipitation events are less predictable due to climate change. In addition, the water is filtered through the sand resulting in better water quality (Lasage et al., 2013). Sand dams can be easily adapted to supply different water features including troughs or collection tanks.

Constructing a sand dam requires knowledge of the complex geology of the catchment area and can reduce downstream flow (Lasage et al., 2013). To be effective, the area above the dam must release gravel and sand during runoff events to fill the dam (Aerts et al., 2007).

The basement layer must be impermeable with no fracture zones in order to effectively store water (Hanson & Nilsson 1986). In addition, the dam must be anchored into bedrock or in the basement layer to function. Spring runoff events supply sand to fill behind the dam and become the artificial aquifer. Sand dams are usually constructed in a confined ephemeral stream and usually made of concrete. This facilitates an easier design process, but can limit the dam's applicability in difficult to access environments.

Troughs


Figure 11: Supplemental watering of livestock in Eastern Oregon during the 2015 drought. Photo credit: Sonia A. Hall. National Climate Assessment, 2018. Chapter 24. (May et al., 2018)

After exclosures, troughs have been shown to be one of the most effective ways to keep cattle out of streams. Studies show that cattle prefer to drink from troughs and will spend 63% to 81% less time in the stream and riparian areas if a trough is available (Franklin et al., 2009; Sheffield et al., 1997). If cattle have access to both a stream and a trough during extreme heat events, cattle prefer to get in the stream due to the cooler temperatures (Franklin et al., 2009).

Troughs have many benefits for the environment. By utilizing troughs, cattle are much less likely to use stream systems, therefore reducing the amount of erosion on stream banks, maintaining riparian vegetation and riparian species habitat, and reducing the amount of non-point source pollution entering the river (Sheffield et al., 1997; Miner et al., 1992). In addition, troughs can provide cleaner water than natural resources (Willms et al., 2002). Cattle will consume more water when clean water is available, resulting weight gains up to 23% (Willms et al., 2002). Higher weight gains can lead to an economic benefit for producers that that can offset the initial investment of a trough system. Cattle have been shown to prefer larger troughs than smaller ones (Filho et al., 2004). In addition, cattle have been shown to prefer troughs that have a larger surface area as opposed to more depth or height (Teixeira et al., 2006) and PVC troughs are preferred over concrete troughs (Coimbra et al., 2010).

Groundwater Recharge

Ground water is foundational in supporting biological resources, ecosystem function, livestock production, and resilience to a changing climate (Taylor et al., 2012). Globally, groundwater supplies provide 42% of the water used for agricultural (Misra, 2014). Globally, groundwater supplies 36% of all domestic water use, 42% of all agricultural use, and 27% of all industrial use (Taylor et al., 2012). Ground water resources are critical for supporting livestock production and ecological function in the Upper Snake River Watershed and Great Basin, especially in the context of a changing climate.

The full impacts of climate change on ground water resources across regions and on individual sites is not fully understood at this point. Yet, tools like the UN Global Groundwater Monitoring Network[7] can help rangeland managers make decisions that help support healthy groundwater use. Changing precipitation patterns and decreasing snow pack are likely to negatively impact ground water resources, and increased temperatures may require producers to increase the use of ground water, which can result in groundwater depletion (Taylor et al., 2012). This is especially true in areas that utilize groundwater-fed irrigation systems. In some areas, an increase in precipitation may result in surplus groundwater recharge, resulting in degraded groundwater resources due to natural contaminants or increased salinization from soils (Taylor et al., 2012).

Replenishing aquifers and increasing the water table can support vegetation growth, prevent desertification, and supply necessary water resources to livestock producers. Ground water and surface water are interconnected and can be used in conjunction in order to reduce the risk of soil salinization and increase water use efficiency (Cui & Shao, 2005). The water content of topsoil depends on the soil type and the distance to the water table. This delicate balance is disrupted by continuous drawdown of the water table and can lead directly to desertification (Cui & Shao 2005). Recharging ground water can raise the water table and increase the soil water content of the vadose zone (zone located between the top of the ground surface to the water table) or of the topsoil. Raising the water table can also increase the amount of condensation water that is available. Natural groundwater recharge processes include recharge from rain and excess leakage from surface waters (Taylor et al., 2012). The process of actively replenishing groundwater supply is known as "artificial recharge." Examples include utilizing techniques like recycling or reusing wastewater to replenish groundwater resources (Misra, 2014). In semi-arid regions, wastewater reuse (also known as Soil-Aquifer-Treatment) can be effective in securing water resources in areas that have low precipitation. This is actively occurring in parts of Los Angeles (Misra, 2014). Candidates for groundwater recharge using wastewater must meet certain geological, topographical, and hydrological requirements.

Supplemental Watering and Distribution

Water distribution plays an essential role in the efficiency and productivity of rangelands. In general, increased time traveling to water can reduce cattle performance (Hodder & Low, 1976). A recent study indicates that extensive irrigation systems, especially in the Pacific Northwest, can help buffer the impacts of drought (Neibergs et al., 2018). Water must be available to livestock when they want to drink, but for producers who work in water remote regions – like many areas of the Upper Snake River Watershed and Great Basin- managers must account for these particularly challenging logistics (Marsh, 2009).

In general, water pumping systems can be powered by solar DC pumps, wind pumps, ram pumps, sling pumps, nose pumps, gravity pumps, and electric AC pumps (Marsh, 2009). Pumping systems should be determined based on the availability and cost of electricity, water supply, and water location (Marsh, 2009). Using electric water pumps is the most cost-effective method for pumping water, but for locations that are further than one third of a

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[7] https://www.un-igrac.org/special-project/ggmn-global-groundwater-monitoring-network

mile from commercial electricity sources, alternative energy sources may be necessary (Marsh, 2009). Alternative pumping methods include solar wind, electric, and hybrid pumping systems.

Solar

Solar powered water pumping operations can provide consistent power during bright sunny days. In general, solar power efficiency coincides with peak usage (Foster & Cota, 2014). During late summer when more water is needed for cattle usage, solar panels generally have access to the most sunlight allowing for more productive and efficient pumping of water. In addition, after the initial investment, solar panels have little or no operational cost. They require minimal maintenance and can be effectively maintained for an extended service life. In addition, solar power based pumping can be suitable in many different locations. Yet, utilizing solar power does have drawbacks. Solar power requires energy from the sun, so it doesn't run all day and night, it isn't 100% efficient during the day, loses efficiency over time, and can be impacted by changing weather conditions (Sontake &Kalamkar, 2016). Peak hours for solar arrays are generally midmorning to midafternoon. This can be extended by installing a bank of batteries or by using a storage tank to store excess water. Battery banks provide constant power while a storage tank provides a buffer until the solar panel is in sunlight again. Storing excess water is more economical than purchasing a battery bank (Gopal et al., 2013).

In order to create enough power to run a water pump, solar panels must be of a relatively significant size. In addition, the type and capacity of the motor attached to the array determines the effectiveness and maintenance of the pumping system. Motors can be Alternating Current (AC), Direct Current (DC), or Switched-reluctance Motors (SRM). DC motors are beneficial because they can be directly connected to the solar array, yet they aren't suited for work above 7 kW (Gopal et al., 2013). AC motors are more powerful, but they require a DC to AC inverter, which will lead to higher cost and some loss in efficiency. SRM motors are cheaper than conventional DC motors and are reported to also have higher efficiencies (Gopal et al., 2013). By eliminating many of the necessary sensor components found in DC motors, using SRM motors can reduce cost. Experts found this motor to be suitable to pump water even during lean sunshine hours, increasing its effectiveness (Gopal et al., 2013).

Wind

Wind energy has been used to pump water for decades especially in arid regions (Badran, 2003). The site must have high enough wind speeds and dense enough air to drive a turbine. Wind turbines also need regular scheduled maintenance to function properly. Wind pumps can function electrically or mechanically (Harries, 2002).

Hybrid Pump Systems

Hybrid wind and solar energy pumping systems utilize two different kinds of energy sources, giving producers more flexibility in location of the sites and type of weather when it can function. Researchers have also found that hybrid systems can deliver 28% more water in peak usage months (Vick & Neal, 2012). However, studies have shown that hybrid systems may not be as efficient, cost more, and result in complex maintenance (Vick & Neal, 2012).

Electric Pumps

For small scale water system pumping, AC electric pumps are the most convenient, dependable, and cost-effective pumping system when access to the electricity grid is available (Marsh, 2009).

5.5 Case Studies

Sand Dams in Action. In the Kitui District of Kenya, a semi-arid region that is experiencing the impacts of climate change through drought and erratic and variable precipitation patterns, communities (with the help of local NGO's) have successfully improved resilience to drought using small-scale water storage structures like sand dams (Lasage et al., 2007). Sand dams have also been implemented in Ethiopia to improve water security and resilience to drought due to climate change (Lasage et al., 2013). In addition, these dams have an "acceptable range" of impact on down-stream flows considering the improved security for water resources (Lasage et al., 2013). Lessons regarding innovative and effective water storage structures can be gleaned from this case study and applied to the Upper Snake River Watershed and Great Basin.

Holistic Water Management in Eastern Washington. Maurice and Beth Robinette, managers of the Lazy J Ranch in Eastern Washington advocate for utilizing holistic management approaches for water conservation to maximize water access during droughts and variable precipitation conditions (WSU CAHNRS, 2016). For them, utilizing the process of "plan, monitor, control, and re-plan" is a foundation that helps minimize the risk for drought. In addition, they strive to minimize the amount of bare soil in their pasture, so that when rain does fall, they can ensure that it will be absorbed into the ground and will result in more forage (as opposed to running off) (WSU CAHNRS, 2016). Additional information about holistic management can be identified in Section 2.4.

Low-tech Riparian and Meadow Restoration with the NRCS and BLM. A study sponsored by the NRCS-led Sage Grouse Initiative and the Bureau of Land Management evaluated the outcomes of three different low-tech wet habitat restoration projects (see Figure 9) around the American West (Science to Solutions, 2018). They looked at the value of Beaver Dam Analogues (Bridge Creek, OR – analyzed 10 years after restoration – left panel); time controlled grazing management (Maggie Creek, NV – evaluated 25 years post restoration – middle panel); and Zeedyk Structures (Gunnison River Basin, CO – evaluated 5 years post restoration – right panel). In every case, they found enhanced soil moisture retention, that plants stayed greener longer, and in some cases up to 25% more productivity from the vegetation. These projects highlight that riparian and wet meadow restoration does not have to be expensive to be successful (Silverman et al. 2018).

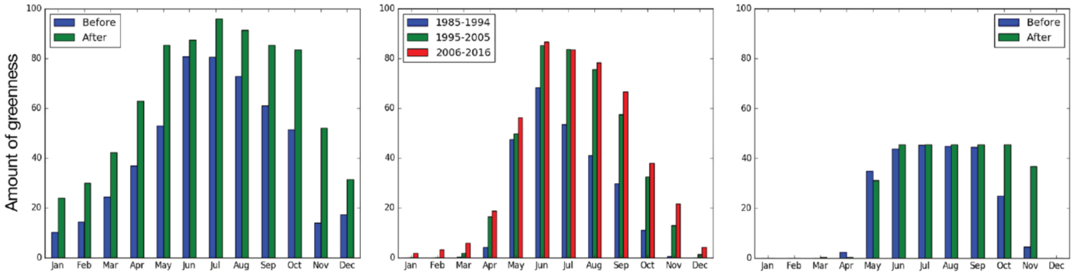

Figure 14: Amount of grasses before and after restoration during the NRCS-led Sage Grouse Initiative. Bridge Creek, OR – analyzed 10 years after restoration – left panel); time controlled grazing management (Maggie Creek, NV – evaluated 25 years post restoration – middle panel); and Zeedyk Structures (Gunnison River Basin, CO – evaluated 5 years post restoration – right panel).

Drought Resistance Networks to Support Rangeland Decision-making. In California, drought is an increasingly significant problem for rangeland managers. In order to best prepare rangeland managers for adapting to drought, the University of California Cooperative Extension utilized workshops and webinars to share recent and relevant research across the state (Macon, 2016). In addition, the Farmer-Rancher Drought Forum was created on social media to share real-time drought adaptation strategies across a wide network. Platforms like *SoundCloud* were also used so that rangeland managers were able to record and share their stories of drought adaptation (Macon, 2016). Traditional methods like workshops and field days are still utilized, but the growing membership of these rangeland networks highlight the importance of exploring additional ways of communicating such as using social media, online forums, webinars, and others.

6. Planning Tools

There has been a significant improvement in the availability, effectiveness, and use of planning tools to support rangeland managers in their efforts to adapt to a changing climate. Promising adaptation tools include: utilizing real-time data and mapping to predict forage production; insurance and risk-management; implementing community-based observers and rangeland networks; and building ranching-focused social networks.

Real-time Data for Forage Production

Rangeland managers need access to relevant and timely data in order to implement adaptive strategies into their operations. Real-time monitoring in specific locations is expensive and requires resources, trained staff, and a clear focus (USDA and USFS, 2018). GrassCast[8] is a tool developed by the USDA to help rangeland managers predict how much forage will be available for livestock for any particular grazing area. In addition, the University of Idaho - in partnership with the Nature Conservancy, BLM, and USDA Northwest Climate Hub – have developed a tool[9] using Landsat imagery that can help rangeland managers make grazing decisions using biomass and vegetation cover estimates. In addition, tools like the Rangeland Production Monitoring Service[10] (Figure 10), developed by Matt Reeves of the Rocky Mountain Research Station, provide rangeland managers with: 1) relevant historical data from 1984-present that show annual vegetation production at 30 meter spatial resolution on all rangelands across the United States, and 2) a forage projection system that utilizes real-time climate data to estimate the "*magnitude and timing of annual production across all rangelands in the Northern region of the USDA, US Forest Service (Region 1)*" (USDA and USFS, 2018, pg. 1). This tool "*enables users to quantify trends in vegetation production through time, evaluate inter-annual variability, and quantify recovery from drought and wildfire*" (USDA and USFS, 2018, pg. 1).

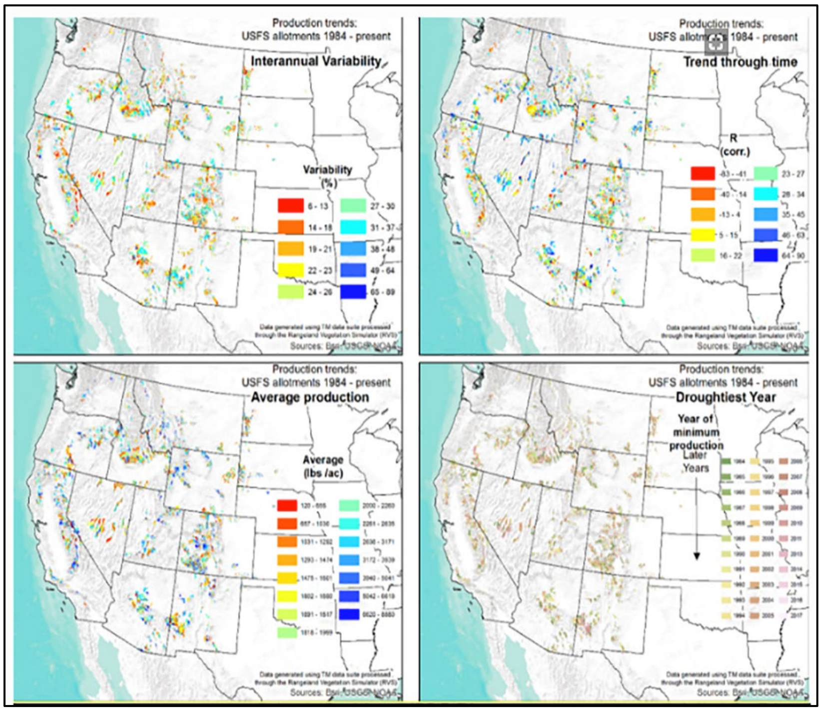

Figure 19: Components of the Rangeland Production Monitoring Service developed by Matt Reeves in partnership with the USDA and the USFS. Four metrics have been used in this particular example to showcase how the tool and dataset is used to predict production trends.

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[8] https://www.climatehubs.oce.usda.gov/hubs/northern-plains/tools/grass-cast-grassland-productivity-forecast

[9] https://www.uidaho.edu/cnr/rangeland-center/projects/space-cowboys

[10] https://www.fs.fed.us/rmrs/projects/development-rangeland-production-monitoring-service-could-improve-rangeland-management

Risk Management Tools & Insurance

Risk Management Tools, like the Pasture, Rangeland, and Forage (PRF) production insurance products[11] developed by the USDA Risk Management Agency may be important for ranchers to compensate for losses from droughts (Niebergs et al., 2018). Defined by geographic grids, livestock producers receive compensation when projected annual rainfall index for a particular geographic grid location dips below average. In addition, the USDA Farm Service Agency[12] (FSA) and Livestock Forage Disaster Program[13] (LFP) compensates livestock producers affected by drought and fire (Niebergs et al., 2018). Livestock Risk Protection insurance and Whole Farm Revenue insurance also assist livestock producers in insuring ranch revenue and beef prices. Tools like the AgRiskViewer tool[14] (developed by the USDA Southwest Climate Hub[15]) helps rangeland managers learn about and analyze publicly available and historical risk insurance data to help inform their adaptive operational decision-making.

Community-based Observers and Rangeland Networks

In addition to utilizing relevant datasets, tools, and projections, one of the most valuable and effective forms of information gathering occurs through interactions with local agency resources (ex. USDA Regional Hubs) or other rangeland managers. Innovative networks for leveraging local and community knowledge, skill-sets, and motivations (as well as state and federal networks and resources) include Rangeland Fire Protection Associations (RFPA's) as referenced in Section 4.3 (Stasiewicz et al., 2018; Abrams et al, 2017). By sharing best practices, resources, and experience throughout the community, rangeland managers can increase the resilience of individual and regional operations. In addition, community-based observing networks and systems and community observer forums play an important role in monitoring social ecological systems and enhancing resilience (Griffith et al., 2018). These models utilize observations made by community members, often times in remote areas and in partnership with government agencies and researchers. Not only can they be cost-effective tools in remote areas, but they can educate community members on complex ecological processes, increase buy-in for regional scale processes, and increase regional resilience (Griffith et al., 2018). They can also have positive implications for cultural values of a land area and be an effective way to integrate Traditional Ecological Knowledges and Western Science (Griffith et al., 2018).

Building Ranching-focused Social Networks

Connecting ranchers so that they can share promising practices and innovations has the potential to accelerate learning and enhance knowledge-exchange among individuals in the region. There are a variety of online and in-person forums that help support this enhanced networking and information sharing. They include:

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[11] https://www.rma.usda.gov/en/Fact-Sheets/National-Fact-Sheets/Pasture-Rangeland-Forage-Pilot-Insurance-Program

[12] https://www.fsa.usda.gov/

[13] https://www.fsa.usda.gov/programs-and-services/disaster-assistance-program/livestock-forage/index

[14] https://swclimatehub.info/rma/

[15] https://www.climatehubs.oce.usda.gov/hubs/southwest

- The Pacific Northwest Climate Conference[16] – an annual conference with a significant focus on ranching and agriculture.
- Art of the Range Podcast[17] - a new podcast focused on building the community of practice and education through conversation with researchers, ranchers, and resource professionals.
- Rangelands & Pastures[18] - a publications hub as part of the Center for Sustaining Agriculture and Natural Resources at Washington State University.
- Agriculture Climate Network[19] - a web-based hub for communications between regional scientists and stakeholders supported by Oregon State University, University of Idaho, Washington State University, the USDA Northwest Climate Hub, and the Climate Impacts Research Consortium.
- Sustainable Rangelands Roundtable[20] – a roundtable discussion that brings together non-governmental organizations, public and private land management professionals, rangeland scientists, and university researchers to share information and identify social, ecological, and economic indicators of rangeland sustainability.

Other Decision-support Tools

The USDA Northwest Climate Hub[21] is an important resource for rangeland managers in the Upper Snake River Watershed and the Great Basin. The Hub provides rangeland managers with science-based solutions, resources, tools, and information from their team of technical experts and partner organizations (National Oceanic and Atmospheric Administration, the National Weather Service, the National Drought Mitigation Center, and the Community Collaborative Rain Hail and Snow Network) to provide daily updates on real-time drought patterns. In addition, the Northwest Climate Toolbox provides a suite of available tools and resources that rangeland managers can effectively access and utilize to help inform their decision-making. Other decision-support tools include the U.S. Drought Monitor[22], the National Integrated Drought Information System[23], the NOAA Climate Predictions Center[24], the USDA Plant Hardiness Map[25], and the USDA Drought Early Warning Program[26] (USDA Climate Hubs, 2018; 25x25 Alliance Adaptation Work Group, 2013). In addition, tools like Thermal Aid[27] help rangeland managers determine the risk for heat stress on individual animals by utilizing an app on their smartphone (25x25 Alliance Adaptation Work Group, 2013).

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[16] http://pnwclimateconference.org/

[17] https://artofrange.com/

[18] http://csanr.wsu.edu/publications-library/livestock/rangelands/

[19] https://www.agclimate.net/

[20] http://www.sustainablerangelands.org/

[21] https://www.climatehubs.oce.usda.gov/hubs/northwest

[22] https://droughtmonitor.unl.edu/

[23] https://www.drought.gov

[24] http://www.cpc.ncep.noaa.gov/

[25] https://planthardiness.ars.usda.gov/PHZMWeb/

[26] https://www.drought.gov/drought/regions

[27] http://thermalnet.missouri.edu/ThermalAid/index.html

7. Conclusion

Figure 27: Cattle grazing in the Upper Snake River Watershed (Photo: Calla Hagle)

Rangelands are complex, intricate, interconnected, and dynamic socio-ecological systems comprised of the humans, livestock, and natural plants and wildlife that inhabit them. They are an integral part of the region's economy and provide valuable income to both tribal and non-tribal ranchers. In addition, the climatic changes that are occurring in the Upper Snake River Watershed are dynamic, complex, and location-specific. These changes are part of a larger global trend. While variable across the region, for the Upper Snake River Watershed, projections indicate that there will be a significant long-term decrease in snowpack, an increase in the variability of precipitation events, and an increase in temperatures across all seasons.

Landscapes are: "…*endlessly emerging, transforming, and vanishing as a result of ever-changing relationships among organisms and environments—soil, plants, herbivores, and human beings. In the process, all organisms are actively participating in creating environments; they aren't merely adapting to them…*" (Provenza et al., 2013, pg. 6).

Adapting to a changing climate will mean more than just modifying approaches to stocking; enhancing, and restoring rangelands; or providing diverse and redundant systems for water management. It will require embracing some amount of uncertainty, and for rangeland managers to be willing to continue to be creative and flexible in order to make the most of the highly variable and dynamic environmental and socio-economic systems on a seasonal, annual, and even decadal basis. It will also require policy frameworks that enhance the ability of ranchers, and the cattle they manage, to respond to these changes in productive ways. In some cases, it may even mean abandoning certain grazing parcels or allotments that may become unsuitable for ranching.

Regardless of the extent of the challenge, rangeland managers are creative, adaptable, and innovative people and they have a proven ability to prepare for and adjust to changing conditions. Yet, the extent and rate of change is likely to go beyond what they have experienced in the past. Climate change is just one of many factors that rangeland managers will have to balance in their quest to continue to be both profitable and sustainable. ***Utilizing holistic approaches that value both the economic success of a ranching operation and the long-term health and resilience of the landscape and wildlife will help ensure that rangelands remain an important part of the social, economic, and cultural fabric of the Upper Snake River Watershed for decades to come.***

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