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A Comparison of Two Methods to Estimate Heifer Activity Using GPS and Accelerometer Data

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There is increasing interest in the use of low cost GPS units to monitor livestock movement and activity patterns on rangeland. Such devices seldom include movement sensors. On the other hand, 2- or 3-axes accelerometers included in several commercially available GPS units often yield activity data with low animal-to-animal consistency. Our objective was to compare two methods of estimating activity of rangeland heifers monitored with collars equipped with GPS and 2-axis accelerometers. The first method (VEL) involved classifying GPS points based on movement velocity thresholds. Resting was assumed when velocity < 2 m/min, velocities between 2-25 m/min were assumed to indicate grazing, and velocities > 25 m/min were classified as traveling. The second method (MOV) included a classification tree model that discriminated between resting, grazing, and traveling activities considering the distance between GPS points and both horizontal and vertical movement values recorded by a 2-axis accelerometer. Lotek 3300LR GPS collars were fitted randomly on heifers (18 days) in spring 2015 (n=20), 2016 (n=18), and 2017 (n=41). VEL calculations were done by entering GPS coordinates into GRAZACT, a Java software that helped automate classification, and a SAS 9.4 code was used to create the classification tree model to calculate MOV. Results from both methods were converted to hours/day and were compared using Wilcoxon's test in SAS 9.4. Estimated time spent traveling was lower (P<0.01) using MOV (0.67±0.02h) vs. VEL (0.90± .02h) but both methods yielded similar estimates (P=0.10) for time spent resting (MOV=13.90±0.11h vs. VEL=13.69±0.08h) and time spent grazing (P=0.07; MOV=9.16±0.13h vs. VEL=9.39±0.07h). Classifying activities based on GPS data alone provided estimates that were similar to those derived from more sophisticated GPS + movement sensor analyses.

A Conceptual Framework for the Adoption of Intensive Grazing Management Strategies

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Pasture and rangeland make up over one-third of the land in the Unites States. Throughout much of this land, unsuitable livestock grazing management has contributed and continues to contribute to soil erosion and the loss of soil carbon, resulting in impaired soil functionality and, therefore, land degradation. However, the adoption of intensive grazing management strategies, exemplified by adaptive multi-paddock (AMP) grazing, hold potential for reversing land degradation by restoring soil health through enhancement of nutrient cycling and water infiltration. Ultimately, this could increase the production of grazing land, above and below ground biodiversity and the delivery key of ecosystem services. Grazing lands in the United States coevolved with large numbers of grazing animals and their associated predators. The predator-prey dynamics caused these herds to bunch tightly together and move frequently across the landscape. The resulting urine and fecal deposition patterns concentrated nutrients that are essential for maintaining soil health, and provided long periods of rest between grazing periods, which allowed the vegetation to recover before being grazed again. The adoption of intensive grazing management strategies, such as AMP grazing, that mimic historic grazing patterns may produce ecological as well as economic benefits for ranchers. Theoretically, the restoration of soil health will result in increased profits due to elevated grass production and, thus, animal production. In addition, ranchers may also benefit from premium prices for their product by obtaining sustainable beef certifications or ecological verifications. These product labels serve to inform the consumer of the ecological benefits of the management strategies used to produce the product, which ultimately make the product more “environmentally friendly”. Ideally, increased consumer demand for ecologically verified or sustainably certified products will provide incentives for more producers to adopt intensive grazing management strategies.

A Diminishing Unique Traditional Practice of Rangeland Resources Management in the Himalayan Kingdom of Bhutan

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Bhutan is a small land-locked country in the Hindu Kush Himalayan (HKH) Region and the geographical area is dominated by mountainous terrain. The population is about 700,000, of which 10% lives in the high alpine mountains and depends on rangelands to rear livestock, in particular yaks. Rangelands provide various livelihood opportunities – such as ecotourism and income sources from non-wood forest products (NWFP) on a seasonal basis. However, yak farming, utilizing the available vast rangeland resources, provides the most sustainable livelihood to the highlanders. These rangeland resources, though large in area and making huge contributions to the livelihood of highlanders, have received a very low priority in terms of development. Nonetheless, the highlanders use their best traditional knowledge and practices inherited from forefathers to sustain rangeland resources through proper management and utilization. Some of the traditional practices are allocation of rangelands through dice systems that ensure fairness and social harmony amongst beneficiary highlanders and the other system is locally called 'northue', wherein the same cattle herd is managed by two individuals in two different rangelands particularly for the summer and winter grazing. The cattle herd belongs to both individuals with full ownership for the grazing periods of four to five months for winter and summer months, respectively. But today, these age-old traditional practices are threatened with introductions of new technologies, changes in government policies and weak policy support. Thus, before diminishing the traditional practices completely, it is important to intervene, document and share information amongst the educators and youth around the world, and most importantly the policy makers within the country in order for appropriate decisions to conserve these rich traditional values of our forefathers in sustaining rangeland resources.

A Forage Quality Calendar of Ventenata (*Ventenata dubia*): Insights into Grazing Potential

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Ventenata (*Ventenata dubia*) is a relatively new invasive grass in the western United States that is rapidly dominating hay systems, pastures, dry forests, and dry shrublands on both private and public lands. Focused and systematic grazing can provide a lower cost annual treatment for controlling invasive grasses when utilized at the optimal time and stocking density, which varies among invasive grass species. Unfortunately, there are no published studies regarding use or suitability of targeted Ventenata grazing. Currently, field reports indicate low or no grazing utilization of Ventenata by cattle. Therefore, our objective was to evaluate the forage quality (crude protein, acid detergent fiber, neutral detergent fiber, lignin, and macro minerals: calcium, phosphorus, magnesium, potassium and sodium) and biomass production of Ventenata over the growing season and phases of its plant growth (April-July). We conducted systematic sampling of Ventenata in a mesic meadow environment within the Great Basin of southern Oregon. We found that over the growing season, Ventenata wet biomass ranged from 27 to 2,452 kilograms/hectare, in comparison with other vegetation in the meadow that ranged from 262 to 3,859 kilograms/hectare. Foliar cover of Ventenata ranged from 25% to 100%. At 100% foliar cover, during the peak of forage quality Ventenata dry weight ranged from 180 to 447 kilograms/hectare. Forage quality peaked in late May at the elongation phase and was adequate for spring calving beef cow/calf grazing from the onset of growth in April until the last week of June. Although it is still unclear why Ventenata may be unpalatable to livestock, our study provides the foundational information for exploring the grazing potential of this invasive annual grass.

A Framework for Understanding Adaptive Capacity Across the Social Landscape

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Around the globe grasslands have undergone an unintentional and unwelcome transformation from grass-dominated to shrub-dominated vegetation. While there is a relatively clear understanding of the drivers and outcomes of woody plant encroachment (WPE), an important challenge is to understand the role private landowners have in facilitating or preventing it. As values across the landscape become more heterogeneous, preferences for the bundles of benefits provided by rangelands may shift from an emphasis on production-based to cultural-based ecosystem services leading to changes in land management and ultimately land cover. We present a framework for understanding ecological change in dryland systems where the dominance of production-oriented land use values is diversifying, resulting in increased heterogeneity across the social landscape. Using data from the Southern Great Plains as a case study, we propose meanings networks as a way to identify the capacity for and barriers to effective adaptation to ecological transformation. Meanings, measured as sense of place, represent the purpose of the land as well as its significance to the landowner. A network perspective recognizes variation in the configuration of meanings within and across landowners, rural communities, and regions. Meanings networks provide the basis for understanding the relationships that connect landowners to their land and characterize the values that guide behavior on the land.

A Hailstorm Reduced Forage, Nesting Cover, and Floral Resources in Southwestern North Dakota Grasslands

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An overlooked impact of anthropogenic climate change on rangelands is greater frequency and severity of hailstorms associated with rising minimum temperatures. Although often more spatially-discrete than management actions like grazing and fire, these natural disturbances are much less predictable and often occur in the middle of the growing season. A set of our experimental pastures and hay fields in southwestern North Dakota were hit with a hailstorm shortly after they were sampled in the summer of 2018. We repeated transects in hail-struck pastures to quantify loss of vegetation structure and floral resources, important to grassland birds and pollinators, respectively. We took visual obstruction readings (VOR) along 100 m transects to approximate forage and nesting resources and measured flowering stems along 100 m and 25 m transects used for butterfly and bee sampling, respectively. VOR and floral counts for all locations were substantially lower after the hailstorm. Overall, VOR was reduced by 49% and floral stem counts were reduced by 81- 90%. The reduction in VOR represents a loss of nesting cover for grassland wildlife and a decline in forage resources for grazing animals and hay production. Fewer flowering stems is especially concerning given the paucity of forbs in post-Conservation Reserve Program grasslands such as ours. Our data describe how detrimental severe, unpredictable weather events during the growing season are to rangeland resources, and underscore the value of landscape-level heterogeneity at a scale broader than localized storm events to ensure redundancy of resource provisioning as the frequency of extreme weather is expected to increase.

A Landscape Approach to Conserving Carbon Stocks in California Rangelands

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Rangelands, including grasslands, shrublands, and woodlands, contain a substantial portion of the global terrestrial carbon stock, both in soil and plants. How to protect that carbon stock is under question. Given that rangelands span over half of the land use in California, maintaining and improving carbon sequestration in rangelands can help offset the rising levels of atmospheric carbon that contribute to climate change. A number of studies on carbon sequestration on rangelands have been conducted in California but none in relation to Ecological Sites – a classification of heterogeneous landscapes into similar climate, topography, vegetation, and land use. We found that carbon stocks in Tejon Ranch, California differentiated Ecological Sites. Within an Ecological Site, shrubland states had significantly higher above- and belowground carbon stocks than grassland states. Abiotic variables such as elevation and soil properties explained most of the variability in carbon stocks, suggesting that Ecological Site Description is a well-suited framework for describing carbon dynamics in semi-arid rangeland ecosystems. The implication of linking carbon stocks to Ecological Sites is being able to scale up information from plot to landscape scale. For range managers, the estimates of carbon stocks could be more useful at the management unit level than those at the state level as rangeland ecosystems are highly variable by site.

A Landscape Approach to Pollinator Conservation

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Conversion and loss of native grasslands along with the continued use of insecticides has led to noticeable declines in pollinator populations. These trends in the native pollinators have resulted in the petitioning of several butterfly and bee species for listing under the U.S. Endangered Species Act. However, very little is known about their population status and habitat requirements, especially landscape composition and configuration. Studies often focus on habitats where species are known to occur and therefore are not broadly applicable and lack the critical information to get at patch size and connectivity thresholds. To better understand relationships between pollinators and landscape metrics, we used a hierarchical sampling framework to select study sites across North Dakota. We stratified our sample using a gradient of grassland patch size and National Resources Inventory (NRI) Similarity Indices. At each of the sites, we conducted butterfly and bee surveys using modified Pollard walks and bee bowls. We found that most of the rangeland is degraded throughout North Dakota and NRI Similarity Indices positively correlated with grassland patch size with patch size increasing westward across the state. In addition, we found several butterfly species dominated our counts and monarch and regal fritillary butterflies were distributed widely within North Dakota. In addition to informing listing decisions, our results will help guide extensive landscape-level grassland conservation efforts underway in the Prairie Pothole Region of North Dakota.

A New Institution to Promote Resilience-Based Rangeland Management in Mongolia

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Rangelands are fundamental to Mongolian agriculture and society, occupying over 80% of the country's land area. Concern about rangeland degradation has been accelerating, however, associated with ever-increasing livestock numbers and the breakdown of traditional governance systems over the past two decades. Since 2008, the donor-backed organization Green Gold Mongolia has established a comprehensive resilience-based rangeland management strategy that integrates rangeland monitoring and evaluation based on Ecological Site Descriptions with rangeland management strategies. Management is implemented via multi-tiered community organizations known as "Pasture User's Groups" in which herder groups and local government design, implement, and monitor the effectiveness of grazing plans. Pasture User's Groups have been organized into higher levels of organization in order to advance training and marketing of livestock products based on environmental quality and animal health. The National Federation of Pasture User's Groups (NFPUG) was recently established to sustain linkages among production, marketing, monitoring, science, and management in Mongolia's rangelands. The NFPUG coordinates with government agencies and international donors, including in the production of periodic national reports on rangeland health and new technologies to advance environment-based certification and tracking of livestock products. The NFPU presents a locally-tailored and innovative solution to rangeland management in Mongolia that could be extended well beyond its borders.

A Policy Analysis of Outcome-Based Approaches to Managing Idaho's Rangelands

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Policy approaches to rangeland management challenges may be most effective if they seek to utilize a full suite of management options, including promoting the social and economic wellbeing of working ranches. One avenue for this may be through administration of grazing permits livestock producers depend upon for annual forage. Permits include terms and conditions such as when and how intensively permittees may graze livestock; these terms and conditions typically do not allow for much flexibility in responding to annual variability or unexpected events (e.g., wildfire). There has been growing interest in outcome-based approaches for rangelands, piloted through Outcome-Based Grazing Authorizations by the Bureau of Land Management (BLM), which seek to address this need for adaptability while also remaining within the boundaries of existing federal administrative rules. Through interviews with permittees and agency staff in three BLM Districts in Idaho in addition to content analysis of grazing regulations, we explored policy barriers to implementing outcome-based approaches and identified conditions that aid BLM staff and permittees in navigating these barriers. Although our preliminary results found general support for outcome-based approaches, there was disagreement within and among permittees and agency staff regarding tools for building adaptive permits and corresponding mechanisms for accountability. We also found outcome-based approaches were not uniformly engaged among BLM Field Offices; Field Offices and permittees with histories of collaboration and experience in undertaking permittee requests for innovation were more inclined to explore outcome-based approaches. As a result, questions remain about how outcome-based approaches may be broadly used to address rangeland management challenges occupying multiple jurisdictions.

A Review of Theories and Methods to Advance Rangeland Social Science

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Rangeland social science has greatly advanced our understanding of manager motivations, innovation adoption and conservation decision-making. And, this information has helped enhance decision-making, collaborative efforts, and outreach to better connect science and management and enhance rangeland stewardship. However, rapid social and ecological change on global rangelands amplify the challenges to achieving rural economic well-being, biodiversity conservation, and rangeland sustainability, creating a need for science that is inclusive of diverse theories and methods. At this time of global change, researchers and managers recognize all forms of knowledge are required to solve complex social-ecological problems. Therefore, social scientists will need a more complete toolbox of theories and methods to better understand social relationships across scales and to test assumptions about social-ecological systems. An array of innovative ideas is being developed in the humanities, geography, gender studies, and post-colonial literature to predict, understand, transform and deconstruct social events, structures and outcomes. Many of these have been used to advance conservation, international agriculture and development research, but they are under-utilized in range social science, perhaps because they have been perceived as inaccessible and full of jargon. In this review, we identify key theoretical concepts and methodologies from the critical social sciences and compare them in an accessible manner. We provide clear definitions, foundational citations, and demonstrative examples of how these ideas can advance our understanding of social-ecological dynamics in rangeland systems.

A Tool for Projecting Rangeland Vegetation Response to Management and Climate

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There are a number of complex problems facing rangeland managers attempting to promote sustainable use of Southwestern semi-arid ecosystems. These challenges include invasions by exotic species, expansion of woody vegetation, altered fire regimes, and drought. Compounding these issues is added uncertainty about how these problems will respond to a changing climate. Despite these problems and uncertainties, land managers and producers must make decisions today that will likely have an impact on landscapes decades into the future. Therefore, tools are needed that allow us to visualize possible future outcomes of today's actions. Conceptual state-and-transition models (STMs), are one tool that allows managers to describe possible vegetation communities that can occur on a particular ecological site, and identify drivers of change that can shift vegetation composition and productivity. However, STMs are limited in their use for making quantitative projections of what a future landscape might look like under different what-if scenarios. In addition, when using STMs it is difficult to account for interactions that can occur between various transitions, stressors and pathways noted in the model. This issue becomes even more pronounced when considering future climate patterns that may occur in an area. One tool that helps make sense of these complicated factors acting simultaneously are State-and-Transition Simulation Models (STSMs) which extend conceptual STMs by quantifying rates at which transitions occur under different circumstances. The main point of this study was to test use of this framework to help understand impacts of climate and management regimes on vegetation composition and annual production. We demonstrated how STSMs can be used in concert with the Rangeland Production Monitoring Service (RPMS: https://www.fs.fed.us/rmrs/projects/development-rangeland-production-monitoring-service-could-improve-rangeland-management) as a tool to make projections of landscape change under different climate and grazing scenarios for the New Mexico Rocky Mountain Region.

Aboveground Biomass Estimation from Unmanned Aerial Vehicles in Rangelands

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The application of Unmanned Aerial Vehicles (UAVs) in the monitoring and management of rangelands has exponentially increased in recent years due to the miniaturization of sensors, pictures with high spatial resolution, lower altitude platforms, and the ease of flying UAVs in remote environments. UAVs could be used to provide a more exact estimate of the vegetation biomass that can be incorporated into management decisions. The methods of field data collection widely used for decades to estimate aboveground biomass do not account for the real-life variability that commonly occurs in rangelands. The aim of this research is to estimate vegetation biomass in rangelands using high-resolution imagery derived from the UAV. The specific objectives are to (1) evaluate the feasibility of quantifying biomass in semi-arid rangelands with high-resolution imagery and (2) determine altitude for optimal pixel resolution of UAV imagery. Imagery at very high (<5 cm) resolution will be acquired by flying a UAV at altitudes of 30, 40, and 50 meters above ground level at a site located in Duval County, Texas. The imagery will produce 3D models of the study site to estimate volumes of vegetation. Biomass data collected in the field is used to calibrate and assess accuracy of the 3D biomass production model derived from exceptionally high resolution imagery at each level of altitude.

Accelerating Growth of Ocelot Thornscrub Habitat

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Loss of habitat is a major issue contributing to the declining number of ocelots (*Leopardus pardalis*) in the Lower Rio Grande Valley (LRGV). Ocelots within this region are limited to two breeding populations, located in Willacy and Cameron Counties, with large areas of land used for urban and agricultural development separating them. The objectives of this project are to test various management techniques on both 1) newly-planted and 2) established thornscrub plants to identify which treatments are most successful in growing high-quality thornscrub habitat for ocelots as quickly as possible. The first phase of the project has already begun; it involves applying treatments to naturally growing thornscrub saplings and recording their effects on growth and plant shape over time. Treatments will simulate mechanical disturbance on individual plants of three species by either 1) clipping plants, 2) mulching plants, or 3) both clipping and mulch. Exclosures will also be placed around several plants in each species and treatment combination to determine the impact browsers have on growth and development. In the second phase we will plant seedlings of seven species that are important components of ocelot habitat. These seedlings will receive the clipping, mulching, or combination of treatments at the time of planting. Results from both phases will allow us to determine effective treatments for enhancing the growth and multi-stemmed habit of young thornscrub plants. It will also help determine when treatments should occur — at the time of planting or a few years later. Results will be used to develop protocols for future ocelot habitat restoration efforts.

Accumulated Heat Units and Perspective of Maize Billbug Population Distribution in Eastern Gamagrass

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Maize billbugs (*Sphenophorus maidis* Chittenden) are considered serious pests of eastern gamagrass (*Tripsacum dactyloides* (L.) L.). Usually, prediction of insect phenological events based on calendar dates is considered to have weaker predictive values. Therefore, we examined the incidence of *S. maidis* in a six-year-old eastern gamagrass establishment and the influence of a specific number of heat units or cumulative growing degree-days (cGDD) on the phenological stages of the pest for two years. Larval, pupal, and adult life stages of the billbug were explored. Adult population was more abundant and evenly distributed throughout the season compared to larvae and pupae. Based on growing degree-days, the 99% quantile for larvae, pupae, and adult maize billbugs was estimated between 1967.8–4234.6 cGDD. Very few pupae were recovered from field sampling, which we relate to short pupation period and weekly sampling interval in our study. However, to gain accurate insight and develop an accurate warning application, location specific, degree-day models need to be developed for predicting seasonal trends of various life stages on the pest. Findings of this study are helpful to facilitate sustainable maize billbug management strategies.

Accuracy of Ground-Surface Elevation Models and Plant Biomass Estimates from UAS Imagery in Two Rangeland Plant Community Types

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Vegetation biomass is an important indicator for monitoring rangeland health and managing land uses such as grazing. However, reliable, quantitative measures of rangeland biomass are challenging and time consuming. The advent of low-cost, autonomous unmanned aerial systems (UAS) with imaging sensors, and subsequent adoption for low-altitude, on-demand image acquisition, have created unparalleled opportunities for high-resolution remote sensing to measure vegetation and site properties. Three-dimensional point clouds from digital photogrammetric techniques have been used to measure plant height and biomass. However, unlike active remote sensing techniques (e.g., LiDAR), image-based photogrammetry techniques suffer in their ability to estimate ground surface elevations when the ground cannot be readily seen from the images. The effect of this limitation on estimating ground surface elevation, and subsequently plant biomass, however, has not been well demonstrated in different plant community types. Our objective was to determine the accuracy of ground surface elevation and plant biomass measurements from UAS-acquired digital aerial photographs in two different plant community types in Idaho. Within two 50x50m plots in each plant community, a Phantom 4 Professional UAS was used to collect overlapping aerial images prior to and following clipping of vegetation within 0.25 m^2 to 1.0 m^2 subplots. Pre- and post-clipping point clouds were constructed using structure-from-motion. Ground surface elevation and plant biomass per subplot were estimated from the pre-clipping point cloud and compared to either post-clipping ground surface elevation or dry-weight of actual plant biomass. As expected, ground surface elevation and plant biomass estimates were most accurate in situations where plant canopy was open and some ground surface was visible. However, it may be possible to model the height of plant canopies in more closed systems. This approach demonstrates the potential for UAS and photogrammetric methods to improve the reliability and efficiency of biomass sampling for rangeland monitoring and management.

Across Scales, Pronghorn Select Sagebrush and Avoid Fences, and Avoid Anthropogenic Features in Winter

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Pronghorn (*Antilocapra americana*) are endemic to western North America where they occupy expanses of grassland and sagebrush (*Artemisia* spp.) habitats. The Red Desert region in south-central Wyoming, USA has historically served as a stronghold for pronghorn populations, but many herds there have experienced declining population trends over the last two decades, concurrent with oil and natural gas development. These demographic changes and the potential for such energy development, its associated infrastructure, and other anthropogenic features including roads and fences to influence pronghorn habitat selection were the impetuses for our study. We sought to evaluate the potential effect of human-induced disturbance on multi-scale seasonal resource use of 142 adult female pronghorn from 2013-2016 using 442 unique animal-season-year datasets. We utilized a traditional resource selection function to evaluate seasonal home-range selection and a step-selection function to assess fine-scale, patch-level seasonal selection. We also compared resource use during daytime and nighttime hours with step-selection analyses. Across all seasons at the seasonal home-range scale, pronghorn selected for areas with more sagebrush and areas farther from fences. This trend was also apparent at the patch-scale level, where pronghorn selected sagebrush-dominant habitats and avoided crossing fences in all seasons during both day and night. Additionally, pronghorn selected areas farther from fences during daytime in summer. At the broader, home-range scale, pronghorn selected areas with greater road density during summer, but selected areas with lower road densities during winter. Avoidance of anthropogenic features was also observed at the finer, patch-scale during, with pronghorn selecting for increased density of roads and oil and natural gas wells during daytime in summer, but selecting areas farther from these features during daytime in winter. We recommend minimizing fencing and other forms of anthropogenic disturbance in high quality seasonal pronghorn habitats with high proportions of sagebrush, particularly during winter when risk-avoidance responses may be amplified.

Activated Carbon Pods and Pre-Emergent Herbicide: A New Option for Annual Grass-Invaded Ecosystems?

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Reestablishing native perennial vegetation in annual grass-invaded rangelands is critical to restore ecosystem services. Control of invasives, often achieved with pre-emergent herbicides, is essential for successful restoration of invaded rangelands. Unfortunately, species cannot be seeded simultaneously with pre-emergent herbicide application due to non-target damage. To avoid this, seeding is commonly delayed at least one year. Delaying seeding increases the likelihood that annual grasses will begin reestablishing and will compete with seeded species. Activated carbon (AC) can provide pre-emergent herbicide protection for seeded species because it adsorbs and deactivates herbicides. Previous studies suggest that a cylindrical pod (8 x 15 mm) containing AC and seeds, herbicide protection pods (HPPs), allows desired species to be seeded simultaneously with the application of the pre-emergent herbicide imazapic. Unfortunately, imazapic is only effective at controlling annual grasses for 1-2 years. Indaziflam is a new pre-emergent herbicide which exhibits longer soil activity, with which HPPs may be useful. To assess this possibility, we evaluated seeding two native species (Wyoming big sagebrush (*Artemisia tridentata* Nutt ssp. wyomingensis) and bluebunch wheatgrass (*Pseudoroegneria spicata* (Pursh) Á. Löve)), both incorporated into HPPs and as bare seed, at four application rates of indaziflam. HPPs protected seeded species at low, mid, and high rates of indaziflam. The abundance and size of plants was greater in HPPs compared to bare seed treatments. These results suggest that HPPs can be used to seed native grasses and shrubs simultaneously with indaziflam application.

Adaptive Rangeland Management Through a Better Understanding of Plant Responses to Drought: Scaling Ecophysiological Responses to Sustain Future Landscapes

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Although the plants that dominate dryland ecosystems have adapted to grow under severe moisture limitations, these ecosystems are still the most vulnerable to drought events. The sensitivity of many ecosystem functions have been documented, such as reductions in productivity, losses of key native plant species creating shifts in plant communities, and reductions in ecosystem services upon which society relies. Although these ecosystem functions are typically measured at plot to landscape scales, the mechanisms driving the sensitivity of dryland ecosystems to drought often occur at the plant level. Plant physiological ecology studies that quantify these responses to drought have always been vital in predicting ecosystem responses to drought, scaling drought responses to landscapes, and informing management decisions that attempt to sustain the important ecosystem services that rangelands provide. We propose to host a half-day symposium that will present current results on the physiological responses of plants to both manipulated and natural drought events and describe how these studies are helping make important management decisions in rangeland ecosystems. The goals of this symposium are to: 1) Highlight the key role that plant ecophysiology plays in landscape-scale management processes, 2) Provide examples of how this data is being successfully integrated into management planning, and 3) Encourage collaboration between ecophysiologists and those using the data for forecasting and/or scaling ecosystem processes. We plan to invite researchers that span the breadth of drought research by progressing from microanatomical research, to leaf-level and ecosystem function, and then finally to landscape-level responses to drought. Each topic area will have two or three speakers with 15-minute time slots. At the end of the symposium we will lead a 30-minute panel discussion to outline key research questions that need to be answered in order to continue improving rangeland management through understanding ecophysiological processes in plants.

Advanced UAS Operations: What's In Store for Range Management

Michael Komp, Noble Research Institute, Ardmore, Oklahoma

In the past five years, we have seen the rapid advancement of drones and associated technology. With this advancement, there have been numerous programs to test these new technologies and demonstrate their utility across many industries. The Noble Research Institute in Ardmore, OK has been a strong advocate for understanding how drone technology can be advanced safely and in a manner with utility for farmers and ranchers. This presentation will walk you through some of the new technology in the drone industry and some of the legal barriers and challenges to using these devices for agricultural purposes.

Advancing Diversity in SRM Sections

Amy Ganguli, NMSU, Las Cruces, New Mexico
Joel Brown, USDA NRCS, Las Cruces, New Mexico

The SRM BoD has identified a need to make our Society a more inclusive place. As with most other activities, the BoD may make a decision to move in a new direction, but accomplishing our goals ultimately depends on the work that individual members and sections do. In this workshop, representatives of individual sections will discuss their efforts to improve inclusion as a means of attracting new and retaining existing members. The individual section presentations will be followed by an informal, facilitated discussion of current challenges and approaches to increasing diversity at the section level.

AIM and Shoot: Delivering and Sharing Range Data Quickly

Colin Dovichin, BLM, Billings, Montana
Jennifer Walker, BLM, Belle Fourche, South Dakota

Good data collection and management practices are paramount to data accuracy and utility. Historically, the BLM and its partners have collected rangeland vegetation data across the West with varying needs, interests, and timelines for those data. While data collection was common, the utility of that data was marginal due to long processing times, inconsistent data collection methodology and poor data management. The creation of the Assessment, Inventory, and Monitoring (AIM) program addressed the consistency issues with data collection methodology, however timely delivery, sharing and analysis of those data are still problematic. The continued development of management tools like the Rangeland Analysis Platform (RAP), which are reliant on these data, has made the implementation of consistent and timely collection methods a necessity. Unfortunately, most data collection systems currently in use are simply unable to efficiently provide data to the management tools on which we depend. We used Survey123 and Collector to create a rangeland vegetation data collection and delivery system capable of meeting the data needs of today. Our application is user-friendly, enabling data collected by multiple groups over large geographic areas to be summarized and shared quickly. We believe the use of this methodology will help large partnerships better coordinate and communicate the collection and use of data in a way that meets evolving needs.

Allometric Measurements of Honey and Western Mesquite Foliage

Douglas Tolleson, Texas A&M University, Sonora, Texas
April Labrecque, Texas A&M UNiversity, Sonora, Texas
Megan Finley, Texas A&M University, Sonora, Texas

Two mesquite species commonly found in the southwestern U.S. are honey (*Prosopis glandulosa*; PRGL) and western (*Prosopis glandulosa* var. *torreyana*; PRGLT). Although sometimes sympatric, both are typically identifiable in the field due to overall morphology, leaf, and bark characteristics. However, these species will hybridize. Knowledge of potential hybridization could inform management. Examination of field and herbarium specimens revealed a significant level of plasticity in foliage characteristics between PRGL and PRGLT. We collected allometric measurements in an attempt to develop an index that might better inform treatment plans. In three different geographic regions of Texas (Trans-Pecos, TP; Edwards Plateau, EP; Rio Grande Plains, RGP), three different ranch/resource management area sites on a north-south transect separated by at least 40 km were sampled. At each site, three different trees of either PRGL, PRGLT, or both were selected. On each tree, three different sample measurements of petiole and leaflet length (cm) were obtained. Differences between species, region, and site were determined by analysis of variance procedures. Petiole ($P<0.07$) and leaflet ($P>0.1$) length for PRGL were 5.11 ± 0.34 and 3.42 ± 0.61; $5.00 \pm 0.31$and 3.01 ± 0.07; 4.24 ± 0.34 and 2.44 ± 0.07 for EP, RGP, and TP respectively. In the TP, petiole ($P=0.1$) and leaflet ($P>0.1$) length for PRGLT were 1.00 ± 0.06 and 0.95 ± 0.03; 1.11 ± 0.13 and 1.03 ± 0.03; 0.85 ± 0.04 and 1.30 ± 0.52 for site 1, 2, and 3 respectively. At one TP site, petiole ($P<0.01$) length was 4.24 ± 0.34 and 0.85 ± 0.04 and leaflet ($P<0.03$) length was 2.44 ± 0.07 and 1.30 ± 0.52 for PRGL and PRGLT respectively. Foliage of PRGL and PRGLT differed as expected; these measurements need to be evaluated in different treatment regimes.

Alternatives to Improve Grazing Distribution, Supplement Placement and Herding

Mitchell Stephenson, University of Nebraska - Lincoln, Scottsbluff, Nebraska
Derek Bailey, New Mexico State University, Las Cruces, New Mexico
Larry Howery, The University of Arizona, Tucson, Arizona
Retta Bruegger, Colorado State University, Grand Junction, Colorado

Success of grazing management is influenced by the ability of a livestock manager to focus grazing livestock on underutilized areas and reduce over use on other areas. Research using low-stress herding and strategic supplement placement has indicated that these management practices are effective in focusing cattle grazing on underutilized areas of large pastures and reducing grazing pressure on riparian areas. Low stress herding in Montana decreased time spent by cattle in riparian zones and increased forage stubble heights near streams. Combining strategic supplement placement and low-stress herding improved our ability to focus grazing. In Arizona and New Mexico, time spent near supplement was related to intake of supplement and, not surprisingly, higher levels of standing crop of grass near target areas increased cattle use. No relationship was observed between time spent near supplement and the slope and distance to water of placement sites, which suggests that supplement placement combined with herding can be effective in rugged terrain in areas located far (>2 km) from water. In Nevada, strategic movement of supplement placement effectively increased cattle use on dormant cheatgrass along a defined line extending over 4 km from water. Although supplement can be expensive, economic analyses showed that increased grazing from strategic supplement placement could pay for the cost of the supplement and associated labor. However, analyses did not suggest that the improved grazing distribution was sufficient to pay for labor costs associated with herding. However, the study upon which the economic analyses was based expected that labor costs could be reduced perhaps sufficiently to recover labor costs. Strategic supplement placement and low stress herding are powerful tools that can be used to manipulate where cattle graze.

An Assessment of Neonicotinoid Exposure on USFWS High Diversity Grasslands in the Prairie Pothole Region

Kyle Kelsey, U. S. Fish and Wildlife Service, Madison, South Dakota
Jonathan Lundgren, Ecdysis Foundation, Blue Dasher Farm, Estelline, South Dakota

In the Prairie Pothole Region, USFWS grassland reconstruction efforts are focused on converting old crop fields to high quality habitat for waterfowl and other trust species, especially pollinators. These high diversity grasslands contain 30+ species of native grasses and forbs. However, landscape scale agricultural practices may have an impact on the function of these grasslands as it relates to pollinators. Neonicotinoids are a class of neuro-active insecticides developed in the 1990s because of widespread pest resistance and environmental objections to organophosphorus insecticides. Neonicotinoids are now the most widely used class of insecticides world-wide. Limited data exists concerning the uptake of neonicotinoids on non-target plants. Recent efforts in eastern South Dakota determined that just over one-third of milkweed (*Asclepias syriaca*) plants located in roadside ditches near corn fields were contaminated with clothianidin just after planting. Almost twice as many milkweed plants were contaminated and the mean content per plant was approximately 50% greater in late July when monarch (*Danaus plexippus*) populations were most abundant. Currently, we are assessing the persistence of neonicotinoids once absorbed by plants and accumulation in plant tissue in the high diversity grassland reconstructions. This information will guide where future reconstructions occur and what species are used.

Analysis of Plant-Soil Microbiomes Surrounding Native and Non-Native Grasses Across a Precipitation Gradient in Kansas

Scout Harrison, Fort Hays State University, Hays, Kansas
Mitchell Greer, Fort Hays State University, Hays, Kansas

Old World Bluestem (OWB, *Bothriochloa* spp.) is a general term for a group of non-native, warm season, perennial bunchgrasses. These problematic grasses were originally introduced to increase forage for livestock and reduce soil erosion, but are now causing problems for our native rangelands as they outcompete native grasses and create monocultures. Within grasslands, there are a wealth of important microorganisms that have an impact on the plant communities they surround. From arbuscular mycorrhizal fungi (AMF) to nitrogen-fixing bacteria, parasitic “cheater” mycorrhizae, to disease causing bacteria, soil microorganisms have a strong effect on the fitness potential of plants. Our study analyzes non-animal soil microbial community differences (i.e., species richness and community composition) between native and non-native grasses and across the precipitation gradient in Kansas. We collected 195 soil cores from the two invasive bluestem species yellow bluestem (*Bothriochloa ischaemum*) and Caucasian bluestem (*Bothriochloa bladhii*), and two native species little bluestem (*Schizachyrium scoparium*), and big bluestem (*Andropogon gerardii*) at four different sites across Kansas. Soil DNA and RNA will be extracted using Macherey-Nagel Soil DNA Extraction Kit protocol and sequenced. Bray-Curtis dissimilarity will be used to contrast variations in the richness and/or community structure between the grass species and/or across the precipitation gradient. We expect to see lower species richness from soil samples surrounding OWBs than native grasses, and moving east to west across the precipitation gradient. Determining if differences in the microbiome exist between these native and non-native grasses will improve the effectiveness of eradication and restoration efforts.

Analytical Approaches to Studying Resource Selection and Movement Patterns of Free-ranging Herbivores

Ryan Nielson, Eagle Environmental, Fort Collins, Colorado
David Augustine, USDA-ARS, Fort Collins, Colorado
Patrick Clark, USDA-ARS, Boise, Idaho

There are many ways to model movement and resource selection/habitat use by animals. Understandably, there are pros and cons to every approach. We will identify the most important considerations for analysis of any animal movement data, provide recommendations for analyses that we have found to be the most helpful (both in terms of application and interpretation), and demonstrate our favorite approach with an example. Ryan, David, and Pat have a combined sum of over forty publications related to animal movement and resource selection. Some example analyses, along with data, will be available upon request after the presentation.

Application of Non-invasive Remotely-Sensed Methods to Predict Forage Quantity and Diet Quality for Grazing Cattle

Douglas Tolleson, Texas A&M University, Sonora, Texas
Ann Zhang, Texas A&M UNiversity, College Station, Texas
Jay Angerer, Texas A&M University, Temple, Texas
Richard Conner, Texas A&M University, College Station, Texas
Urs Kreuter, Texas A&M University, College Station, Texas
Jason Sawyer, Texas A&M UNiversity, College Station, Texas

Prediction of plant crude protein (CP) from growing degree day (GDD) has been reported for native range grasses. Our objective was to apply GDD in conjunction with biophysical models to predict the nutritional environment and weight change of grazing cattle. PHYGROW (Phytomass Growth Simulator) employs remotely-sensed weather and ground-truthed ecosystem site characteristics to predict above ground plant biomass as well as herbivore intake. NUTBAL (Nutritional Balance Analyzer) is a grazing animal nutritional decision support software designed to work with fecal near infrared spectroscopy (FNIRS) derived estimates of CP. We conducted grazing trials with three growing Angus steers (227 ± 16 kg) in fall and three growing Angus heifers (196 ± 10 kg) in summer on a 2.7 ha Post Oak Savanna pasture in central Texas. Forage samples were clipped to determine dry matter standing crop. Water and minerals were provided *ad libitum* but there was no supplemental feeding. FNIRS predictions of CP were obtained weekly. Individual animal weights were obtained every two weeks. The following comparisons were accomplished via simple linear regression: clipped (1609.9 ± 632.2) versus PHYGROW (1513.3 ± 622.5) standing crop (kg/ha; r^2=0.98, SE=229, P<0.01); FNIRS (8.15 ± 0.48) versus GDD (8.22 ± 0.44) CP (%; r^2=0.92, SE=0.64, P<0.01); observed (0.59 ± 0.07) versus FNIRS/NUTBAL (0.56 ± 0.06) ADG (kg/d; r^2=0.89, SE=0.19, P<0.01); observed (0.59 ± 0.07) versus GDD/NUTBAL (0.61 ± 0.06) ADG (kg/d; r^2=0.88, SE=0.22, P<0.01); FNIRS/NUTBAL (0.56 ± 0.06) versus GDD/NUTBAL (0.61 ± 0.06) ADG (kg/d; r^2=0.84, SE=0.26, P<0.01). Application of GDD and FNIRS in concert with these models to determine forage quantity and diet quality accurately predicted grazing animal performance under the conditions of the study.

Application of the Growing Degree Day Technique to Assess Grazing Cattle Diet Quality

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Jay Angerer, Texas A&M University, Temple, Texas
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The daily nutritional balance of free-ranging cattle is the net result of intake from available forage biomass and nutritive value weighed against the nutritional requirements of the animal. A number of methods can be applied to obtain information on the nutritional status of pastured cattle. These include visual assessment of body condition, chemical analysis of clipped or hand-plucked plant tissue, or similar analysis of fecal material. These assessments can be labor and/or cost prohibitive. Conversely, remote sensing techniques, once calibrated for the specific application, can be automated and accessed from the internet. For instance, plant "greenness", an aggregation of biomass and phenology, can be remotely sensed. Plant phenology influences nutritive value. Plant phenology is dictated by time of year and an accumulation of photosynthetically active days. Growing degree day (GDD) is a concept that quantifies this relationship and has been used to predict nutritive value in perennial range grasses. GDD (acquired remotely and automated) could be substituted for chemical analysis to inform grazing animal nutritional monitoring efforts. We hypothesized that in predominately C4 grass rangelands of the southwestern US; GDD calculations would provide similar forage crude protein (CP) predictions to those obtained by fecal near infrared spectroscopy (FNIRS), and could be used to predict grazing cattle performance at the herd or pasture scale. Therefore, the objective of our research was to determine the relationship between GDD-derived and FNIRS-derived predictions of dietary CP in grazing cattle. Fecal samples were collected from free-ranging cattle on seven commercial ranches in MLRA 42. Comparisons of FNIRS-derived CP to GDD were accomplished via regression techniques. Relationships between GDD and FNIRS CP were quadratic ($P<0.05$), ranging in RSQ from 0.52 to 0.99 (0.80 ± 0.07). GDD can be used to remotely sense forage CP in free-ranging cattle under the conditions of this study.

Applying Native Prairie Lessons to Prairie Reconstructions

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Jill Gannon, U.S. Fish and Wildlife Service, Fort Collins, Colorado
Clint Moore, U.S. Geological Survey, Athens, Georgia
Terry Shaffer, U.S. Geological Survey, Jamestown, North Dakota

The loss and degradation of North America's grasslands present a formidable challenge to managers attempting to conserve this ecosystem. Reconstructing prairie in cropland dominated areas of the Northern Great Plains provides opportunities to remediate some of the grassland losses. Land managers striving to reconstruct prairies that provide a diversity of native plants over the long-term are often hindered by non-native plant invasion. Current restoration efforts on native (remnant) prairies of the North Great Plains provide insights into improving reconstruction outcomes. The primary threat to reconstruction success is invasion by cool-season introduced grasses including smooth brome (*Bromus inermis*) and Kentucky bluegrass (*Poa pratensis*). A central restoration effort on U.S. Fish and Wildlife Service native prairies is the Native Prairie Adaptive Management program (NPAM), which provides a decision tool that focuses on increasing native plants on prairies invaded with cool-season introduced grasses. Experiences with designing and implementing NPAM evidence that smooth brome and Kentucky bluegrass are prominent and persistent invaders; therefore, reconstruction objectives should include provisions for invasion of these species. Planning for defoliation treatments is an important factor in achieving desirable reconstruction outcomes. The annual decision policy produced through the NPAM program provides recommendations for burning, grazing, or resting based on the current plant composition and defoliation history. This information could be used to inform the frequency and types of defoliation treatments for prairie reconstructions. Certain NPAM recommendations target phenology windows for treatments using accumulated growing degree days, which could be used for reconstruction treatments where the objective is to reduce smooth brome and increase warm-season native plants. We have also learned that defoliation treatments involving fire produce higher gains in native plant cover when abiotic factors (i.e., prior-year precipitation and the ecological site) were considered compared to grazing and rest treatments.

Approaches to Analyzing Terrain Use by Livestock in Relation to Watering Locations

Derek Bailey, New Mexico State University, Las Cruces, New Mexico
Tatjana Mercado, New Mexico State University, Las Cruces, New Mexico

In rugged terrain, livestock have the opportunity to use steep or gentle slopes, high or low elevations and areas near and far from water. However, the selection of grazing locations are complicated because terrain use is multi-dimensional. For example, use of steep slopes is more demanding at areas far horizontally and vertically from water compared to areas near water. The goal of this presentation is to discuss alternatives to evaluate cattle terrain use on rugged rangelands using multi-dimensional metrics. One approach is to estimate expected (and unexpected) use at varying slopes and distances horizontally and vertically from water using published studies and reviews. Using polynomial regression, relationships of expected (and unexpected use) can be developed for terrain metrics. For example, it would be totally unexpected for cattle to use areas further than 3.2 km from water, while 50% of the time cattle may graze 1.6 km from water. Unexpected use of terrain from various metrics can be readily combined by averaging or summing. Another approach is to normalize terrain use metrics and then average them together into indices. This allows metrics with varying units (e.g., percent slope and meters from water to be combined). However, the proper weighting of each metric is unknown. Resource selection functions may be a tool that can be used to weight normalized terrain use metrics for development of indices. Terrain metrics that are more predictive of actual resource use could be weighted more than less predictive metrics.

Are Community Rules or Formal Tenure More Effective to Achieve Sustainable Grazing in Mongolia?

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María Fernández-Giménez, Colorado State University, Fort Collins, Colorado

Mongolia, like many pastoral systems, relies on common pool rangelands as the primary resource to support its expanding herds. Commons theory predicts that in the absence of rules to govern this resource a “tragedy of open access” may ensue, but that pastoralists, like other user groups, often develop and enforce rules to self-regulate grazing and avoid overexploitation. Secure rights to the shared resource are often assumed to be a precondition for successful commons governance. This assumption has been challenged for some pastoral systems, including Mongolia, where rules to coordinate timing of grazing and movement of herds are thought to sufficiently regulate use, without need for formal tenure rights to pastures. We draw on a database of 700 pastoral household surveys to evaluate the probability that a household will undertake key management practices (e.g., reserving seasonal pastures) as a function of the formality of their tenure over resources compared to the formality of rules on the timing of grazing influence. Prior research showed that reserving winter pastures was positively associated with desirable rangeland conditions. Here, we assess the hypothesis that rules are more strongly associated with use of grazing reserves than formal tenure. Contrary to our expectation, we find that reserving seasonal pastures is most significantly associated with informal customary rights to pastures and campsites, rather than the presence of formal rules, as well as participation in a formal community-based management group. However, there is some variation in the strength and direction of these relationships across ecological zones. In particular, informal rules have a stronger positive effect in the more arid and variable desert steppe. These spatial variations in the influence of informal rights and rules may have implications for current Parliamentary negotiations over the proposed rangeland law, or how it could be implemented across the different regions of Mongolia.

Assessing and Managing for Rangeland and Pasture Land Soil Health: Outcomes of a National Workshop

Kristie Maczko, Sustainable Rangelands Roundtable - University of Wyoming, Laramie, Wyoming
LaKisha Odom, Foundation for Food and Agriculture Research, Washington, District of Columbia
Chad Ellis, Noble Research Institute, Ardmore, Oklahoma
C. Wayne Honeycutt, Soil Health Institute, Morrisville, North Carolina
Sara Place, NCBA, Centennial, Colorado

Compared to other ecosystems, the soil health of grasslands and shrublands has received little attention in the scientific literature, despite the global expanse of these land types, covering nearly one quarter to one third of the world's habitable land area, their high levels of biodiversity, and the substantial economic and social benefits provided by rangeland ecosystems. However, there has been an increased interest from a wide variety of stakeholders, spanning livestock producers to policy makers, in rangeland and pasture land soil health recovery due to the critical role these lands play in our environment. To begin addressing this gap, a national workshop to determine extant research and information needs was convened by Foundation for Food and Agriculture Research, Sustainable Rangelands Roundtable, Noble Research Institute, Soil Health Institute, and National Cattlemen's Beef Association in November 2017. The workshop was structured implementing the concept of usable science, involving end-users – in this case ranchers – in the discussions, decision-making, and knowledge co-production. Information needs identified by producers included: better information about current conservation practices and expected effects; exploration of linkages between soil health and animal welfare; economic data linking soil health to ranch profit; economic viability of conservation practices by region; soil ecosystem activities through drought; and, enhanced strategies for producer engagement. Continued workshop discussions with producers, researchers, scientists, and agency staffs resulted in four priority areas for immediate efforts: (1) Soil health literacy, describing and defining rangeland and pastureland soil health in terms of indicators, as well as, a full census of below-ground communities; (2) Relationships among rangeland and pastureland soil health and rangeland/pasture production outputs, and whether these relationships are significantly affected by management; (3) Defining the relationship between soil health and rangeland/pasture restoration; (4) Research on rangeland/pastureland soil health and economics, including socio- ecological- economic interactions and integration.

Assessing Post-Fire Trajectories in Sagebrush-Steppe Ecosystems of the Western United States

Stephen Boyte, SGT, Inc at U.S. Geological Survey EROS Center, Sioux Falls, South Dakota
Bruce Wylie, U.S. Geological Survey, Sioux Falls, South Dakota
Donald Major, U.S. Bureau of Land Management, Boise, Idaho

The sagebrush ecosystem of the western United States is experiencing substantial invasion by annual grasses. This invasion leads to increased continuity of fine fuels and increased fire frequency and size. These fires contribute greatly to the loss of biodiversity, which compromises services that the ecosystem provides to both wildlife species and humans. The goal of the study is to compare post-fire trajectories of actual sagebrush and annual grass land covers to post-fire trajectories from the expected ecosystem performance (EEP) mapping models. When trajectories of actual annual grass percent cover decline and trajectories of actual sagebrush increase and align with the EEP mapping model outputs, this suggests sagebrush recovery. The EEP mapping models predict actual sagebrush growing season Normalized Difference Vegetation Index (GSN) and actual annual grass percent cover. To make these predictions, the EEP models integrate, into regression-tree software, temporally dynamic monthly and seasonal weather data. The EEP models also integrate temporally static site potential variables that measure the spatial variability of the two land covers. The EEP mapping model results for both land covers are strong: sagebrush training/test R^2=0.94/0.94 and mean absolute error (MAE) rates=1.7/1.7; annual grass training/test R^2=0.90/0.90 with MAE rates=5.7/5.8 percent cover. The outputs of the EEP models are compared to actual sagebrush GSN and actual annual grass percent cover land covers, with statistically significant differences classified as anomalies.

Assessing the Long-Term Water and Vegetation Response to Western Juniper Removal and Recovery

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Nicole Durfee, Oregon State University, Corvallis, Oregon
Tim Deboodt, OSU Extension (emeritus), Prineville, Oregon

For this study conducted in a 358 mm·year^{-1} precipitation site in central Oregon, we evaluated water and vegetation response to western juniper (*Juniperus occidentalis*) removal that occurred 13 years ago. Precipitation, interception, and soil moisture dynamics were evaluated at the 2000 m^2 plot scale and surface water and groundwater relations were characterized across the 500 ha study area that includes a control watershed, a treated (juniper removed) watershed, and a riparian valley where both watersheds drain into. Overstory-understory vegetation variables such as species frequency and canopy cover were measured in both the treated and untreated watersheds. Results show that juniper woodlands have the capacity to intercept up to 46% of total precipitation, altering soil moisture distribution under the canopy and in the interspace. Also, findings indicate that precipitation reaching the ground at the study site can rapidly percolate through the soil profile and into the shallow aquifer, and that strong hydrologic connections between surface and groundwater components exist during winter precipitation and snowmelt runoff seasons. Streamflow rates up to 1,020 L·min^{-1} and springflow rates peaking 190 L·m^{-1} were observed in the watershed where juniper was removed over a decade ago. Overall, greater herbage production and greater perennial grass and shrub cover have been observed in the treated watershed since juniper removal. Even though a significant number of juniper saplings were found in the treated watershed that is significantly lower than the number of mature and juvenile juniper trees observed in the untreated watershed. Results contribute to improved land management through the better understanding of the ecological and hydrological processes in western juniper ecosystems and the role that woody vegetation encroachment may have on altering the ecology and hydrology of the site.

Audubon's Conservation Ranching Program: How Markets Are Driving Landscape Scale Conservation in the Northern Great Plains

Marshall Johnson, Audubon Dakota, Fargo, North Dakota

Grassland birds have experienced some of the steepest, most consistent declines of any guild of bird in North America. Since the 1960s – when the Breeding Bird Survey began tracking North American bird population trends – grassland birds have declined by nearly 40%. The loss and degradation of native, intact grasslands throughout the northern Great Plains has played a major role in their decline. To address this threat, Audubon has initiated the first market-based conservation program, the Audubon Conservation Ranching (ACR) Program. With much of the remaining grassland in private ownership (85%) it has never been more important for conservation organizations to partner with the stewards of this imperiled landscape – ranchers. Audubon's approach is to create incentives for cattle ranchers to manage their grasslands for the benefit of grassland birds throughout the Central Flyway, from Canada to northern Mexico. The ACR program is the first scalable self-sustaining model for a linked network of producers and consumers of beef from bird-friendly certified ranches. In summer 2017, Audubon certified the first ACR ranches in the Dakotas, Colorado, and Missouri, and now has 45 participating ranches in 10 states, impacting over 600,000 acres of grasslands. To become certified, the enrolled ranch must meet ACR program protocols related to habitat management, forage and feeding, animal health and welfare, and environmental sustainability. For each ranch, an individualized habitat management plan (HMP) is developed in accordance to with ecoregion-specific program protocols to benefit target grassland birds species. Within the next three years, the ACR program is expected to enhance two million acres of grasslands throughout the central and western U.S.

Back to the Future: Management for Sustainable Great Plains Grasslands

Lora Perkins, South Dakota State University, Brookings, South Dakota
Marissa Ahlering, The Nature Conservancy, Moorhead, Minnesota
Diane Larson, U.S. Geological Survey, St. Paul, Minnesota

The grasslands of the northern Great Plains region of North America are considered endangered ecosystems and priority conservation areas. Because the challenges facing the region are dynamic and complex, its future will look very different from its past. These challenges include habitat loss and fragmentation, alteration of disturbance regimes, and the abundance and diversity of both invasive plants and anthropogenic chemicals on the landscape. The implications of these challenges (recovery debt, ecological traps, and extinction debt) are daunting and serious. Therefore, a paradigm shift is needed in how we approach management of the grasslands in the northern Great Plains. To move toward a sustainable future, we provide the following considerations for management of these grasslands including: moving beyond managing for historical fidelity; recognizing the importance of resilience and variability; increasing genetic diversity to allow grasslands to adapt to a changing environment; recognizing the advantages of adaptive management; and acknowledging the requirement of patience. Understanding the historic conditions that created the grasslands (such as fire, grazing, and climate) provides insight into ecosystem function but historical fidelity as a management target may be ill-informed and unlikely to be successful. A more valuable management target is to maintain and increase diversity and heterogeneity that supports ecosystem resilience. Management should also consider the genetic variability of native species. Genetic variability will allow species to adapt as we move into a more variable future. Finally, active adaptive management and patience are essential to stay focused on long-term success for sustainable management of northern Great Plains grasslands.

Beyond the Range Ecology Debate: Embracing the Human Component of Rangeland Systems

D. Layne Coppock, Utah State University, Logan, Utah

In the lead presentation for this symposium, Briske outlines recent controversy in the historical development of rangeland ecology, namely the debate concerning equilibrium versus nonequilibrium models. He also identifies emerging challenges for ranching, pastoralism, and ecosystem-service delivery. In the second talk, Fuhlendorf describes ecological lessons learned from the debate regarding spatial scale and functional heterogeneity. I will close by illustrating why a societal perspective must compliment ecological knowledge as we contemplate progress in future rangeland stewardship. In my broad interpretation, a fully nonequilibrium livestock production system is characterized by uncoupled plant-herbivore relationships, density-independent herbivore productivity dynamics, and a population of humans facing near-chaotic management circumstances. How managers can better cope with high risk and uncertainty under such conditions is the key intervention, exemplified by reliable access to key resources during crisis. While some nonequilibrium dynamics may be exacerbated by increasing drought or fire risk due to climate change, other factors are forcing systems in an opposite direction. Global drivers and institutions can constrain the adaptive management necessary to contend with growing systemic variability. This includes human population growth and critical land annexation in the developing world, as well as rigidity in public land grazing administration in the US. Local subsidization has been applied as a technological fix for these challenges. This can occur as water development, livestock disease control in the absence of offtake incentives, livestock supplementation, human food aid, livestock insurance schemes, or other relief programs. Adverse outcomes of subsidization can include increasing poverty for rangeland residents, resource degradation, or intensified, density-dependent livestock productivity dynamics. The socioeconomic and policy spheres thus make major contributions to the overall trajectory of rangeland systems, yet research attention on this has been minimal. One way forward is to accelerate widespread adoption of social-ecological systems approaches to meet evolving societal demands from rangeland ecosystems.

Big Data Assist Adaptive Management of Rangeland Land Treatment Planning

David Pilliod, U.S. Geological Survey, Boise, Idaho
Justin Welty, US Geological Survey, Boise, Idaho
Michelle Jeffries, US Geological Survey, Boise, Idaho

Resource managers for public lands plan and implement vegetation manipulations known as land treatments across a wide variety of ecological and climatological conditions. To aid in this planning process, the U.S. Geological Survey partnered with the Bureau of Land Management to create the Land Treatment Planning Tool. This geospatial, online tool is designed to help natural resource managers identify and access information about past treatments that are similar to their planned treatment. The tool taps into information on >45,000 land treatments that are stored in the Land Treatment Digital Library (LTDL). We demonstrate how users can upload or digitize planned treatment areas, extract biophysical attributes about the proposed treatment, and compare those attributes to historical treatments in the LTDL. The resulting information can be mapped, tabulated, and exported for inclusion in planning and reporting documentation.

Biodiversity Habitat Phone App – Which Animal and Plant Species Do Land Managers Want to Understand?

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Tegan May, The Nature Conservancy, Boulder, Colorado
Rachel Murph, USDA-NRCS, Denver, Colorado

By using the free, open source Land-Potential Knowledge System (LandPKS) mobile app, ranchers can rapidly identify soils, as well as inventory and monitor vegetation. LandPKS (http://landpotential.org) already provides essential information for ranchers to make management decisions, but the tool is not widely used in the United States. Also, the tool cannot yet assess biodiversity values that are essential for managing grazing lands for sustainability in highly variable and changing environments. Through an NRCS Conservation Innovation Grant, we will be designing and implementing a Biodiversity module for LandPKS. This poster shows what types of potential habitat information will be provided through the app and which species we are considering highlighting in the initial offering of the app. We are soliciting feedback on the suite of species, types of information being provided, and suggestions on other species to include.

Botanical Comparison of Mesic Grasslands in North America and Brazil: Implications of Fire Dependency and Rangeland Function?

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In North America, fire has long been recognized as an important driver of vegetation patterns, particularly in mesic grasslands. Consequently, fire has been successfully used as a conservation and restoration tool. In southern Brazil, grasslands appear to present many similarities to tallgrass prairie in terms of composition and ecology, but the role of fire has been poorly studied and it is not generally applied for conservation. We compared plant genera and family composition of North American tallgrass prairie and South Brazilian grassland sites. We found striking similarities in terms of dominant families, genera, and functional types. For example, in both regions, the families Poaceae, Cyperaceae, and Asteraceae combined contributed to greater than 75% of total vegetation cover. Common and dominant C4 graminoid genera in the South Brazilian Campos grasslands included *Andropogon*, *Schizachyrium*, and *Sorghastrum*, which were also dominant in the tallgrass prairie of North America. Proportions of plant functional groups (>60% graminoid in both locations) and grass photosynthetic pathways (>75% C4 grass and < 25% C3 grass in both locations) were comparable. The similarities between plant communities suggest similarities in ecological processes and should lead to a re-thinking of conservation strategies in South Brazilian grasslands. Research on the role of fire is needed, and comparative North–South studies on grasslands in the Americas likely will provide important insights for grassland ecology and management.

Bud Bank: A Novel Ecological and Managerial Approach to Improve Biomass Production

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Resiliency and sustainability of swards of switchgrass (*Panicum virgatum* L.) in response to systematic annual biomass harvest depend on annual plant regeneration from belowground buds. To better predict plant growth and persistence responses to annual biomass harvest, enhanced understanding of the timing of meristem activity and dormancy in bud banks is needed. Our primary objectives of this study were to determine if genetic variation among switchgrass cultivars and N addition affects bud regeneration, spring activity, tiller recruitment, and tiller mass. The experiment was a split-plot design with five switchgrass cultivars and two treatments. The two treatments were 112 kg N/ha vs. no fertilizer, with six replicates per treatment per cultivar. The cultivars were in 6 m x 6 m plots established in 2012, with the N fertilizer treatment on one half of each plot. The study was conducted over the growing season and samples were taken at the four to five leaf stage, boot stage, anthesis stage, and senescence after the first killing frost. Three tillers were taken from each replication and treatment at each stage to determine the number of proaxis nodes, buds, the number and types of re-growth tillers from buds (reproductive vs. vegetative), and tiller mass. The data were analyzed to evaluate bud bank characteristics, tiller recruitment, and tiller mass density among the genetic variation and in response to nitrogen addition treatment. This study provides a descriptive and quantitative framework to predict potential switchgrass biomass production from surrogate traits such as tiller density, the frequency of reproductive tiller, and tiller mass from the size and vigor of belowground bud bank populations.

Can Mowing Replace Fire in Semiarid Grassland?

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Land managers are increasingly aware of the benefits of a prescribed fire program, however, many are hesitant to incorporate a burning program into their current management plan. The nonselective removal of biomass and increased light availability are two characteristics of fire that may also be achieved with severe grazing or mowing. The objectives of this study were to 1) describe spring mowing and spring prescribed fire effects on plant and soil variables; and 2) determine if mowing is analogous to prescribed fire on rangeland. Treatments consisted of spring prescribed fire, spring mowing, and non-treated controls arranged in a completely randomized design with seven replications of each treatment on two ecological sites in southeastern Montana. Current-year biomass was similar across treatments (1000 ± 64 $kg \cdot ha^{-1}$), however, mowing shifted functional group composition, relative to non-treated and burned plots, by reducing C3 perennial grass and increasing forbs. Fire increased bare ground, decreased litter, and eliminated standing dead the first growing season post-fire. Mowing had a neutral effect on bare ground, increased litter cover, and reduced standing dead the first growing season post-mowing. Fire more than doubled plant available N and S and increased forage concentrations of N, P, K, S, Mn, and Cu, relative to control and mow treatments. Mowing and fire reduced forage ADF and NDF, with fire having greater effects. Additionally, TDN, IVNDFD, and IVDMD were increased by mowing with fire producing greater increases. Mowing and fire had neutral effects on current-year biomass, however, mowing resulted in slight shifts in functional group composition. In general, fire had nearly inverse effects on ground cover as well as greater positive effects on soil nutrient availability and forage quality. These results indicate mowing is not a suitable substitute for fire.

Can Native Plant Communities Be Restored in Great Basin Crested Wheatgrass Seedings?

Mike Pellant, BLM, Boise, Idaho

Introduced perennial bunchgrasses have been widely used by Great Basin managers to increase forage production, reduce threats from undesirable plants and to stabilize soils after a wildfire. This has resulted in millions of acres of seedings dominated by crested wheatgrass (*Agropyron cristatum*) and related introduced wheatgrasses. Managers now desire to convert some of these monoculture seedings to native species and are looking for strategies to accomplish this objective. The Bureau of Land Management's Great Basin Native Plant program initiated a multi-state program in 2005 to investigate treatments to reduce crested wheatgrass competition and establish native plant species. Treatments to reduce competition included various herbicide and disking combinations over a minimum two year period. Initial results in Utah and Oregon were not promising since the treatments to reduce crested wheatgrass competition did not result in a successful native plant seeding. Another project in northern Nevada included multiple year control treatments followed by a native plant seeding. Initially, native species establishment looked promising, however crested wheatgrass eventually suppressed the natives. In all three studies, invasive annual grasses increased to partially fill the void left by the reduction in crested wheatgrass. Another strategy for reestablishing the sagebrush component in crested wheatgrass seedings includes an herbicide application to reduce crested wheatgrass in small patches and planting sagebrush seedlings. It is evident that multiple types of treatments over multiple years will be required to adequately control crested wheatgrass and restore a diverse native plant community. Opportunistically using livestock grazing and timing treatments to correspond to drought conditions may also facilitate success. Unintended consequences (increase in other invasive or undesirable species) are a threat that must be considered in project planning, implementation and post-establishment management.

Case Studies on Building Rangeland Resilience to Climate Change in The Pacific Northwest

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Rangelands represent about 21.6 million acres in the Pacific Northwest. Cow-calf operations are the primary users of this grazing resource and will have to adapt to climate change effects on rangelands. However, management directed toward current rangeland stresses which may be amplified under a changing climate – including fire risk, invasive plants, and droughts – is beneficial under every future scenario. And although climate change discussions have become highly politicized, our experience suggests that Pacific Northwest ranchers support "no-regrets strategies" that provide ecological and economic benefits in addition to those relating to climate change. Our goal is to foster adoption of “no-regrets strategies” by sharing individual success stories. Successful ranchers are already experienced at considering economic, production, and weather risks in their decision making. They are well poised to identify and implement practices that increase resilience to climate change, while balancing the other risks they face. Forward-thinking ranchers can provide insights into their resilience management practices, enabling others to join them. Our multi-media case studies are designed to share those insights and encourage other ranchers to consider making changes to enhance the resilience of their operations. Each case study consists of a video highlighting an innovative rancher and their climate-resilient practices and a peer-reviewed written factsheet with descriptions of the rancher’s context and motivations; process of innovation; benefits, challenges and solutions to adopting practices. This narrative is paired with easy-to-digest sidebars providing key science findings relevant to the practices being discussed. By pairing these insights with key science findings we also give ranchers tools to adjust these practices to their particular operational context.

Cattle Grazing and Forb Production for White-tailed Deer Can Be Compatible

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Cattle (*Bos* spp.) grazing has been recommended as a tool used to improve wildlife habitat, but research that is available are not conclusive and sometimes contradictory. Forbs are an important part of a white-tailed deer (*Odocoileus virginianus*) diet and reduction of grass by cattle grazing can potentially confer a competitive advantage to forbs resulting in increased forb standing crop. Forb standing crop is also strongly influenced by rainfall and soil properties. Our objective was to determine the relationship between grass disappearance resulting from herbivory and forb standing crop on the East Foundation ranches. To evaluate cattle grazing effects on grass and forb composition, we selected six 2,500 ha study sites located on the East Foundation ranches in south Texas. Fifty 1.5-m^2 grazing exclosures were randomly placed in the six study sites. We sampled vegetation at the end of the autumn growing season within exclosures and in a paired plot outside the exclosures. We then stored the collected samples in a portable drying room trailer maintaining a temperature of 45° Celsius, which resulted in achieving a plant dry weight (kg). Forb standing crop was optimized (245-326 kg/ha) when grass disappearance was between 420 and 1,960 kg/ha, which correspond to 20-50% grass utilization by herbivores. This study provides the scientific basis to support the hypothesis that cattle grazing may be used to optimize forb production for wildlife in south Texas. Managers are now sufficiently able to determine a certain threshold of grazing levels in order to maintain increased white-tailed deer forb productions.

Challenges of Livestock Behavioral Research: Examples from Western US and East Africa

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A predictive understanding of livestock behavioral responses to environmental changes and management actions is crucial for promoting livestock productivity, enterprise profitability, and effective resource management planning and policy making. While GPS tracking holds some promise for providing that understanding, particularly where traditional techniques have fallen short, there are many conceptual and analytical challenges to be overcome. Some examples follow. Predicting livestock distribution responses to change or treatment using GPS position data is not straightforward but resource-selection function (RSF) models can be useful. Quantifying livestock activity budgets and energetic strategies is possible with intensive GPS sampling but this typically requires situation-specific validation. GPS-based observations potentially provide means for detecting behavioral events (e.g., wolf-cattle encounters) objectively with reduced bias compared to visual observation and other traditional approaches but a thorough understanding of animal behavior and event thresholds are needed up front thus creating a circular logic problem. Understanding resource selection and other behavioral responses in herded systems is challenging because animal and human decision-making are intertwined but continuous GPS monitoring may allow differentiation of animal- and human-dominated segments of the herding day. Use of modern technologies like GPS tracking have already advanced the science of livestock ethology yet, the potential of these technologies will not be fully tapped without careful pairing of technology with well-considered conceptual models and suitable analytics. Tapping this potential will, on the other hand, greatly aid our efforts to address global problems concerning the sustainability, productivity, and environmental impact of livestock agriculture involving millions of rural livelihoods.

Challenges of Old-World Bluestems

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The introduction of non-native plants into disturbed US grasslands has been prevalent since the early 1900's. In the southern US, warm-season grasses introduced from Africa and Eurasia were commonly selected for use as livestock forage and soil erosion control with several of these grasses the focus of extensive breeding research, and promoted by government programs. Unfortunately, many of these species subsequently escaped their intended boundaries and became invasive. Old World Bluestems (OWB), a group of non-native, invasive, warm-season grasses, (e.g., Caucasian (*Bothriochloa bladhii*), yellow (*Bothriochloa ischaemum*) and Kleberg's (*Dichanthium annulatum*) bluestems) have been extensively planted throughout the Central and Southern Great Plains for livestock forage production, perennial vegetation cover in the Conservation Reserve Program (CRP) and erosion control. Within the past 20 years, research on these species has shifted from an agricultural forage production focus to an invasion ecology focus. Invasive OWB have been found to reduce native plant and animal species diversity, as well as change soil microbial populations in a manner that inhibits colonization by native grasses, resulting in difficulty in restoring native communities following invasion. Not only have we found restoration challenges to be ecologically challenging, but also culturally challenging, as many producers still desire these species for their use. In our research program the focus for restoration efforts has been on determining the best management practice to eradicate OWB, which frequently has been met with limited success. We propose the challenges to grassland restoration projects in these systems might be overcome if focus were also placed on more mechanistic traits of the invaders: propagule pressure, extensive seed banks, competitiveness, allelopathic effects, and subsequent plant-soil feedbacks.

Characterising Large Wildfire Patterns in the Great Plains

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Although large wildfires were historically frequent across the Great Plains, the region has been largely considered to be at low risk for large wildfire over the last century. In recent decades, a surge in wildfire activity has highlighted the need to understand contemporary wildfire patterns across the region. We assessed patterns in large wildfires (>400ha) across land cover types and drought conditions in the Great Plains to identify where and when wildfires burned most frequently in recent decades. Over half (53%) of large wildfires burned during near normal moisture conditions (PDSI ranging from -1.9 to 1.9), however, this was disproportionately less than expected based on the proportion of months that experienced near normal moisture conditions in the Great Plains. In contrast, 38% of wildfires burned during drought conditions (PDSI<-2), which was more frequent than expected based on drought occurrence. Eighty-eight percent of the areas burned by large wildfires were composed of woody and grassland vegetation. Woody vegetation burned more than twice as frequently as expected based on the amount of woody cover in the Great Plains. In contrast, wildfires burned less frequently than expected in croplands, pastures/hay fields, and developed areas. Relationships between woody and grassland vegetation in the Great Plains indicate that wildfires burn disproportionately more when there is between <30% and >80 % woody vegetation cover relative to grassland cover on a landscape, suggesting continued woody encroachment into grasslands could lead to increased large wildfire risk. Unlike climate, woody vegetation can be managed at local and regional scales. Continued monitoring of the relationships between wildfire, drought, and land cover will be necessary for predicting large wildfire patterns in the future.

Characterization and Monitoring of Shrubland Components in the Western U.S. Back to 1984, Climate Drivers

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The USGS Earth Resources Observation and Science (EROS) Center National Land Cover Database team in collaboration with the Bureau of Land Management (BLM) has produced the most comprehensive remote sensing based quantification of western United States shrublands to date. Nine individual products have been developed that represent the primary shrubland components: percent shrub, percent sagebrush, percent big sagebrush, percent herbaceous, percent annual herbaceous, percent litter, percent bare ground, shrub height, and sagebrush height. This approach relies on three major steps: creating training datasets using field measurements and high-resolution satellite imagery at selected sites, extrapolating these training datasets to the landscape level using Landsat 8, and validating the final products with independent field measurements. Product creation was prioritized to focus on sagebrush ecosystems, with nominal date products from 2013-2017 now available for download. For sagebrush ecosystems, research has shown these products enable more successful monitoring of gradual change and are now being used to support historical quantification of changing trends across shrubland ecosystems. Methodologies have been developed to use this data to quantify these landscapes historically across time using the Landsat archive. Products provide the quantification of component change from 1984-2016 and are being used to not only understand where and when change is happening, but to assess what is causing that change. Product methodologies will be overviewed, and case study examples of applications in vegetation monitoring, sage grouse habitat analysis, climate change effects, restoration monitoring and grazing assessment provided. Overall products will provide unprecedented new opportunity to inform science and management across the West.

Classifying Livestock Grazing Behavior With the Use of a Low Cost GPS and Accelerometer

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Patricia Johnson, South Dakota State University, Rapid City, South Dakota
Kenneth Olson, South Dakota State University, Rapid City, South Dakota

The ability to remotely track livestock through the use of GPS technology has tremendous potential in the study of livestock use patterns on the landscape. High frequency accelerometers may give researchers and managers the ability to accurately partition GPS points into differing behaviors, giving further insight into livestock grazing selection, pasture use, and changes in forage preference through time. A study was conducted in 2016-2018 at the Cottonwood Research Station in southwest South Dakota to test the effectiveness of predicting livestock behavior through the use of low-cost GPS collars outfitted with a high frequency 3-axis accelerometer to determine head position. GPS devices were set to record a fix at one-minute intervals. Accelerometers were programmed to record X, Y, and Z position at 12 Hz (12 records per second). The accelerometer data were aggregated to one-second intervals initially, and mean, minimum, maximum, and standard deviation of X, Y, and Z axes were calculated between the start and stop time of each GPS fix. Further data were extracted from the GPS device to include identification of rate of travel, change in turn path metrics, and stationary points to aid in classification. Direct visual observations were recorded to classify data into three primary behaviors: grazing, walking, and resting (to include standing and lying down). A random forest model was fitted to the data and out-of-bag error rates used to assess misclassification rates and predict behavior of unobserved data. Overall misclassification rate was low (<10%). Time spent grazing ranged from 8-10 hours daily, and timing of grazing tended to be heaviest during morning and evening hours, both of which are expected from yearling steers grazing native pasture in summer. These results show great promise in accurately identifying livestock grazing locations, which could benefit researchers and land managers monitoring rangeland use.

Climate and Edaphic Factors Influence Ecological Integrity of Prairies in the Northern Great Plains

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Terry Shaffer, U.S. Geological Surivey, Jamestown, North Dakota
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Biological diversity and ecological integrity of native prairies in the northern Great Plains are greatly modified from pre Euro-American settlement. About 90,000 ha of native mixed-grass and tallgrass prairie are managed by the U.S. Fish and Wildlife Service (Service) in North Dakota, South Dakota, and northeastern Montana. We used belt transects to inventory plant composition of all Service-owned prairies in the Dakotas and northeastern Montana. Collectively, prairie plant composition was significantly compromised, mainly by invasion of introduced grass and forb species and by native shrubs. Smooth brome (*Bromus inermis*) and Kentucky bluegrass (*Poa pratensis*) were the most persistent threats to floristic diversity of Service-owned prairies. Degradation of prairies was spatially variable and also invader-specific, corresponding to patterns in precipitation and temperature that varied across the study area. Cooler and drier sites occurring to the north and west were more floristically intact relative to warmer and wetter areas located farther to the south and east, primarily because these latter prairies were substantially invaded by smooth brome. Kentucky bluegrass was the most widespread invader of Service-owned prairies, with less frequent occurrence only in prairies dominated by smooth brome in South Dakota or by native grass-forbs in northwestern North Dakota and northeastern Montana. Prairies were more intact farther from habitat edges such as cropland and roads, and on harsher ecological sites composed of poorer soils, steeper slopes, and southern or western exposures. Patterns of invasion related to climate and edaphic variables suggest new opportunities for prairie restoration by focusing where probability of restoration success is greater.

Climate Change Adaptation Planning for Restoration and Management in the Eastern Great Plains

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In the coming decades, climate change is forecast to increase the incidence of drought and diminish water supply in the midcontinent of North America. Effective climate change adaptation strategies are needed in this region to conserve and expand the extent of grasslands and wetlands capable of supporting the region's biodiversity. A significant gap remains between national and regional planning and site-based decision making, which is typically the relevant scale for land acquisition, vegetation management and restoration, and monitoring of special concern species. In this presentation, I will discuss ways to "downscale" adaptation planning from region to site in order to identify 'no regrets' adaptation strategies that should not be deferred.

Climate Change Impacts on Soil Microclimate and Seed Germination Timing in the Sagebrush Steppe

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Past/projected changes in atmospheric climate have/will alter soil microclimate, and as a result impact seeds that use soil moisture and soil temperature as cues for germination. Seed germination and establishment are among the most important processes regulating plant community assembly in response to climate change. Changes in germination timing lead to seedling exposure to new abiotic and biotic factors that affect recruitment success. Species that have developed seed dormancy strategies to avoid harsh winter conditions could experience more mortality if changes in germination timing lead to early germination and subsequent exposure to freezing conditions. We analyzed the changes and trends of soil microclimate in the sagebrush steppe during the period 1979-2016 using a soil physics model (SHAW) and calculated germination timing of native species using wet thermal response curves. Our results indicate that warmer/wetter falls are becoming more prevalent and are leading to accelerated germination of native plants in the sagebrush steppe. Changes to spring soil conditions favor more germination during April, but onset of spring soil conditions showed little to no movement. Trends in climate are creating drier and warmer soil bed conditions which will likely increase summer seedling mortality. Historic cycles of alternating slow/fast germination appear less frequently during the last 12 years of the study (2004-2016). Changes to soil bed microenvironment are likely to lead to increased exposure of native seedlings to freeze/thaw cycles, and increased abundance of invasive annual grasses, leading to declines in native plant establishment.

Clipping Reduces Geyer Larkspur Aboveground Mass and Toxicity

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Many larkspurs (*Delphinium* spp.) are poisonous to livestock and considered the most damaging poisonous plants on rangelands in the western United States. For over a century, the most commonly used strategies to minimize cattle losses to larkspur poisoning have included some form of avoidance, and some managers go to great lengths to ensure that their cattle eat little to no larkspur at all. Avoidance strategies have most likely helped ranchers avoid some degree of livestock poisoning, but recent estimates of livestock losses to larkspur are surprisingly similar to those from a century ago. Has a century of avoidance allowed larkspur to become more dangerous, and if larkspur is grazed, might it become less dangerous in the future? These questions prompted us to conduct a field clipping study to determine the extent to which grazing might affect Geyer larkspur (*D. geyeri*) toxicity and plant size. Individual larkspur plants (81) were randomly assigned to one of three clipping treatments at bud stage: removal of 25% of mass, removal of 75% of mass, and a control. Plants assigned to clipping treatments were clipped in both 2016 and 2017. Changes in plant mass and toxicity were determined from 2016-2018. Plant mass was estimated using a linear model based on a leaf count and the average length per stem (R^2=0.906). Toxicity (MSAL concentration) was determined from three leaves collected from each plant each year using liquid-chromatography mass-spectrometry and the protocol developed by the USDA Poisonous Plants Lab (Logan, UT). Preliminary results suggest that plant mass, MSAL concentrations and alkaloid pools (MSAL concentration x plant mass) declined for all plants (clipped and unclipped) from 2016-2018, but plants clipped at the highest intensity showed the greatest reduction in all response variables, especially after the second year of clipping.

Communicating Ecological Data for Land Management: Lessons Learned

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Communicating ecological data for land management represents a different challenge than communicating with the general public or research community. Land managers need to understand both results and the inherent limits and assumptions in order to make effective and legally defensible decisions. However, many face barriers including time, resources, and technical skills. Our group, a partnership among the USDA Agricultural Research Service (ARS), the National Aquatic Monitoring Center (NAMC), and the Bureau of Land Management (BLM), has been working on the BLM Assessment, Inventory, and Monitoring Strategy (AIM) since 2010. The purpose of AIM is to provide robust, high quality monitoring data gathered with consistent methods and statistically-sound sampling techniques. Through this effort, we have experienced both successes and failures in communicating data. As a result, our data communication has evolved. We refined the amount of data, their format, and the kinds of delivery mechanisms. This process has required working iteratively with land managers to identify general principles for what analyses and data visualizations are useful and how to make them more accessible. We find that starting with conversation about users' analysis objectives and existing decision-making workflows that use the results often shapes data requests. High density, high complexity figures are less likely to be impactful; we aim to produce simple, direct figures which display only one kind of result. Graphical figures are often easier to draw general conclusions from, but tabular results may be necessary for documentation; we provide equivalent data in multiple formats for use in different analyses. We aim to present statistics in ways that users can comfortably interrogate and discuss; especially statistics like uncertainty that users may have more intuitive and less formal understandings of. We plan to continue refining our approaches through workshops with the community of practice of land managers who are using the data.

Comparison of Grazing Behavior of Rangefed Raramuri Criollo Cows, Heifers and Steers During Five Seasons

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George Ruyle, University of Arizona, Tucson, Arizona
Dennis Moroney, Cross U Cattle Company / 47 Ranch, McNeal, Arizona
Gary Nabhan, University of Arizona, Patagonia, Arizona
Samuel Garcia, University of Arizona, Tucson, Arizona
Larry Howery, The University of Arizona, Tucson, Arizona
Derek Bailey, New Mexico State University, Las Cruces, New Mexico

For the past 20 years, drought has strongly affected the southwest United States and northwest Mexico; described as arid to semi-arid, with annual precipitation of less than 406.4 mm. Choosing cattle breeds which are adapted to this climate and topography in order to maximize the feed resources without degrading them is an ongoing challenge in the region. The Criollo breed, originally from North Africa and Spain, and naturalized throughout the Americas for the past 500 years, is a type of cattle which seems to be well-adapted to the drought conditions currently prevalent in the region. This study was conducted on the 47 Ranch in southeastern Arizona. We collared two groups of cattle from September 2017 to October 2018. The objective was to observe grazing behavior differences between the sex of the animals (mature cows, heifers and two year old steers), and the seasons (fall [October-November], winter [December-February], spring [March-April], pre-monsoon [May-June], monsoon [July-September]). The first group collared in September 2017 was composed of 20 cows, 20 heifers and seven steers. The second group collared in May 2018 was composed of 13 cows, 13 heifers, three steers and four bulls. We were interested in looking at the time spent near water, distance traveled from water, and use of the different pastures (spatial and elevation) for each category of animal and each season.

Comparison of Grazing Behavior of Rangefed Raramuri Criollo Steers During Pre-Monsoon and Monsoon Seasons

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Larry Howery, The University of Arizona, Tucson, Arizona
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Conifer Management in Context: Prioritizing Tree Removal Projects for Sagebrush and Woodland Obligates

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Conifer encroachment among sagebrush steppe landscapes have resulted in detrimental impacts to sage grouse and other sagebrush-dependent wildlife such as migratory songbirds. Highly-targeted removal of conifers among sagebrush has been an effective tool for restoring habitats for sagebrush-obligate wildlife, as well as providing ecosystem benefits including improved carbon capture and water storage. However, successes in large-scale conifer removal begets an investigation of potential impacts to species that rely on pinyon and juniper habitats. Understanding patterns of abundance for sagebrush-dependent wildlife and declining woodland obligates can help practitioners target conifer removal projects in the right places to provide multi-species benefits. We used Breeding Bird Survey data from across the sagebrush ecosystem to develop habitat-based relative abundance maps for nine sagebrush and woodland-dependent species, including declining Brewer’s sparrow, sage thrasher, green-tailed towhee, and pinyon jay. We overlaid data from past conifer removal projects with predicted abundance for each species and found that cuts had largely targeted the highest predicted abundance for sagebrush-obligates, while avoiding important pinyon jay habitats. We made spatial layers available online such that practitioners can use an interactive web-based tool to help inform local decisions when targeting conifer removal projects. Lastly, we used a Strategic Conservation Planning Approach to prioritize conifer removal projects intended to best target sagebrush-dependent wildlife, while avoiding declining woodland obligates.

Conserving North Dakota's Native Pollinators: From Planning to Action

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The North Dakota Monarch and Native Pollinator Strategy outlines voluntary actions meant to increase the monarch population in its summer range and further pollinator conservation in North Dakota. The strategy was created in 2016 with the intent of precluding the need to list the monarch and other pollinators as threatened or endangered under the Endangered Species Act. Since its creation, the North Dakota Game and Fish Department, along with collaborators, have used this strategy as a tool to implement conservation actions, from pollinator plantings to changes in land management. This short talk will update participants on the process of creating the strategy and putting it into action on a state-wide, multi-agency scale.

Considerations for Riparian Complex Ecological Site Description Development

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Land managers need consistent, broadly applicable terminology and classification frameworks to discuss the ecological status of the land. A common framework used in upland terrestrial systems is an Ecological Site Description (ESD), but creating ESDs in riparian areas must follow a different framework than upland systems because function of riparian systems is driven by hydrology, while function of upland systems is more influenced by soils, topography, and vegetation. This research describes a study to categorize riparian areas by hydrology using geomorphic parameters, namely the Rosgen Stream Classification System. Stream cross section and longitudinal profile data was collected from seventy-five reaches from nineteen streams in North Dakota, USA from 2012-2018. Streams were classified by channel type (E, C, B, F, and G), and stability class (stable and unstable). A stream parameter matrix was constructed using entrenchment ratio, width-to-depth ratio, sinuosity, slope, channel bed material, bank height ratio, and meander width ratio. A multiple response permutation procedure showed that the parameters differed based on both channel type and stability class. An indicator analysis showed that entrenchment ratio, bank height ratio, and meander width ratio were the parameters most influential in separating the reaches by stability class. ER, which was the strongest indicator of stable streams in this study. However, MWR and BHR were significant indicators of stable and unstable reaches, respectively. The parameters used in this study to delineate channel type can be used to consistently discriminate between stable and unstable channels. This information may be a useful tool in describing the state and transition of stream development in riparian complex ESDs, validating the continued use of Rosgen Stream Classification System in ESD development.

Constitutionalism, Institutional Protection of Traditional Grazing Rights in Sub-Saharan Africa: The Missing Case for Uganda

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On Thursday April 12,2018 Uganda's national Army, the Uganda People's Defence Forces (UPDF) issued a 12-day ultimatum to pastoralists commonly known as Balalo to withdraw from northern Uganda in areas close to South Sudan and western DRC Congo, or face forceful eviction back to their homes in southern, central and eastern Uganda. The UPDF 5th Division spokesperson, Maj Telesphor Turyamumanya, followed up with the threat, and by April 22, the pastoralists had been removed from Lango, Acholi and West Nile regions in what is now the "new normal". Pastoralist's communities in Uganda, like in many post colonial subAfrican countries are living on the margins of a disappearing way of life, livelihood and survival. Their needs are not adequately protected by the Ugandan constitution, the Uganda Land Act of 1998, as well as the national Land Policy. The pastoral communities, many of them held land communally for millennia, are waking up to new realities of modern States with borders, visas to cross and look for pastures; and hostilities within their own countries and neighboring countries. Fragile, porous borders present additional cross-border armed thefts, further fueling fear, un-certainty and missed opportunities in being incorporated into the national development agenda.

Constructing and Deploying GPS Collars and Processing Data to Inform Ranch Management

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As GPS collar technology becomes more affordable and available, it has the potential to provide valuable ranch management data, as well as, information for researchers. However, utilizing inexpensive GPS technology requires that user have basic skill sets related to construction, deploying the device, and processing and interpreting the data generated. In this session, attendees will go through basic steps to create a reliable and inexpensive GPS collar using a thoroughly field-tested design. In addition, participants will learn how to properly attach the collars to cattle, eliminating any apprehension they may have about how tight the collar needs to be. Following the construction and application demonstrations, everyone will have the opportunity to download and process GPS data on their computers with step-by-step instructions. This portion will show how to remove inaccurate data and format the information to be user friendly. Most importantly, after the data has been processed and formatted correctly, authors will explain how to visualize and interpret the results in an easy to understand format using spreadsheet and GIS software. This session will cover basic grazing behavior data such as: distance traveled, distance traveled from water/supplement, slope utilization, and elevation information. A list of software, example data files, and instructions will be made digitally available to registrants.

Continuous Satellite Derived Estimates of Annual Production on US Rangelands

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Rangeland managers and livestock producers need more timely and consistent tools that produce information to inform grazing strategies, risk management, and allotment management plans. In addition, National Forest systems are now in various stages of Forest Plan Revisions which require assessments of current rangeland conditions and past vegetation performance in a clear, unbiased manner. On the ground monitoring is extremely expensive and difficult to employ due to limited resources, fewer trained staff, and shifting priorities. In response to this need, we have generated and provide a new and unprecedented data service. These satellite derived data represent annual production estimates, calibrated across 110 vegetation types, on coterminous US rangelands from 1984 to present day and are freely available. Correlations with observations range from 0.96 to 0.31, with higher values achieved across production ranges between 15 and 3,250 pounds per acre. This system has been used by private industry and public land management agencies to quantify vegetation performance and evaluate the effects of past management across the western US.

Continuous Season-Long and Rotational Grazing Systems in Northern Colorado: An Economic Cost Analysis

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Justin Derner, USDA-ARS, Cheyenne, Wyoming
Steven Paisley, University of Wyoming, Lingle, Wyoming
Brian Lee, University of Wyoming, Lingle, Wyoming

There are few studies comparing the economic viability of continuous season-long grazing systems with rotational grazing systems, specifically at the same stocking rates. Our study considers infrastructure and labor differences of these two systems over a suite of economic assumptions. Data for this study comes for the USDA-ARS Central Plains Experimental Range where a 10 year collaborative adaptive rotational management experiment is being conducted comparing these two systems; however, due to the variability of what a “typical” ranch looks like in the region, we model various cost structures to cover a broader scope of operations. The costs of implementing a rotational grazing system comes from the differences in infrastructure (fencing and water) and labor, and are dependent on the layout of the ranch (ranging from one large, sub-divided tract of land to multiple non-contiguous pastures). Five scenarios are modeled to determine the costs of transitioning to a rotational grazing system: 1) One large continuous pasture, grazed continuously; 2 & 3) Large pasture subdivided into 10 pastures using permanent or electric cross-fencing and rotationally grazed; and 4 & 5) 10 non-contiguous pastures grazed either continuously or rotationally. Our results indicate that other than the additional fencing required to convert to a rotational grazing system, labor costs are much higher for the continuously grazed systems. These results have implications for producers who 1) may receive NRCS cost share assistance to build the required infrastructure, or 2) beginning producers who will likely have higher annual costs due to not having contiguous parcels of land.

Continuous Season-Long and Rotational Grazing Systems in Northern Colorado: Economic Returns over Variable Costs

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Studies indicate that rotational grazing systems often produce lower average daily weight gains (ADG) in cattle than a continuous season-long grazing system; however, few of these studies are conducted at the same stocking rate, and even fewer incorporate beef market trends such as cyclical prices and slide based on weight. In our study, returns over variable costs, specifically derived from the fall sale of steers using a Monte Carlo probability distribution of historic (20 year) steer prices, are incorporated to directly compare the returns over variable costs among the two grazing systems. Furthermore, additional ecosystem benefits to the rotational grazing system are included as non-monetary benefits, including increases in prairie bird species populations, greater vegetation heterogeneity, and mitigation of negative drought consequences through grass banking. Data for this study comes for the USDA-ARS Central Plains Experimental Range where a 10 year collaborative adaptive rotational management experiment is being conducted comparing season-long continuous and rotational grazing systems at the same stocking rate. Economic returns derived from this study are then compared to five separate cost scenarios which represent different potential ranch infrastructures (e.g., contiguous vs dispersed pastures, and various types of fencing). Our results indicate that while steers from the rotational grazing systems have lower ADG, the difference in gains as compared to continuous grazing systems have the potential to decrease overtime as managers better understand how to manage the grazing system. Additionally, due to the price slide in the cattle markets, revenue differences between continuous and rotational grazing systems are not as large as the ADG differences. The results of this study may have potential to influence conservation subsidization as the costs of managing for non-market ecosystem services are broken down into opportunity costs of providing the services across a variety of physical and economic scenarios.

Debate Development, Current Status and Lessons Learned

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The concepts underpinning global rangeland ecology and pastoral development shifted from equilibrium to nonequilibrium in the 1980s. The debate emerged from the failure of classical models to accommodate observed vegetation change, as well as the notion that climate-driven events may override plant-herbivore interactions in arid rangelands. The debate rapidly contributed to major shifts in the theory and application of range science. State-and-transition models began to dominate discourse in the developed world focused on ranching, while nonequilibrium models were proposed to explain the failures of US-based, range management interventions in African pastoral systems. Investigation of the nonequilibrium concept over the past 30 years has revealed that nonequilibrium models were applied too broadly. Research addressing forage resource heterogeneity, plant-herbivore interactions, and climate-vegetation dynamics have documented the coexistence of equilibrium and nonequilibrium dynamics in rangeland systems. Both ranching and pastoralism face similar problems of drought, resource degradation, livestock market fluctuations, and – in some cases – declining human welfare. System subsidization via water development, supplemental feeding of livestock – and even human food aid – have become more frequently applied as a solution. The global trend of increasing rangeland subsidization has contributed to greater nonequilibrial dynamics by supporting larger and more stable livestock numbers than those that could exist with rangeland resources alone. This suggests that some of the challenges and strategies confronting ranching and pastoralism are beginning to converge in the 21st century. The fundamental challenge facing the global rangeland community may not be identification of a unified model of rangeland ecology, but how to best organize and govern rangeland social-ecological systems to provision optimal combinations of ecosystem services to support human societies and the biosphere. This challenge has clearly surpassed the capacity of traditional range science and it provides a strong justification for development of a more comprehensive rangeland systems framework.

Decision-Making on Privately-Owned Grasslands: Stocking Rate, Non-Native Grasses, and Changing Perceptions Toward Conservation

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Grassland ecosystems are dynamic landscapes from which society demands both goods (e.g., forage and livestock production) and services (e.g., biodiversity). Even though most grasslands are privately-owned, few studies address the social factors that influence the possibilities for advancing conservation on private land. To this end, we surveyed landowners in the eastern Great Plains to gain insight into decision-making surrounding two practices that affect the value of grazing lands for biodiversity: reducing stocking rates and controlling non-native grasses used as cattle forage. Notably, this survey was a follow-up to an earlier survey conducted a decade earlier, which allowed for longitudinal evaluations. We found that when comparing 2007 and 2017, the population of landowners was older with more negative views toward grassland restoration and biodiversity, and with more rented land on average. Landowners who rented more land were less willing to reduce stocking rate. Lower willingness to reduce stocking was also associated with increasing prevalence of the non-native grass tall fescue (*Schedonorus arundinaceus*) on landowners' properties, potentially because tall fescue can withstand heavy grazing pressure. When exploring willingness to manage non-native grasses like fescue, we found that landowners who felt a sense of personal responsibility to prevent the spread of these grasses in their neighborhood implemented management more often. Overall, our results suggest that rented land, non-native forage grasses, and deteriorating perceptions of grassland restoration are barriers to implementing conservation practices. Despite this, a sizeable population (~40% of our sample) was willing to reduce stocking rates or remove non-native grasses. Our results suggest that beliefs about stewardship and responsibility factor prominently in landowner decisions. Based on this, we develop recommendations to effectively engage producers in conservation practices that benefit biodiversity in these working landscapes.

Demography of an Encroaching Shrub in Response to Fire and Herbivory in Tallgrass Prairie

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Woody encroachment alters the community structure and ecosystem function of grasslands worldwide. This leads to a loss of forage for livestock, while removal of woody plants is both time intensive and expensive. Clonal shrubs are of particular management concern because of their ability to resprout after fire and brush removal. Although fire and herbivory are known to be important drivers of grassland systems, the effects of herbivory on the growth and demographics of woody species are not well understood. In this study, we quantified the growth rate and demographic characteristics of the clonal shrub *Cornus drummondii* in response to fire frequency, grazing, and browsing. Growth rates were low across all treatments in response to extreme drought during the summer in 2018. Browsing reduced and nearly eliminated sexual reproductive effort of browsed shrubs, but vegetative reproduction did not differ between treatments. Fire increased stem densities likely in response to a pulse in resource availability and reduced aboveground competition with grasses. Grazing was not found to have effects on either the growth or demographics of established shrubs. In addition, we conducted a 15N tracer study to assess nutrient retranslocation within shrub clones. The tracer was taken up, but not redistributed among clonal ramets throughout the season, suggesting limited nutrient movement during drought and the potential for seasonal lag effects in N translocation. These results highlight mechanisms of woody expansion in response to disturbance and may be used for the development of future management techniques to delay or reverse the process of woody encroachment.

Detection and Management of Two-Lined Spittle Bug (*Prosapia bicincta*) on Hawaii Rangelands

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Two-lined spittlebug (TLSB), *Prosapia bicincta*, (Hemiptera; Cercopidae) was first detected in Kailua-Kona, Hawaii in September of 2016 where it had damaged nearly 2,000 acres of rangeland in just a few months. Surveys that began in 2017 revealed that the pest rapidly expanded its range and currently infests an estimated 45,000 acres of rangelands. In highly infested areas, the TLSB has resulted in nearly 100% die back of key range grasses including Kikuyu (*Pennisetum clandestinum*) and pangola (*Digitaria eriantha*) grasses. The loss of these important livestock forages provides entry for the establishment of many undesirable, and often invasive plants including Pamakani (*Eupatorium adenophorum*), wild blackberry (*Rubus* spp.), fireweed (*Senecio madagascariensis*), Hilo grass (*Paspalum conjugatum*), and several other weeds. In response to the alarming spread and extent of damage inflicted by TLSB a cooperative taskforce was established with funding from the Hawaii Department of Agriculture, Hawaii Invasive Species Council, and Hawaii County. The taskforce developed a multifaceted program with the following strategies to address TLSB: 1) rancher outreach and education; 2) detection and surveillance; 3) development of Integrated Pest Management (IPM) protocols (Pesticides, Grazing management, Forage replacement); 4) biological control agent exploration; and 5) research into the biology and ecology of TLSB in Hawaii. Early rancher outreach and education efforts have been focused on affected operations and the distribution of factsheets. Detection and surveillance of known TLSB populations have revealed new information on TLSB habitat selection, nymph and adult biology, and population dynamics. Additionally, an indigenous parasitic nematode was found to readily infest TLSB nymphs in the laboratory. Field trials are being planned to determine if the results can be extended to range sites. The data from the population surveys and biological control trials will be used to inform the development of IPM strategies for the management of TLSB on Hawaii rangelands.

Determining Appropriate Utilization Measurements for Multiscale Spatial Analysis of Wildlife-Livestock Interactions in Southern Idaho

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Intensity and timing of cattle grazing can have diverse effects on rangeland vegetation structure and composition which influences wildlife-livestock interactions. Yet, commonly implemented methods for measuring grazing were not designed for use at broad spatial and temporal scales that facilitate rigorous examination of effects on wildlife species, such as greater sage-grouse (*Centrocercus urophasianus*). Understanding the strengths and limitations of these methods with respect to their precision and scalability is fundamental to effective management of multiple-use landscapes. In 2012 the University of Idaho, Idaho Department of Fish & Game, and Bureau of Land Management initiated a broad-scale 10-year research project investigating the effects of spring cattle grazing on the demographic traits and habitat characteristics of greater sage-grouse. Sage-grouse and vegetation data were collected at five study sites in central and southern Idaho comprising more than 30,000 acres of rangeland. As part of that study, grazing utilization was measured using five different methods concurrently, which represent commonly accepted and widely used protocols across rangelands in the west: landscape appearance, biomass clipping from utilization cages, vegetation height/weight, percent cover of grazed plants and ocular estimates of percent forage removed. This study looked at the correspondence among these five methods and compared their efficacy across different scales relevant to greater sage-grouse life cycles. Results indicate correlation between different methods varies across spatial and temporal scales and in some cases across environmental gradients. Main drivers of non-sampling error such as inter-observer bias varied among the methods. Creating hybrid indicators from combinations of methods proved useful in minimizing error and strengthening statistical inference. Spatial analysis of these measurements with cattle telemetry data may further improve our understanding of patterns of grazing intensity across the study area. These conclusions highlight the importance of selecting appropriate monitoring methods which can provide valuable information for sustainable multiple-resource management.

Determining Spatial and Temporal Distributions of Grassland Butterflies through Statewide Monitoring

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Over 30 species of butterflies in the United States are currently listed as either endangered or threatened by the Fish and Wildlife Service, with even more currently proposed for listing. This includes multiple species of concern in North Dakota. To direct conservation efforts for these species, and to proactively increase our understanding of all grassland butterflies, we need comprehensive information on their current distributions through space and time. The goal of our project is to develop these distributions for the grassland butterflies of North Dakota through four years of statewide monitoring. Since 2017 we have been surveying butterflies at three grassland sites in each of ND's 53 counties, visiting each site twice per summer. During each visit we perform visual encounter surveys and line transect distance surveys. We also record the floral resources available for pollination using belt transects and the overall vegetative community using cover quadrats. Over two summers we have already collected tens of thousands of butterfly detections over 50 species which we are using to create spatial and temporal distributions. These population metrics, in conjunction with associated vegetation characteristics, provide vital baseline information on North Dakota's butterfly communities that can help inform future conservation efforts across the state and beyond.

Developing a Tool to Monitor Drought Impacts on Semi-Arid U.S. Grasslands: Nebraska Sandhills Case Study

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Drought is one of the costliest natural disasters that differs from other hazards by its large spatial extent and long duration. Drought lowers the productivity of grasslands, directly affecting the number of cattle that can be raised. Suitable drought monitoring tools that indicate the effect of drought on grassland productivity can help producers with their decision-making. Remotely sensed vegetation indices can be used to monitor the impacts of drought on vegetation health. However, it may be challenging to distinguish between weather and other vegetation health stressors. This study develops a data-driven multiple regression grass productivity model that uses environmental and climate variables to separate the effect of weather from other disturbances. The satellite-derived Normalized Difference Vegetation Index (NDVI) is used as a proxy for grassland productivity and is converted to a total growing season biomass using a previously developed empirical equation. A biomass productivity map is generated over the Sandhills ecoregion using model results. Productivity extracted from 1,000 randomly placed points in the Sandhills area is regressed on various drought indices and tools to evaluate which ones can better explain the interannual variability in productivity caused by a drought. The indices and tools used in this study include the Standardized Precipitation Index, United States Drought Monitor, and the Vegetation Drought Response Index. This research uniquely combines the ecosystem performance modeling approach with various drought indices to evaluate drought based on numerous input variables. The goal of this research is to develop an interactive management decision tool with 250-meter spatial resolution and a large spatial extent to provide producers with an estimate of total growing season forage production under various weather scenarios. The results of this research can help land managers to better understand drought impacts on grassland systems and to make optimal management decisions based on predicted forage scenarios.

Development of a Multidimensional Metric to Assess Terrain Use of Rangeland Cattle

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Livestock grazing distribution is a critical factor for rangeland management in the western United States, especially on public lands. Slope and horizontal and vertical distance to water, alone and in combination, affect how cattle use mountainous rangelands, which makes terrain use a multidimensional trait. Assessment of terrain use by cattle is difficult because the metrics used to describe aspects of terrain use different scales of measurement. For example, slope is measured in percent or degrees, while distance from water is measured in meters. The objective of this study is to develop a metric that can be used measure and evaluate terrain use of cattle on rugged rangeland. Fifteen randomly selected mature Angus cows within a herd of 40 cows were tracked in a 1,201 ha pasture in mountain rangeland near Mayhill, NM from June to September during 2015. A total of 205 non-overlapping randomly selected plots that were 100 m in diameter were used to evaluate resource use by tracked cattle. Slope, elevation, distance to water, aspect and cattle use was determined for each plot and evaluated using a general linear model with a negative binomial distribution. Slope, elevation and distance to water were important predictors of cattle use. Regression coefficients differed in magnitude because of the units of measure. Feature scaling was used to normalize these variables and then evaluated in the same model. Similar to the previous analysis, slope, elevation and distance to water were important predictors of cattle use, but the magnitude of the regression coefficients were similar. These results suggest that feature scaling may be a tool to help evaluate the multidimensional aspects of terrain use in cattle, but more research and analyses are needed.

Development of Genetic Selection Programs for Grazing Distribution

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Livestock grazing distribution is both an economically and environmentally important aspect of beef cattle production, particularly in western rangelands and global regions that use extensive grazing systems. In order to improve efficiency of rangeland use, producers must either intensify management of rangeland resources by modifying infrastructure, implement herding strategies, or select individuals that are genetically predisposed for efficient grazing habits. Effective selection practices require information on all candidate individuals and can make use of either a phenotype or estimated breeding value. For grazing distribution, selection decisions based on phenotype are not ideal because females are typically the individuals on which phenotypes are measured, yet male selection drives genetic progress as a result of the higher number of offspring produced. Prediction of breeding values for a trait requires both a readily available data resource and evidence of genetic variability through either/both quantitative or molecular information. Collection of grazing distribution phenotypes is costly and time consuming, a hindrance for accurate genetic predictions. For a selection program targeting grazing distribution to be truly effective, its relationship to all aspects of the production system, particularly to economically relevant traits need consideration, further increasing data requirements from phenotyped individuals. Data collection has begun and has yielded evidence for genetic variability in these traits. In studies published in 2015 and 2018, results suggested that genetics explained 34-36% of the variability in phenotype. In order for wide scale implementation of a genetic selection program, a sizeable database is required to yield more accurate predictions over a broader population of animals. This resource could then be used to ascertain relationships amongst grazing distribution traits and other economically relevant traits. In the end, EPD from this data, both phenotypical and molecular information, could be integrated into a multi-trait selection system addressing both environmental and production concerns.

Dig Deeper into the Details: A Peer-Review Checklist

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Peer-reviews ensure quality science. Here is a checklist of questions about a manuscript you are reviewing. Introduction: Is the topic introduced well and appealing to a wide audience? Does the introduction provide a literature review and lead the reader to a specific hypothesis? Do the authors provide a hypothesis? Is there a rationale? Do they provide the theoretical basis for the research? Is it novel? Does the hypothesis address the main question posed in the introduction? Do the authors describe how they intend to advance the topic? Does the hypothesis make a biological “prediction”? Does the hypothesis let you anticipate the tests/measurements? Materials and Methods: Does the experimental design test the hypothesis? Is the design statistically/scientifically-sound? Does it provide enough detail to be repeated? Results: Are the results understandable? Do data and graphs have units? Do data match anticipated measurements? Do data show variation and/or error around the means? Are there missing results? Were data presented a subset of data collected? On what basis were the data presented chosen? Are there too many figures with redundancy? Discussion: Does the discussion re-familiarize the reader with topic, issue, or problem? Does it revisit the hypotheses and indicate whether they were accepted or rejected? Do the conclusions fit within the study design? Are the results novel? Is the discussion related to past research? Does it discuss similar studies and describe similarities and differences? Do authors address unexpected findings and explain why it happened? Do they provide clear implications and show how they advanced the topic as they indicated in the introduction? Did the authors broaden the implications to be relevant to a wide audience?

Disturbance Limits Utility of Unmanned Aerial Systems for Counting Sharp-Tailed Grouse on Leks

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Manned aerial surveys are an important tool for wildlife managers, but they are expensive to conduct, dangerous, and difficult to replicate. In recent years, interest has been expressed in using unmanned aerial vehicles (UAV) to alleviate concerns associated with traditional, manned aerial surveys. To assess the potential of UAV technology in North American avifauna surveys we established a research project studying the behavioral response of sharp-tailed grouse (*Tympanuchus phasianellus*) to two different UAV platforms (fixed winged and quadcopter) on National Grasslands in North and South Dakota. In addition, we aimed to describe technical requirements with each and identify pitfalls. A total of 13 leks were tested; seven with a fixed winged vehicle, and six with a quadcopter. Lekking grouse showed a measurable response to UAVs during all flights regardless of UAV platform. Lek observers recorded four of the seven fixed winged flights and three of the six quadcopter flights flushed all grouse from leks. The level of disturbance we observed inhibits imagery collected by UAVs to accurately portray bird densities at lek locations in our study. UAVs show promise for improving survey replication and limiting dangers associated with manned, aerial surveys. However, our preliminary findings suggest UAVs are not a worthwhile substitute at this time. Future investigations need to consider variables such as survey elevation and UAV type to identify physiological responses lekking grouse express towards UAV exposure.

Disturbance Severity and Type Shapes Sagebrush Community Resilience and Resistance to Invasion

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Fire and invasive annual grasses interact to degrade ecosystem services and function in the sagebrush biome of the Great Basin, which has become a major management issue. Climate influences this interaction; cooler and wetter sites tend to have greater resilience and resistance, and while fire has been well studied, there is limited information on the impacts of fire severity and interactions with other disturbances. In the northern Great Basin, we examined the response of native shrub, native grass, and invasive plant cover to the type and severity of disturbance using over 1,600 vegetation plots, collected from 2011 to 2015, from the Bureau of Land Management Assessment Inventory and Monitoring strategy. Fire extent and severity was measured for fires from 1984 to 2015, and anthropogenic disturbance was classified based on the amount of physical disturbance within 2.5 km. We modeled the relationship of native perennial grass cover, native shrub cover and invasive plant cover against climate, fire, and anthropogenic disturbance using beta regression to test the influence on community resilience and resistance to invasion. After accounting for precipitation, fire more than doubled the proportion of invasive plant cover and decreased the proportion of native shrub cover by 26%, while perennial grass response depended on annual precipitation. Furthermore, increased fire severity was associated with the largest declines in shrub cover and the greatest increases in invasive plant cover. The influence of anthropogenic disturbance was more complicated, at low fire severity, increased anthropogenic disturbance was related to increased invasive plant cover. However, with more severe fire, invasive cover was high regardless of anthropogenic disturbance. Our results support the convention that wetter sites have higher resilience, while also illustrating severity thresholds for sagebrush communities. Therefore, management flexibility is reduced for fire-prone areas in the sagebrush biome with increased anthropogenic disturbance.

Diversifying Seed Mixes, Incorporating Cover Crops, and Adjusting Planting Date to Establish Native Cover in Difficult Sites

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Grasslands are one of earths most threatened biomes. As such, many of the organisms that inhabit them have experienced population declines. Immediate threats to grasslands include conversion to crop farming, urbanization, fragmentation, and energy development. Despite ongoing conversion of native grasslands across the United States, grassland restoration projects are frequent across some landscapes. Reestablishing native plants can be challenging even in favorable conditions. Soil type, cropping history, topography, and precipitation all may influence the success of native seedings. In areas with particularly poor soil, extensive cropping history, and limited precipitation, establishing native plants can be particularly challenging. The badlands region of western North Dakota represents one such location, where native prairie restoration may be impeded by low annual precipitation and highly weathered soils. Western North Dakota lies in the Bakken formation, which has experienced increased energy activity in recent years resulting in the need for greater information concerning native prairie restoration techniques in badlands type soils. We examined the effect of planting date, diversifying species mixes, and using cover crops (radish and turnip) on native plant establishment. We established multiple 25x25 m research plots (replicates) in a former crop field in the heart of oil country. In general, planted grass cover was greater in four-year-old spring plantings (47%), regardless of cover crop presence or absence relative to fall plantings that were in their third growing season (26%). The use of cover crops during planting reduced the total planted grass cover (40.5%) relative to those treatments not seeded with cover crops (53.5). Forb establishment was low regardless of planting date with forb cover accounting for 3.6% in spring and 1.4% in the fall plantings. Our findings suggest that grass establishment is achievable in badlands setting and that future work should focus on ways to improve forb establishment in badland reclamations.

Do Different Smartphone Cameras Agree About Measured Fractional Green Canopy Cover?

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The ubiquity of mobile devices with integrated digital cameras has prompted researchers to develop applications to derive plant indices like fractional green canopy cover (FGCC). While these devices were designed to collect general photographs that represent a subject well from a human perspective, they are not calibrated scientific instruments. As such, it's unclear whether measurements made with one device agree well with measurements made with another device or, given that these devices are hand-held and subject to slight variations in height and view angle and the image sensor processing is all automated, whether measurements made by the same device are repeatable. We quantify same camera repeatability and the range of between camera agreement. We acquired replicate images in eight perennial grass plots of four species under varied conditions related to illumination, the camera application used, and whether a color palette was present in the image. We then processed these images and calculated four versions of FGCC and analyzed those data to determine the effects of these varied conditions on FGCC. Sun-angle and illumination type had large effects, shifting FGCC by up to 24% and up to 13.6%, respectively. Performing a white-balance adjustment moderated sun-angle and illumination type effects and reduced among camera variation in FGCC. Using the same device, repeatable results for FGCC can be obtained (e.g., differences typically less than 2.5% to 9.6%, depending on the device) and with careful sampling should be suitable to use for ranking plots or treatments. However, the relatively poor agreement among devices coupled with the complexity of the relationships between device pairs calls in to question whether these devices can be used to characterize absolute FGCC values. Furthermore, image datasets acquired using multiple devices are unlikely to provide useful data without first developing and applying conversion equations among devices.

Does Laboratory Selection for Increased Seed Germination of Little Bluestem Improve Field Establishment?

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Drought is the leading cause of plant establishment failure. This research investigated the percentage field emergence of seven populations (NU1, NU2, UC1, UC2, UO1, UO2, and UO3) of little bluestem, *Schizachyrium scoparium* (Michx.) Nash, and three generations of selection (Syn-0, Syn-1, and Syn-2). Two cycles of recurrent selection were used to develop Syn-1 and Syn-2 populations from seven Syn-0 populations. Cycle 1 consisted of germinating 3,500 open-pollinated seeds of each Syn-0 population in water of -0.8 MPa potential to simulate a moisture stress. All seed that germinated within seven days (approximately 250 for each of the seven populations) were selected to create seven Syn-1 populations. Cycle 2 selection was identical to Cycle 1, except the Syn-1 populations were used to create seven Syn-2 populations. Our objective was to determine if laboratory selection of little bluestem for increased seed germination would improve its field establishment. Field testing in 2018 involved planting the 21 populations in a randomized block design replicated four times at four locations. Percentage field emergence was determined using a frequency grid method at 30, 60, and 90 d after planting (DAP). Moderate to extreme drought occurred during the establishment period across all locations. The percentage field emergence decreased from 30 to 90 DAP at one location, but increased across the same period at the other locations. At each location, percentage field emergence varied with little bluestem populations (P) and generations of selection (G, $P<0.05$), but not with P×G interactions ($P>0.05$). At 90 DAP, field emergence varied across locations from 3% to 46% for Syn-0 populations, 5% to 43% for Syn-1 populations, and 4% to 55% for Syn-2 populations. The Syn-2 populations of NU1, UC2, and UO2 performed well across all locations. Thus, selection for increased seed germination in little bluestem populations resulted in better field establishment.

Does the Signature of Sea Surface Temperature Anomalies Influence Livestock Production in the Western Great Plains?

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The impact of Pacific Decadal Oscillation (PDO) and El Niño-Southern Oscillation (ENSO) sea surface temperature anomalies has been demonstrated for aboveground net primary production (ANPP) in semiarid rangelands of the western Great Plains. During cold phase PDOs, mean ANPP was lower and more variable, and the frequency of low ANPP years (drought years) was much higher compared to warm PDO years. When ENSO index values were negative (El Niño), there was a higher frequency of droughts and lower frequency of wet years and higher ANPP regardless of the PDO phase. When PDO was in a warm phase and ENSO was positive (La Niña), drought only occurred about 20% of the years; when PDO was in a cool phase and ENSO was negative (El Niño), drought occurred almost half of the years. Questions remain though as to the influence of sea surface temperature anomalies on secondary (livestock) production (kg/ha) in these rangelands. Here, we use a long-term (since 1939) grazing intensity study at the USDA-Agricultural Research Service's Central Plains Experimental Range, a Long-Term Agroecosystem Research (LTAR) site, with livestock production data from light (20% use), moderate (40% use), and heavy (60% use) grazing treatments. We hypothesize that the influence of sea surface temperature anomalies on livestock production is more pronounced with heavy than moderate grazing, and the effects are more prominent during cold phase PDOs and when ENSO is negative (El Niño). We hypothesize that livestock production in the light grazing treatment largely unaffected by sea surface temperature anomalies due to the very conservative stocking rate employed in this treatment. We also relate these findings to rancher decision-making in this ecosystem with the recent switch in the PDO phase from cold (1998-2013) to warm (2014-present).

Dos and Don'ts of Drought (Climate Change) Workshops

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Drought poses multiple financial, ecological, and social risks for ranchers and rangelands. Despite the severe impacts of drought to ranching operations, it is a regular occurrence on western rangelands, and ranchers may have to take more drastic actions to adapt their operations in the future. Extension and outreach efforts need innovative, effective methods to reach producers with new science and decision-tools related to drought and weather. Colorado State University Extension and the USDA-Northern Plains Climate Hub collaborated through the Colorado Range School technical team to develop interactive, culturally relevant drought workshops. In this presentation we report on the planning process and lessons learned from these workshops, which were targeted at beef producers and local technical transfer partners across the state. We used literature on adult learning and rancher decision-making, and collaborated with local USDA and Extension professionals, to design locally-relevant and drought-responsive workshops. The format avoided excessive presentations from "researcher experts" and activities were based on the assumption that ranchers are experts in ranch drought management. Learning objectives focused on mitigation, preparedness, and response, and interactive activities and discussions sought to increase planning and goal setting skills, networking, and peer-learning. Workshop evaluations and team reflections provide key lessons learned for the design and implementation of engaging, effective drought workshops, including the importance of learner-centered design and cultural competence. This presentation will provide valuable insight for those looking to increase the efficacy of drought planning, and application of drought and climate science by rangelands managers.

Drought and Belowground Buds: Potential Impacts on Perennial Grass Bud Production, Quality, and Mortality

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In perennial grasslands, most stem recruitment occurs from belowground buds rather than from seeds. Therefore, bud banks are a key mechanism determining grassland response to climate and other disturbances. Drought could affect the bud bank directly by causing bud mortality or indirectly by affecting the provisioning and dormancy of buds and the provisioning of bud-bearing organs. First, we examined how bud traits of the dominant tallgrass perennial grass *Andropogon gerardii* responded to annual precipitation by focusing on how tiller density, bud production, bud size and mass, rhizome mass, and bud:rhizome allocation differed among years. Secondly, we examined the difference in bud survival and vegetative regrowth of three dominant mixed-grass and shortgrass steppe perennial grasses (*Bouteloua* spp.) along a simulated gradient of water stress. Over three precipitation years (570mm, 915mm, 1153mm; MAP=835mm) near Manhattan, KS, USA, plants of *A. gerardii* were harvested at the end of the growing season and their buds and rhizomes were counted and weighed. Precipitation had minimal effects on the numbers and mass of buds produced each year but did affect bud size. Although years differed in their cumulative precipitation, early season precipitation during the primary period of bud formation did not differ enough to greatly impact tiller recruitment and subsequent bud production. In a subsequent study, tillers of *B. curtipendula*, *B. dactyloides*, and *B. gracilis* were harvested from western SD, USA. Individual tillers were exposed to one of ten levels of osmotic drought and regrown under favorable conditions. Regrowth from the apical meristem depended on the species and level of drought. Axillary bud mortality was minimal. In summary, drought timing may affect bud quantity and quality (i.e., mass) more than cumulative season-long precipitation. Drought severity appears to determine apical meristem mortality and may influence the bud bank through bud dormancy rather than bud mortality.

Drought Effects, Early Detection, and Management Interactions in Montana Rangelands

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Precipitation is the single strongest controlling factor for rangeland productivity in eastern Montana. A series of experiments has determined rangeland response to timing of drought and potentially interacting management practices of grazing and fire. Rangeland production is strongly and positively related to April-May precipitation. Drought is common in the region, with more than 40% of the last 82 years having had April-May precipitation at least 25% less than average. Sixty percent of droughts have been one year in duration and 80% are less than three years long. The short period of effective precipitation limits potential for same-year drought recovery. Average perennial grass production is 69% complete by 1 June and 91% complete by 1 July, indicating forage availability can be determined by late spring or early summer. Summer precipitation adds little to production, but can be important for maintaining forage quality. Grazing and drought effects are typically independent of one another, but when there is an interaction, drought tends to nullify grazing effects observed without drought. Fire and post-fire precipitation effects on current-year production are independent as well. The primary differences have been with the dynamics of litter and standing dead. Drought has a lag effect on the next year's dead component that affects the magnitude of standing crop differences between burned and non-burned sites. Regionally, large reductions in biomass with spring drought can necessitate stocking rate reductions and precipitation is highly variable among years. However, data indicate grazing and fire can occur without compounding drought effects. The trigger point for drought effects on rangeland production is April-May precipitation and forage availability can accurately be assessed by 1 July.

Drought, Plant Adaptation, and Restoration in Sagebrush-Steppe Rangelands

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In sagebrush-steppe rangelands, restoration of perennials in response to wildfire and risks of exotic plant invasion has had mixed success. Drought is frequently cited as an obstacle to seeding efforts in these ecosystems, and information is needed to enable planting “the right seed at the right time and place”. We measured ecophysiological responses to low temperatures and water in 55 populations of big sagebrush from throughout the western US that were planted together in common gardens. Sagebrush is widespread and has high intraspecific variability attributable to subspecies, cytotypes (diploid, tetraploid), and local adaptation. Preliminary data reveal surprisingly little variation in photosynthetic water-use efficiency across the subspecies and cytotypes (range in delta 13C<0.75 per mil, N>500 plants), especially compared to the large variation observed among populations (≈5 per mil). Variation in 13C among populations was not well correlated with populations’ climate of origin, except for modest relationships for particular subspecies and gardens (0.5 per mil increase per 1000 degree-day increase; R^2=0.26). In contrast, responses to freezing were highly variable among populations, and were related to climate of origin, particularly in the critical wet-but-cool growing period in spring. Populations from continental climates where temperature extremes are greater exhibited greater freezing avoidance but less tolerance, as revealed by temperatures at which leaf freezing occurs and photosynthesis decreases by 50% (FvFm, chlorophyll fluorescence). Interestingly, populations from colder origins with correspondingly greater freezing tolerance had less survival in the gardens, implicating a freezing-tolerance and growth tradeoff that can help explain lower success of the historically common transfer of seed from cold to warm planting areas. We propose that a growth strategy of freezing avoidance, but not tolerance, confers ability to make physiological use of the spring moisture and thereby increase chances of drought survival.

Dynamic Rangeland Species Composition in the APEX Model

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APEX is a process-based model that simulates agricultural productivity and environmental outputs. The model has been primarily used to simulate cropland but has recently been adapted for rangelands. We evaluated the model's ability to simulate competition among species and to identify areas for improvement. Specifically, we simulated decadal changes in plant species composition in response to grazing management. We simulated prairies at Hays, Kansas, recreating experimental treatments described in the published literature. Experimental treatments included: 1) intensive early stocking (0.5 or 0.7 ha·steer^{-1}) vs. season-long grazing (1.4 ha·steer^{-1}) and, 2) a stocking reversal experiment where long-term stocking densities were followed by five years of a new stocking density (0.8 to 2.0, constant 1.4, or 2.0 to 0.8 ha·steer^{-1}). We also simulated an additional, "extra-early" grazing treatment not found in the published studies (grazing from 15 April to 1 June at 0.5 ha·steer^{-1}). For the intensive early-stocking study, the model and field work both identified decreasing percentages of *Pascopyrum smithii* and increasing *Bouteloua dactyloides* over time when the stocking rate was 0.5 ha·steer^{-1}. However, the simulation also predicted increases in *Ambrosia psilostachya* and *Bouteloua dactyloides* that were not identified in the published study. Under the most extreme simulated treatment ("extra-early"), the C4 shortgrasses *Bouteloua dactyloides* and *Bouteloua gracilis* increased while the C3 grasses *Bromus arvensis* and *Pascopyrum smithii* decreased. In the stocking reversal experiment, the field study showed a decrease in *Bouteloua dactyloide*s when stocking changed from 0.8 to 2.0 ha·steer^{-1} but the simulation failed to capture this dynamic. Overall, results suggested the model's strength is to simulate long-term rather than short-term vegetation dynamics and relatively extreme management scenarios rather than small changes to stocking density. Simulated predictions might be improved by adding species-specific input parameters for vertical biomass distribution and regrowth after grazing.

Ecological Impacts of Drought Depends on Seasonal Timing in a Semi-Arid Rangeland

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The southwestern US is projected to become warmer, drier, and with more frequent and intense droughts with climate change. Winter and spring precipitation is also forecast to decrease in the region, and this may have large ecological effects on ecosystems such as the Colorado Plateau, which rely heavily on cool season precipitation for soil moisture recharge. Livestock production in the Colorado Plateau may be particularly vulnerable to cool season droughts because cattle rely heavily on cool season forage, which is dominated by C3 grasses. To investigate the impacts on changes in the seasonality of drought on the Colorado Plateau, we conducted an extreme drought experiment in a native semi-arid rangeland in southeastern Utah starting in 2015. The experiment consisted of three treatments: a control (ambient precipitation), a warm season drought (66% precipitation reduction May-Oct.) and a cool season drought (66% precipitation reduction Nov.-Apr.). We measured species-level responses of the dominant C3 grass, *Achnatherum hymenoides*, and the dominant C4 grass, *Pleuraphis jamesii*, as well as community- and ecosystem-level responses. Our goals were to assess the resistance to the seasonal timing of drought of these key species, and identify the underlying mechanisms governing the observed responses. After three years of the experiment, we found strong responses to the seasonal drought treatments, with differential responses by plant functional type. Cover and biomass of the C3 grasses and forbs decreased the most with cool season drought, while warm season drought had the biggest impact on the C4 grasses. At the species-level, we observed effects on phenology and ecophysiology related to the timing of drought and the temporal availability of soil moisture. These results suggest that the seasonal timing of drought in this semi-arid rangeland can alter the structure and function of the ecosystem, resulting in large ecological effects as well as potentially negative impacts on livestock production.

Economic Effects of USFS Permitted Grazing Reductions due to Wild Horses on the Devil's Garden

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The Devil's Garden is a vast basalt plateau located in Modoc County in northeastern California. Managed primarily by the United States Forest Service (USFS), resource uses include livestock grazing, wild horses, and a blend of upland and wetland wildlife habitat. In recent years wild horse populations (3,900 animals) have significantly exceeded appropriate management levels (204-402 animals). A short-term response by the USFS has been to decrease the number of permitted AUMs of cattle grazing in an attempt to alleviate grazing pressure. The objective of this study is to quantify potential economic impacts of reductions to grazing permits on the Devil's Garden. Fifteen ranchers who graze cattle on the Devil's Garden were surveyed and given scenarios of grazing reductions of 10%, 25%, 50%, 75% and 100% for their USFS permits. This information included possessory use taxes, money spent to maintain grazing allotments, number of trips taken to their grazing allotment each year, anticipated actions they would take if their permit was limited and others. Under current grazing reductions, the impact to the county is relatively small totaling $250,735 or 0.09% of the total county budget, but additional cuts showed a potential increase to over $3.8 million or 1.38%. Impacts were also estimated over a per AUM basis and totaled $45-$113/AUM lost to the county. Most of the money lost in these scenarios from taxes impact the Modoc County general fund which funds county services such as the ambulance, rural fire, and the county libraries. The Modoc County general fund totaled $5.1 million in 2018 and is decreasing. A large portion of the Modoc County budget is state and federal funding. A complete loss of grazing on the Devil's Garden would greatly impact this fund and the services that the county currently provides to its residents.

Effect of Growing Season Burns on Forage Quality of Browse Plants in the Cross Timbers

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Prescribed burning is a popular land management tool used in the southern Great Plains that is typically used during the dormant season. Growing season burns are growing in popularity, but the impact of fire on the forage quality of browse species is important to understand so land managers can better manage their resources for wildlife and livestock. Five browse species were sampled in the growing season of 2017 before and after a July burn and compared to an adjacent site that was not burned. The five browse species sampled were Chickasaw plum (*Prunus angustifolia*), smooth sumac (*Rhus glabra*), poison ivy (*Toxicodendron radicans*), roughleaf dogwood (*Cornus drummondii*) and greenbrier (*Smilax bona-nox*). It appears that growing season burns do not impact TDN or ADF. However, all species except for roughleaf dogwood showed an increase in crude protein following the burn compared to the control. The burn effect on crude protein lasted for two months for greenbrier and smooth sumac. There was only a one month effect of fire on crude protein for Chickasaw plum and poison ivy. These results indicate a need to frequently burn areas of native vegetation throughout the year to provide a high plane of nutrition at all times.

Effectiveness of Mechanical Cutting Versus Prescribed Fire as Means of Controlling Juniper Expansion in Sagebrush-steppe

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Woody vegetation has increased on rangelands worldwide the past 100-200 years, often because of reduced fire frequency. An aversion to re-introducing fire, in part due to the risk of exotic plant invasion and habitat loss, has lead land managers to employ mechanical treatments to control expanding woody vegetation. Information on treatment longevity, sagebrush recovery, and post-treatment exotic plant response of burn versus mechanical treatment of woody vegetation is limited. We compared mechanical cutting with prescribed burn treatments applied over the last ~30 years to control western juniper (*Juniperus occidentalis* Hook.) expansion into sagebrush-steppe communities on 77 sites in Eastern Oregon. Fire resulted in longer control of juniper than cutting. Juniper density in burned areas took 30 years to approach the density in cut areas measured immediately after treatment. Recovery of juniper cover and density were more rapid on cut than burned areas. Sagebrush was reduced with burning but post-treatment change over time in burn vs. cut areas were similar. Sagebrush, however, is predicted to dominate the overstory longer in burned than cut areas as a result of more effective juniper control. Exotic annual grass cover was similar between treatments and was not influenced by time since treatment. Variation in annual grass cover was correlated to site characteristics, perennial grass density, and their interaction. Re-introducing the historic disturbance, fire, was more effective than cutting at controlling juniper expansion in sagebrush-steppe communities. Counter to general assumptions, burning compared to cutting did not increase annual grass cover. Results suggest prescribed fire remains a valuable ecosystem tool to meet management objectives in sagebrush-steppe communities. Environmental characteristics and perennial grass abundance can be used to predict where exotic annual grasses may be problematic and indicate where cutting would be more effective or where additional management inputs may be necessary.

Effects of Defoliation Frequency on Regrowth Potential of Clonal Non-Native Grasses

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Perennial grass population persistence against various environmental disturbances such as grazing is mediated by the belowground bud bank. Furthermore, clonal traits associated with the rhizomes contribute to plant population dominance, persistence, and spread in plant communities. However, we know little about the role of these regenerative traits in regulating persistence and spread of invasive perennial grasses like smooth bromegrass (*Bromus inermis*) in response to control managements. Our objective was to evaluate the impacts of mowing frequency on belowground bud compositions and their viability, and rhizome morphological traits of smooth bromegrass. The study was initiated at Oak Lake Field Station in eastern South Dakota in 2013. The experiment consisted of four mowing treatments (no-mowing control, mowing once, twice or three times annually in June, August, and October) in a randomized complete block design with four replications. In October 2015, three soil cores (10-cm dia. X 10-cm depth) were taken from each plot. Underground plant structures were washed free of soil and examined for the number of axillary buds, rhizome buds, bud viability, tiller recruitment, and rhizome vigor in terms of length and biomass. We found mowing had no effect on total axillary and rhizome bud production (#/0.1m^3) at this sampling time. However, mowing treatments significantly decreased the number of tiller outgrowths from distal crown positions (#/0.1m^3, P=0.0055), rhizome dormant bud density (#/0.1m^3, P=0.039), viable rhizome length density (cm/m^3, P=0.0007), viable rhizome and total rhizome biomass (P=0.0001). Mowing three times reduced daughter tiller density by 55% compared to control. We also found that ~70% of total viable buds were rhizome buds, while ~30% viable buds were axillary buds across all treatments, which prioritized guerilla growth form via bud bank. Our results suggested constant removal of photosynthetic area can effectively deplete rhizome reserve and may reduce tiller recruitments, but there is a lag effect on the bud production.

Effects of Disturbance on Soil in the Northern Great Plains Grasslands

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Disturbances, such as grazing and fire, in the Northern Great Plains influence soil hydrological processes. This study assessed the impact of intense winter grazing (winter 2016-17; IWG) and a wildfire burn (October 2016; WFB) disturbances compared to regular season-long continuous grazing (non-burned and non-intensely grazed pastures; CG) on changes in soil moisture, temperature, and infiltration rates in western South Dakota grasslands. Nine exclosures (3 IWG, 3 WFB, and 3 CG) were monitored over the two growing seasons (summer 2017 and summer 2018) following the disturbances. Prior to application of disturbances, the pastures were grazed at low (two pastures) or moderate intensity (one pasture) season-long continuous grazing. Preliminary data analysis indicates CG pastures display higher amounts of soil moisture. A greater statistical difference was observed at greater depths. CG treatments maintained the highest average soil temperature over the two-year period, followed by IWG and WFB. The greatest variation in soil temperature between treatments occurred in warmer months of the growing season (May-September). Soil infiltration varied across treatments as well as within the same treatment in different pastures. This research will provide information on the effects of grassland management practices on soil health.

Effects of Fire Exclusion on Vegetation in Fire-Managed Rangeland of the Edwards Plateau

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Long-term (>100 yr) fire exclusion is associated with numerous ecological consequences in grasslands and savannas, including transitions of these systems into shrub-dominated woodlands. Several studies have reported differences in woody vegetation resulting from long-term experiments comparing burned and unburned pastures, as well as pastures burned during different seasons. We evaluated the effects of fire exclusion on herbaceous and woody canopy cover (overstory and understory) using line-intercept measurements, as well as herbaceous biomass, in pastures with known burn histories. Pastures were burned in summer or winter in 1994, 2000, and 2006, followed by a period of fire exclusion. After 11 years of fire exclusion, herbaceous biomass was similar among all treatments. Herbaceous biomass was also lower in 2017 (85.4 g/m^2) than in 1994 (177 g/m^2). Understory canopy cover increased in all treatments between 2006 and 2017, while overstory canopy remained similar. Herbaceous cover decreased in all treatments but was higher in burned treatments than controls. These trends support other research findings that demonstrate the importance of prescribed fire at historic seasons and return intervals in maintaining grassland and savanna systems.

Effects of Grazing on Reed Canary Grass Invasion on Restored Wet Meadows

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Reed canary grass (*Phalaris arundinacea*) is an exotic grass species that can dominate wet meadow plant communities. Cattle will graze reed canary grass if given the opportunity. We investigated if grazing by cattle on restored wet meadows suppresses reed canary grass thereby promoting the restored pant community. This study was conducted at two locations in northwest Minnesota. One of the restored locations was managed with a patch-burn grazing cycle started in 2010 and the other restored location had a four-pasture grazing rotation started in 2012. The patch-burn location had season-long grazing with patches being burned on a four-year cycle. The four-pasture rotation location used a high-intensity targeted grazing system with several short 7-day rotations when reed canary grass was vigorously growing. Due to watering problems, the rotation system ended up most years with pastures being grazed for two to three months with no rotation. Data was collected using percent cover in three 1 m^2 frames randomly located in reed canary grass dominated patch with a paired plot located on a patch not dominated by reed canary grass, but within 30 m of the patch. A pretreatment survey was conducted before any grazing followed by surveys four to five years after grazing started. Preliminary results found that at the patch-burned grazed location there was 49% reduction in reed canary grass canopy cover compared to ungrazed control sites with a similar reduction at the four-pasture rotation site. This demonstrates that grazing can reduce the cover of reed canary grass. Analysis of the restored plant community after grazing at both the reed canary grass dominated patch and the outside patches not dominated by reed canary grass are ongoing.

Effects of Huisache and Honey Mesquite Canopy Cover on Soil Nutrients

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Huisache (*Acacia farnesiana* [L.] Willd.; Fabaceae) and honey mesquite (*Prosopis glandulosa* Torr.; Fabaceae) are small trees or shrubs readily invading Texas rangelands, inhabiting approximately 2.7 million acres (huisache) and 22.7 million acres (honey mesquite). Conventional control methods such as mechanical and chemical control can be expensive and difficult, due to their ability to expand in density quickly and the capability to resprout after disturbances. The objective of this study is to look at the effects of canopy cover on soil nutrients. Total canopy cover (including individual huisache and honey mesquite canopy covers) and soil samples were taken on four test plots with a total of 10 transects (n=10 each). Soil samples were evaluated for pH level, N, P, K, Ca, Mg, S and Na by Texas A&M soil labs. Total canopy cover varied between 48.3-138%, huisache canopy ranged from 19-93.67% and honey mesquite varied from 3.67-88%. The effects of huisache + mesquite, huisache and mesquite canopy cover were evaluated against soil nutrient levels using a one-way ANOVA with a significance level of P=0.1. The combination of huisache + mesquite canopy cover significantly influenced pH levels (P=0.0557, df=9, Radj=0.307864). Likewise, Ca levels were significantly influenced by huisache + mesquite canopy cover (P=0.0780, df=9, Radj=0.255058). In addition, Ca levels were significantly influenced by mesquite canopy cover (P=0.0827, df=9, Radj=0.245722). Mg levels were also significantly influenced by mesquite canopy cover (P=.0788, df=9, Radj=0.253384). All other comparisons between percent canopy cover and type to soil nutrients were not significant. Although legumes such as huisache and mesquite might be expected to affect soil nitrogen, we found instead effects on pH, Ca, and Mg. The mechanism for these effects is unknown, but should be further studied.

Effects of Single-Season, High-Stocking Rate, Short-Duration Grazing on Texas Wintergrass (*Nassella leucotricha*)

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The Cross Timbers and Rolling Plains ecoregions, once diverse grasslands, are succumbing to woody encroachment by honey mesquite (*Prosopis glandulosa* Torr.) and the concurrent herbaceous takeover by Texas wintergrass (*Nassella leucotricha* Trin. & Rupr.). Documentation of this problem is extensive with no clearly stated solution. Researchers hypothesize that the cattle industry has largely driven this encroachment via overgrazing and changing of historic usage of the land. Attempting to utilize the cause as a solution we will use an average stocking density associated with high-intensity grazing (approximately 33,600 $kg \cdot ha^{-1}$) to jumpstart the restoration to a balanced native vegetation. We propose that cattle, when managed correctly, can benefit ecosystem health. We will determine if a single defoliation event (via high-stock grazing or mowing) opposed to repeated defoliation influences Texas wintergrass seed production, wildlife habitat structure, and herbaceous biomass and whether grazing affects soil health (bulk density, soil moisture, and nutrient composition) over the course of one growing season. Proposed benefits of this type of high-stock system include increased nutrient availability and forage yields via carefully timed defoliation events, in winter grazing we attempt to remove wintergrass overstory (to stress plants and reduce seed production) while increasing nutrients available (via cattle waste) to promote native warm season grasses and forbs. Restoring these ecosystems could create habitat diversity for many native bird species, including bobwhite quail (*Colinus virginianus*), as well as improved forage for cattle operations.

Effects of Wild Horses on Wildlife at Springs and Riparian Zones on the Devil's Garden

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In Modoc County, located in northeastern California, there is a unique rangeland area heavily populated by wild horses and managed primarily by US Forest Service known as the Devil's Garden. Currently, there are 3,900 wild horses, significantly exceeding appropriate management levels projected between 204 and 402 horses. In recent years wild horses have also expanded their range outside of the herd management area of 250,000 acres and on to private and tribal lands, expanding to 450,000 acres. This increase has prompted concern about resource degradation particularly associated with spring areas. In otherwise arid sage steppe rangelands springs provide critical watering sources as well as wildlife habitat for sage grouse, deer, elk, pronghorn, and other wildlife. Our objective is to quantify the relative frequency, duration, and timing of use by horses, permitted livestock, and wildlife at spring locations. In turn, we assess to what extent there is competition between species for watering sites. We also correlate how varying levels of horse and/or livestock use affects spring site vegetation and riparian health standards. Five representative study locations were selected on the Devil's Garden and motion sensitive cameras were deployed at each location for a six-week sampling period during the summer of 2018. All photos were visually assessed to record species present, number of each species, and the time, date, and location of the observation. We present preliminary occupancy data, as well as results of corresponding vegetative cover, plant community, and bank alteration sampling. Implications for management and on-going research are discussed.

Effects of Fire, Drought, and Soil Fertility on Herbaceous Communities in a Semi-Arid Savanna

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Understanding the responses of savanna vegetation to disturbance and altered resource conditions will gain importance under climate-change induced modifications to precipitation patterns and nutrient cycling. We are investigating 1) how an herbaceous community within a semi-arid savanna will respond to prescribed fire, drought, and soil fertility and 2) how these factors will interact to alter those responses. We established 64 5x5m, grass-dominated plots at the Texas A&M AgriLife Research Station on the Edwards Plateau, a generally shallow-soiled savanna ecoregion (lat 31°N, long 100° W). We randomly assigned a prescribed fire treatment (burned or control), precipitation treatment (rainfall interception or ambient), and nutrient treatment (nitrogen addition or control) to each plot in a full factorial, completely randomized experimental design. Changes in soil nitrogen (Pre-treatment $\bar{x}$: 0.32%), total organic carbon (Pre-treatment $\bar{x}$: 3.32%), pH (Pre-treatment $\bar{x}$: 7.63), and vegetation nitrogen (Pre-treatment $\bar{x}$: 2.35%) are being compared pre- to post-treatment years. Vegetation community parameters including Shannon's diversity and biomass (Pre-treatment $\bar{x}$: 57.36 g/m^2) are also being compared between treatment groups across seasons. Preliminary results, though not statistically significant ($p>0.05$) indicated that Shannon's diversity was lower during the droughty summer months than in winter months and was lowest in the burning combined with nitrogen addition treatment. Ongoing comparisons between treatments will identify the effects of fire, drought, and soil fertility on herbaceous vegetation in semi-arid savanna ecosystems, and will also demonstrate how these factors may interact in a changing climate. These results will provide insights into how managers and ecologists can use the feedbacks between prescribed fire, drought, and soil fertility to maintain biodiversity, desirable cover ratios, biomass production, and protect semi-arid savanna systems from degradation.

Enhancement of Hay and Crops Straw Using Urea and Sodium Hydroxide, North Kordofan, Sudan

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The study was undertaken at the range-livestock research laboratory, El-Obeid Agricultural Research Station, with the objective of improving the digestibility of hay and crops straw. Samples were treated using 5%, samples (Cowpea and Groundnut haulms, Sorghum and millet straws, early hay, lately hay and Roselle straw) were fermented for three periods (15, 30 and 45 days). Proximate analysis and in vitro digestibility were done. The experiment was arranged as factorial in an RCBD. The results showed that groundnut haulms, sorghum straw and millet straw had the highest crude fiber content (53%, 47.5% and 42%, respectively) while cowpea and groundnut haulms recorded the highest crude protein content (16.5% and 14.5% respectively). Urea and sodium hydroxide treatments resulted in significantly increased IVDMD of cowpea hay, and groundnut haulms compared with Roselle and untreated residues, with combined urea + sodium hydroxide treatments recorded the highest IVDMDs. Fermentation for a period of 30 days had resulted in higher IVDMDs compare with periods of 15 and 45 days. Respective IVDMDs for cowpea hay for 0 (control), 15, 30 and 45 days were 65, 70, 88 and 87%, those for groundnut haulms were 65, 70, 85 and 80, and those for Roselle were 34, 45, 69 and 69%). *Cassia fistula* mature pods recorded 19 and 19.5% crude protein and fiber, while green pods were 17 and 17%. The IVDMD were 68, 62.6 and 61.48% for green pods, leaves and mature pods respectively. The study concluded that urea, sodium hydroxide mixture and sodium hydroxide improve hay and crops residues; nutritive value in the terms of IVDMD and CP. Therefore we highly recommend the use of urea and sodium hydroxide mixture to improve hay and crops residues by fermentation for 30 days.

Establishment of Select Native Legumes of the Canadian Prairies

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Interest in identifying native legume species for forage production in mixed stands is increasing due to their recognized potential benefits to forage quality, soil health and other ecosystem services. There is a need to determine the establishment success of individual legume species, particularly those displaying adaptation to low rates of precipitation and high evapotranspiration which can limit forage production in semi-arid regions. Regions projected to increase under the present climatic changes. At this time there is little species specific information available on germination, seeding rate and establishment in semi-arid regions of *Vicia americana*, *Dalea purpurea*, *Hedysarum boreale* and *Astragalus flexuosus*. Therefore, the objective of our study was to determine the establishment potential of these four native perennial legumes in the dark brown and light brown soil zones of Saskatchewan for use in forage production in the Canadian prairie region. The species were seeded in monoculture and polyculture plots with Meadow brome at a rate of 100 PLS/m. The establishment success of the selected legumes was evaluated in the fall following spring seeding, and repeated two years after planting to determine their comparative rates of survival between the two climatic regions.

Estimates of Butterfly Density in Mixed-Grass Prairie with Restored Disturbance Regimes

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Grassland organisms evolved with the interaction of fire and grazing, but traditional management often decouples these disturbances. Restoring the interaction of fire and grazing can create heterogeneity in vegetation structure, which could benefit grassland organisms. However, fire can cause direct mortality to organisms such as invertebrates, so it is important to assess the influence of management practices that promote restoring disturbance on invertebrate communities such as butterflies. We quantified butterfly densities in northern mixed-grass prairie under three different management regimes that varied in the spatial and temporal application of fire and grazing. One treatment consisted of burning ¼ of a pasture in the dormant season each year (PBG1), one consisted of burning 1/8 of a pasture during the dormant season, followed by 1/8 of the pasture during the growing season (PBG2), and the third treatment represents traditional management with season long grazing in the absence of fire. All treatments were moderately stocked with cow-calf pairs. Overall butterfly abundance did not vary between treatments, but we did find varied species-level responses depending on life history needs. Three grassland obligate species showed higher densities in the PBG treatments as compared to the SLG treatment, and four facultative species, which are those not solely dependent upon grassland habitats, had higher densities in the PBG treatments as compared to the SLG treatment. No species showed a higher density in SLG when compared to the PBG1 or PBG2. These results include two years of the four years required to fully implement the PBG treatments, but preliminary results indicate that restoring the interaction of fire and grazing could have a positive influence on butterfly densities, especially grassland obligate species.

Estimating the Economic Value of U.S. Beef Cattle Ranching Based Ecosystem Services

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Ranching operations in the United States use 337 million acres of land to produce $33.9 billion in gross revenue from the production associated with 20.4 million head of beef cows. Of the 337 million acres, 257 million are classified as permanent pasture and rangeland. Clearly, the economic value of beef production is just one component of the suite of values derived from cattle ranching. Additional economic values associated with cattle ranching also include ecosystem goods and services such as recreation opportunities and wildlife habitat. If only the economic value of beef production is considered, decoupled from associated benefits, the total economic value of cattle ranching will be underestimated. Previous research has shown that there are substantial ecosystem service values associated with the pasture and rangeland used for cattle production (NRCS 2010; Taylor et al 2011; Rashford et al. 2013; Maczko et al. 2011; Maczko and Hidinger (eds) 2008). Building on work by Rashford et al. (2013), the economic value of several aspects of cattle ranching related ecosystem services was estimated using readily available data. Specifically, this project estimates the ecosystem service values of forage production, general ecosystem services, and wildlife recreation for pasture and rangeland used in cattle production for the U.S. Forage production values were based on National Agricultural Statistic Service pasture rental rate data, and other values were extracted from Farm Services Agency and US Fish and Wildlife Service information. Calculations and analyses permitted estimation of the economic value of beef cattle ranching ecosystem services by state, and an estimate of the total values for the U.S. Results include estimates of the total value of rangeland and pasture land ecosystem services, as well as values per beef cow and per pound of beef produced. This project is funded by the Beef Checkoff through the Sustainable Rangelands Roundtable.

Estimation of Available Browse Biomass Productivity in Semi-Arid Areas of White Nile, Sudan

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This study was conducted in “Clikis” forest plantation at White Nile State of Sudan, where browsing plays an essential role in feeding animals especially during dry seasons when herbaceous forage is unavailable. The objective was to estimate available browse in the forest. Nine circular sample plots 0.01 ha were used. Twig count method was applied to estimate available browse and the growth parameters, total height (H) and crown area (CA) were measured from 10 sampled trees for each species. Leaves and edible twigs of the sampled trees were clipped, oven dried, weighed and recorded as dry weight. Regression equations were developed between the estimated available browse (AB) and the growth parameters of the trees. The results showed that *Acacia seyal* exhibited the highest average available browse per tree (0.21 kg/tree) and highest tree density (1,470 tree/ha) compared to *Acacia nilotica* and *Prosopis juliflora* that indicates the amount of available browse increases linearly with increasing the tree density. Results indicated that only CA showed a strong correlation with AB for *Prosopis juliflora* (R^2=0.94) and H showed strong positive correlations with AB for *Acacia seyal*, *Acacia nilotica* and *Prosopis juliflora* (R^2=0.93, R^2=0.80 and R^2=0.76, respectively). The study concluded that growth parameters including crown area and height can be used as a correlation variable to assess AB for the trees studied. Different densities interfere with the determination of AB and for this different levels of densities and ages might be further investigated in relation to browse assessment.

Evaluating Native Perennial Grass Tolerance to Indaziflam Treatments

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Invasive winter annual grasses, such as *Bromus tectorum* (downy brome), currently occupy up to >22 million hectares in the western United States, with an estimated annual spread rate for *Bromus tectorum* of ~14%. The loss of ecological resilience, biodiversity, and deviation from historic fire regimes from these winter annual grasses have been well documented. Limited viable treatment options exist, but chemical control options with long-term residual soil activity have been stated as important factors to native regeneration and recovery. Indaziflam, a new herbicide option for invasive winter annual grasses in non-grazed rangeland and natural areas, has been shown to provide long-term residual control of germinating cheatgrass while showing little to no effect on native perennial grass species production. Previous published research has shown no negative impacts from indaziflam treatments to desirable species abundance and biomass, although no published research has evaluated impacts to seed production and viability. A field trial was conducted at the Plants Material Center in Meeker, CO to assess tolerance of 14 desirable perennial grass species to the herbicide indaziflam. Herbicide applications of indaziflam (73 and 102 $g{\cdot}ai{\cdot}ha^{-1}$) were made to perennial grasses in August 2017. In August 2018 (1 YAT) vegetative biomass, seed production biomass, and seed viability data were collected to assess any herbicide impacts on the perennial grass species. There was no significant decrease in vegetative or seed production biomass across all 14 perennial grass species in plots treated with indaziflam at both rates compared to the control plots. This data provides critical tolerance information to aid land managers in understanding the effects of this new tool for invasive annual grass control on desirable perennial grasses.

Evaluation of Noninvasive Specimens to Diagnose Livestock Exposure to Poisonous Plants

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Economic losses to the livestock industry from poisonous plants in the western United States is estimated to be over $500 million annually. Larkspurs (*Delphinium* spp.) and lupines (*Lupinus* spp.) are two such poisonous plants found throughout western rangelands. Livestock losses from larkspur have been reported to range from 2-5% annually with losses as high as 15%. Some lupines are teratogenic to cattle and cause crooked calf syndrome when consumed between 40 and 100 days of gestation. Determination of livestock deaths due to poisonous plant ingestion can be difficult and often requires the collection of serum, tissue, rumen and gastrointestinal samples, often from dead animals, for a proper diagnosis. The use of noninvasive specimens such as earwax have not been evaluated as potential specimens that may be used in investigating plant poisoning cases. Earwax, hair, oral fluid, and nasal mucous from livestock in controlled dosing studies were analyzed for toxic plant alkaloids by high-performance liquid chromatography-high resolution mass spectrometry (HPLC-HRMS). These samples may prove to be valuable forensic tools in the diagnosis of livestock exposed to and poisoned by toxic plants.

Evening the Playing Field for Reclamation Evaluation on Colorado Rangelands

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Rangelands are typically characterized by low precipitation and low biomass which makes them susceptible to disturbance and difficult to reclaim. This becomes a management issue when considering the widespread and significant impact of oil and gas development on rangelands. Reclamation from this land use also involves the complexities of dealing with multiple agencies, private land-owners, and their sometimes conflicting rules, when performing and evaluating reclamation. Reference sites (e.g., nearby undisturbed sites) can help with these issues because they are selected to provide a comparison that is similar to a reclamation area in most aspects except for the disturbance activity, so that the relative condition of the reclamation site can be determined. Since selection of reference sites is normally expert-driven on a site-by-site basis, it can be ineffective in helping to meet reclamation goals over large landscapes. The Automated Reference Tool (ART) was developed to improve the efficiency and efficacy of reference site selection though remote sensing and indicators of land potential by selecting reference sites of similar land potential to the reclamation area based on soil texture, topography, and geology. We evaluated the ART in the context of well-pad reclamation to determine if ART-selected areas were appropriate to use as reference areas when compared to an existing reference site network. We applied the ART to reclamation sites managed by the Bureau of Land Management’s (BLM) White River Field Office, Colorado which had existing reference sites. Based on field collected and spatial analysis results, plant diversity and cover were usually similar between the ART selected reference area and their matching reference site. They were also found to be similar based upon particle size class, depth to restricting layer, and other soil characteristics. These results demonstrate that ART could be a useful tool in helping managers meet their reclamation goals.

Examination of Fire and Grazing-Induced Vegetation Heterogeneity on Trophic Level Relationships – Small Mammal Diversity

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Small mammals are important indicators of biodiversity and directly and indirectly affect biota. Understanding how land-use practices such as grazing management may affect biodiversity, specifically for small mammals, is needed. Because existing studies typically focus on the diversity of single trophic groups, particularly producers/plants, neglecting the fact that the functional effect of any trophic group may depend on the abundance and diversity of others. Our study took place at the South Dakota State University (SDSU) Cottonwood Range and Livestock Field Station located in western South Dakota, where mixed-grass prairie is predominant. Our objective was to examine and document what impacts patch-burn grazing (PBG), winter-patch grazing (WPG), and summer season-long grazing (CG) managements may have on species richness, abundance, and diversity for small mammal communities. We trapped three consecutive nights every two weeks from July to August in 2018. We placed Sherman live traps (76-mm X 89-mm X 229-mm) in three enclosures (5-m X 5-m) per treatment for three livestock pastures with peanut butter and rolled oats. We evenly placed five traps within each enclosure for a total of forty-five traps per night per pasture and three treatments. We surveyed trapping sites for a total of 495 trap-nights. We caught thirty-five small mammals total with seven recaptures belonging to only one species, deer mice (*Peromyscus maniculatus*). We captured most individuals in the WPG and PBG treatments. Species richness is one. While we expected low small mammal diversity, the presence of only one species was unexpected. This could be related to the few number of traps and trap-nights. Lack of diversity could also be related to livestock presence, and weather condition. Results from this study will help land managers understand the impact that grazing management has on small mammal biodiversity.

Exploring Utilities of Spectral Diversity for Representing Plant Diversity and its Spatial Pattern

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Patterns of spatial heterogeneity in vegetation are important in pyric-herbivory studies, potentially influencing the patterns of burn, vegetation regrowth, livestock use, and subsequent burns, but have rarely been explored. In this study, we explore the utilities of spectral diversity for representing the herbaceous plant diversity and its spatial pattern. Airborne hyperspectral imageries with 120 bands at 5.1826-nm bandwidth (381.895-nm and 998.622-mn) and 0.5 m resolution were acquired on two research ranches (~5,000 acres each) in the Edwards Plateau of Texas. Herbaceous plant composition and cover were sampled in randomly located 1mX1m quadrats stratified by representative soil types and physiognomy of vegetation. We examined the relationship between spectral diversity, in Shannon's diversity and evenness indices calculated based on the spectral data, and the field data-based herbaceous plant richness, Shannon's diversity and evenness indices at the sample locations. Our preliminary results showed there was a significant correlation between the spectral- and field-based Shannon's indices ($r=0.2484$, $p=0.0176$). When examined for different vegetation classes, areas dominated by bare ground/rock, grasses, small shrubs, and large shrubs, the correlation between the spectral- and field-based Shannon's indices were statistically significant only in the areas dominated by grasses ($r=0.3808$, $p=0.0456$). It was possible that the spectral information related to the bare ground or woody vegetation might introduce noise for the relationship. There was also a significant correlation between spectral-based Shannon's index and herbaceous plant richness ($r=0.3012$, $p=0.0037$). We are currently exploring subsets of the bands and their transformations that may be more relevant to the herbaceous vegetation and its diversity, as well as other variables representing spectral diversity. Findings of these explorations can potentially help develop spectral diversity measures that can meaningfully represent the herbaceous plant diversity and its spatial patterns.

Facilitating Cheatgrass (*Bromus tectorum*) Fuels Reduction: What Defines a Resistant Plant Community

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The Martin fire near Paradise Valley Nevada burned over 400,000 acres in less than a week during July 2018. This was the single largest fire recorded in Nevada history. The ease to which fires start and spread can largely be attributed to cheatgrass fine fuels. Managing cheatgrass to prevent habitat loss is critical for the survival of native plants, wildlife and domestic animal sustainable grazing practices. The best means to suppress cheatgrass is the presence of a long-lived perennial grass. This intuitive concept now termed “resistance” involves many questions such as which species exhibit the greatest suppression effect. We present results from three experiments to examine these questions. One experiment examined establishment and cheatgrass “resistance”. A second experiment examined abiotic factors that affect cheatgrass suppression. A third experiment measured perennial grass soil resource depletion, or ability to “resist” cheatgrass. Results found cheatgrass herbicide control was required to establish native grasses unlike introduced perennial grasses. Introduced grasses suppressed cheatgrass fuels by 93% compared to 74% for native grasses. Abiotic factors found to effect suppression were increased precipitation and cheatgrass litter which both increased soil moisture resulting in decreased suppression. We found that four of nine perennial grass species tested significantly depleted soil moisture and nitrogen, the mechanism by which cheatgrass suppression occurs. Of the four, two species readily established during the first experiment, crested wheatgrass and bluebunch wheatgrass and they reduced soil nitrogen by nearly 75% and soil moisture by 50%. Resource depletion by perennial grasses is a suppression mechanism and differs by species making some species ineffective and some highly effective for fuels reductions. Competition for resources is the means by which resistance can be defined. In order to facilitate resistance, perennial plants must have the potential to establish, persist and effectively compete for resources.

Factors Influencing Prescribed Fire Application in North Dakota Rangelands

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Rangeland ecosystems are dependent on fire and grazing to maintain the biodiversity that upholds ecosystem function and services. Removal of these disturbances results in degradation due to invasions by non-native species, woody encroachment, and homogenization. In the Northern Great Plains, the bulk of rangelands are privately-owned working landscapes managed for livestock grazing. Thus, land management decisions, such as the decision to use prescribed fire, are shaped by individual landowner attitudes and perceptions. To further understand the sociological influences of implementing prescribed fire in the region, we mailed a self-administered questionnaire to 460 landowners in six counties in North Dakota. We identified four latent factors indirectly from the data; attitudes, constraints, skill and resources, and subjective norms, and fit a measurement model to verify relationships. We built a structural equation model to test relationships between these factors and the respondents' decision of whether to implement a prescribed burn. Of the 460 surveys that were mailed out, we received 96 usable responses for an adjusted response rate of 21%. We found that overall, landowners sampled viewed prescribed fire as a beneficial tool (51% agree, 30% disagree), but when we focused on rancher responses, a majority disagreed with this statement (31% agree, 43% disagree). Furthermore, we found that knowledge and experience, attitudes, and subjective norms had a moderate influence on respondents' intentions to burn. Once respondents had decided to include the periodic use of prescribed burns as part of their management plans (burn intention) there was a strong likelihood that they would perform a prescribed fire (β= 0.86, $P<0.0001$). This information is essential for better understanding the sociological factors that have ecological implications on rangeland ecosystems in the region. If prescribed fire is to be restored to the landscape, these landowner constraints need to be defined and addressed.

Finding a Way: Getting Prescribed Fire on the Ground

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Rangeland systems frequently need fire to remove invasive weeds, increase plant vigor, create improved wildlife habitat, and increase ranch profitability. Educating landowners about the value of fire for managing their land is just the first step. How do you move from motivation to practice? Often training and practical experience can be difficult to find. Burn workshops can provide education, and burn associations can provide the practical on-hands training and experience that create more opportunities to burn, and result in more landowners skilled in prescribed burning. The benefits are improved rangelands, safer burning conditions, and a sense of community.

Fine Fuels Management at the Landscape Scale: A Collaborative Model in the Northern Great Basin

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Invasive annual grasses, such as cheatgrass, medusahead, and ventenata negatively impact sagebrush steppe communities on a landscape scale. Within the northern Great Basin alone, more than two million acres of rangelands have burned in the last decade. Wildfires are devastating plant and animal life, watershed function, wildlife populations, recreation opportunities, and rangeland-based businesses within the sagebrush steppe. To break the grass-fire cycle and shift annual grass dominance to plant communities dominated by desired perennial species, research needs to evaluate potential management tools and strategies on a landscape scale. We will first highlight a grazing operator's perspective related to the recurring fire regime and a successful grassroots effort to establish a landscape scale fine fuel management research and education project that implements dormant season grazing on public land. The research scientist will then highlight the collaborative endeavor between the Vale District Bureau of Land Management (BLM) and Oregon State University (OSU). There will be a brief review of the National Environmental Policy Act (NEPA) review processes, including the two categorical exclusions used to secure a Decision Record for the authorized project. The researcher will then provide an overview of sample methods, as well as illustrate current rangeland plant conditions, such as grass cover, shrub cover, litter cover, gap percentage, gap number, and biomass. Ultimately, the authors will highlight a successful collaborative model authorized to conduct landscape scale research on public lands.

Fire and Grazing Alters Flower Phenology and Resource Use by Bumblebees

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Native pollinators are experiencing population declines due to human-driven factors, namely landscape homogenization. In this study, we imposed a mosaic of fire onto grazed landscapes to simulate patch-burn grazing, a form of heterogeneity-based management. We then studied the effects of patch-burn grazing on floral resource stability for bumblebees. Since bumblebees display high floral selectivity, we also evaluated bumblebee selectivity in areas of varying floral diversity. Experimental treatments included season-long grazing in the absence of fire (SLG), dormant-season burns with a four-year fire return interval and season-long grazing (PBG1), and a combination of dormant-season and growing-season burns with a four-year fire return interval and season-long grazing (PBG2). We conducted weekly flower counts across treatments while performing three rounds of timed floral visitor surveys. We used these data to construct pollinator interaction networks to compare with floral availability across the growing season. In total, we detected 1,239 bumblebees comprised of seven species across the three treatments. Bumblebees interacted with 32 flower species throughout the season. Bumblebee detections and floral richness were similar among treatments during the early part of the season. The treatments later diverged and patch-burn units had over twice the number of detections as the SLG treatment in the latter two sampling periods. The PBG1 and PBG2 treatments had 2.1 and 2.6 times as many ramets overall as the SLG treatment, respectively. Floral richness followed the same trend, with 1.3 and 1.5 times more species in PBG1 and PBG2, respectively, compared to SLG. These trends became more pronounced over the course of the season. We did not find any patterns in flower selectivity between treatments or sampling periods. Preliminary results suggest that patch-burn grazing can increase the amount, diversity, and stability of native pollinator resources, potentially benefitting declining bumblebee species by providing consistent resources through time and space.

Fire Behavior Associated With the Application of Prescribed Fire in the Northern Great Plains

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Although fuel and weather conditions affect fire behavior, fire behavior is not often measured when applying fire in grassland management. We aim to quantify prescribed fire behavior in northern grasslands to improve current fire models by characterizing fire behavior of managed grasslands in response to fuel and weather variables at time of ignition. To quantify grassland fire behavior, we employed an integrated system of 27 Arduino-based K-type thermocouples to collect and record rapid measurements of advancing fire fronts. Fire behavior was collected on 13 prescribed fires at three locations that span mixed- to tall-grass ecosystems in North Dakota. We used these data to quantify temperature rate of increase, maximum temperature, and the rate of fire spread. Prescribed fires conducted during the autumn season occurred in low stature grassland fuels (Leaf Area Index= 0.342-0.575, Soil Volumetric Moisture Content= 4.041-11.724%) and exhibited mean maximum temperatures of 488℃, from a narrow range of 451-524℃. Late spring prescribed fires were conducted in moderate stature grassland fuels (Leaf Area Index= 0.698-3.472, Soil Volumetric Moisture Content= 15.756-31.559%). Spring fires exhibited more variability as the mean maximum temperature was 693℃, ranging from maximum temperatures of 408-992℃. These efforts both address the paucity of basic fire science in the northern Great Plains and support management decision-making across the region.

Fire Frequency Mapping Using Remote Sensing and GIS of a Savannah Vegetation in 2009 to 2015 at South Kordafan State- Sudan

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The study was conducted at South Kordofan State, Sudan, with aims to determine the fire frequency mapping, seasonal fire and total brunet area. Moderate Resolution Imaging Spectroradiometer (MODIS) images from seasons 2010 to 2015 were obtained and classified for burnt area fire frequency mapping. Data image for seasons in order to investigate the fire frequency through burned area map using a collection images per each dry season for six seasons were processed to extract the burned area. ENVI 5.2 and ArcGIS 10.2 software were used for image processing and maps production. The result revealed that, the burned areas was high in season (2011-2010) were 316,086.20 hectare, then season (2009-2010) with area 312,401.20 hectare and lower season (2011-2010) with burned area 258,179.03 hectare also calculated fire frequency with indicate time frequency were detect between two to six times. These findings considered as a basis for an informed management system in the study area which will be invaluable in developing sustainable forest and rangeland management strategies.

Floristic Richness of a Grassland in Southeast Coahuila, Mexico

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Grasslands dominated mainly by grasses, present in valleys with deep soils, are well distributed in Mexico and North America. In Coahuila grasslands are distributed in isolated areas and occupy only 8% of the state, including semi-arid, gypsophile and halophitic grasslands. For northern Mexico these areas are subject to overgrazing, which causes changes in structure, composition of species and impacts on forage production. The study aims the knowledge richness of species of this community, dominated by grasses of the genera *Bouteloua* and *Aristida* and is located south of the Sierra de Zapalinamé, a natural protected area in state. The average altitude is 2,176 m, in alluvial soils. The land tenure is private and ejidal. The pasturelands are used for extensive grazing of cattle, goats and horses. Botanical collections were made and deposited at ANSM herbarium of the Antonio Narro University. The floristic richness is composed of 35 families, 100 genera and 134 species. The important families are: *Poaceae, Asteraceae, Fabaceae* and *Euphorbiaceae*. The richness increases in the rainy season when annual species appear, the abundant species are: *Euphorbia serrula* and *Sanvitalia angustifolia*. Seventeen ruderal weeds were recorded. The overgrazing increased the invasion of shrubs with low palatability as: *Mimosa biuncifera* and *Prosopis glandulosa*, its density increases with more grazing. Currently signs of overgrazing due to the invasive species and some indicator species such as *Zinnia acerosa*, *Tiquilia canescens*, as well as annual species such as *Aristida adscensionis*, *Enneapogon desvauxii* and *Munroa pulchella*. The invasive species *Asphodelus fistulosus* is reported more frequent in areas with greater intensity of use by the local population. Invasive species could be more abundant and replace native species, because they are better competitors and displace native species. Grazing management is recommended through the decrease of animal load capacity in order to achieve recovery of native species with good forage value.

Free-Roaming Horses in Montane Riparian Areas of Arizona: Determining Use of Forage Resources?

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In the western U.S., herds of free-roaming horses are widely distributed and may occur in sufficient number to affect the forage resources and other environmental characteristics in the areas where they occur. Of particular concern are the effects of free-roaming horses grazing in montane riparian areas, which are more sensitive to overgrazing and trampling than adjacent upland areas. Free-roaming horse populations are likely to continue to increase over the next decade, making the study of the effects of free-roaming horses on their environment increasingly important. In the White Mountains of Arizona, free-roaming horses, cattle, and native ungulate species forage in montane riparian areas. Forage utilization to production ratios in these areas often exceed 80%. We used motion-activated and time-lapse trail cameras to estimate the frequency of site use by cattle, horses, and elk, and developed an adjusted utilization metric to estimate the proportional consumption of forage by each species. Production and utilization was estimated from dried clippings taken from five $1m^2$ grazing exclosures and five $1m^2$ grazed plots at each site. Preliminary results indicate that in 2018 free-roaming horses consumed 46% of available forage, cattle 34%, and elk 20% in montane riparian areas in the White Mountains of Arizona. Additionally, free-roaming horses were detected more frequently in the stream channel and on the stream bank than cattle or elk, and therefore free-roaming horses may have a larger effect on stream bank erosion than cattle or elk. The ecological impacts of free-roaming horses should be considered when designing a grazing management plan as the effects of free-roaming horses may outweigh those of cattle or elk in certain areas.

From Cornfield to Wetland: Progress toward Ecological Restoration in a Prairie Pothole Region Wetland Complex

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Prairie potholes provide ecological benefits and services vital to the health and stability of Prairie Pothole Region (PPR) ecosystems. The ability of PPR wetlands to provide these ecological benefits and services is dependent on the integrity of the surrounding grasslands. With the rapid decline of PPR wetland and grassland communities, it is imperative that restoration takes place before the damage is beyond repair and the vital functions and services are forever lost. This study reports the progress toward ecological restoration of a formerly-cropped 19-hectare parcel located in southeastern North Dakota, five years post-restoration. Approximately 11 hectares of the restoration area were divided into nine plots to compare the effectiveness of three restoration treatments: 1) seeding only, 2) applying seed and native hay mulch, and 3) applying seed, native hay mulch and transplanted vegetation plugs containing native species. In 2018, we surveyed the vegetation of the nine treatment plots and used ANOVA to compare plant community characteristics of the three restoration treatments. Five years post-restoration, we found no significant differences in species richness or total plant cover among the restoration treatments. Average species richness values for the three restoration treatments ranged from 29.33 to 30.33. While our current evaluation of the developing plant communities may not have yielded significant differences at this time, our results do indicate marked improvement in plant community composition in a formerly cropped field. Restoration and management will continue at this site and we expect that the plant community will continue to develop over time.

Gamma Radiation on Natal Grass [*Melinis repens* (Willd.) Zizka], Germoplasm to Induce Nutritional Content Variability

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Natal grass (*Melinis repens*) is a native species in Africa. In America, it is one of the most invasive grasses. In northern Mexico, natal grass lacks morphological and nutritional variability. This grass has a low protein content and has lignified stems, which makes its digestibility low, compared to native grasses. Gamma radiation is a useful technique to induce genetic variability in grasses because it causes mutations that can be used for breeding purposes. The objective of this study was to induce variability in natal grass by using gamma radiation and then identify nutritionally modified mutants. For that, seeds of natal grass collected in wild populations of the state of Chihuahua were irradiated with a 60Co source. The doses used were: 0 (control), 10, 50, 100, 150, 200, 250, 300 and 350 Gray (Gy). The plants from such seeds were then grown under greenhouse conditions. The content of hemicellulose, cellulose and lignin was evaluated in three phenological stages (growth, reproduction and latency) in control plants (M0), and in a group of plants that were differentiated morphologically, which were identified as first-generation mutants (M1m). A fractionation of fibers was carried out, in three replicates by treatment, by following the Ankom protocol, based on the Van Soest method. Once Neutral Detergent Fiber (NDF), Acid Detergent Fiber (ADF) and Acid Detergent Lignin (ADL) were estimated, the percentages of hemicellulose (HEM), cellulose (CEL) and lignin (LIG) were determined by difference. Crude protein content (PC) was determined with the LECO protocol based on the DUMAS combustion method. Data analysis was performed through an Analysis of Variance and means comparison with the Tukey test. Nutritional variability was found in all M1m individuals. Taking into account the three plant phenological stages, all M1m presented differences ($p<0.05$) with respect to the M0 in at least one nutritional compound. However, only the M1m R250-10 showed a higher nutritional value ($p<0.001$) than the M0's in the three phenological stages. The gamma radiation, applied to the seeds of natal grass, modified the nutritional value of the plants by effect of induced mutagenesis.

Generating Residual Dry Matter Maps with ArcMap 10

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Residual dry matter (RDM) is the old plant material left standing or on the ground at the beginning of a new growing season, and is a key management factor influencing forage productivity and species composition on annual rangeland. Minimum RDM guidelines are based on climatic region, percent slope, and percent woody canopy cover. Government agencies, land conservancies, and private operators use RDM guidelines to inform grazing management decisions and monitor grazing intensity. RDM maps can be sketched on paper or digitized manually in GIS programs, but this process is time-consuming. We developed a model to generate RDM maps in ArcMap 10.3. Precipitation data is from PRISM; slope is calculated from National Elevation Dataset; canopy cover is from the National Land Cover Database. Symbology can be changed to represent RDM classes relevant to management or monitoring objectives.

Genetic Relationships Among Different Chemotypes Of *Lupinus sulphureus*

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Lupines (*Lupinus* spp.) are a common plant legume species found on western U.S. rangelands. *Lupinus* spp. may contain quinolizidine and or piperidine alkaloids that can be toxic and or teratogenic to grazing livestock. Alkaloid profiles may vary between and within a species. The objectives of this study were to 1) further explore the characteristic alkaloid profiles of *L. sulphureus* using field collections and 2) to explore the phylogenetic relationship of the different populations and chemotypes of *L. sulphureus* using AFLP method of DNA fingerprinting, thus providing possible explanations to the phenomena of multiple chemotypes within a species. Forty-nine accessions of *L. sulphureus* were classified into 7 chemotypes. The DNA profiles showed that one *L. sulphureus* chemotype, chemotype A, is genetically divergent from the other chemotypes of *L. sulphureus*, suggesting it represents an unresolved lupine taxon, possibly a new lupine species. Additionally, the different chemotypes of *L. sulphureus* chemotypes represented different genetic groups as shown by Bayesian cluster analysis and principle component analysis.

Geospatial Analyses to Improve Rangeland Vegetation Inventory of the Uintah and Ouray Indian Reservation

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The more than 1 million acres comprising the Uintah and Ouray Indian Reservation in northeastern Utah, USA, have not been widely studied, and access to non-tribal members is highly restricted. We assembled a unique dataset of the vegetation in this region by sampling vegetation on 300,000 acres of previously unsurveyed Reservation lands and pairing these data with stocking rate surveys conducted by the Bureau of Indian Affairs (BIA) from 2010-2015. These vegetation data were then associated with biophysical covariates including site soil characteristics, precipitation and NDVI measured in the year of sampling. We built a random forest model using this database to predict aboveground vegetation production throughout the Reservation and surrounding lands in the Uinta Basin. This model will improve the inventory of rangelands in the region by providing fine-scale predictions of annual aboveground vegetation production that are sensitive to site-specific characteristics. These predictions can be used to estimate cattle stocking rates and identify potential wildlife habitat in remote, unsurveyed areas. We modeled vegetation production yearly from 2000 to 2017, allowing us to analyze year-to-year variability and trends in production throughout the Reservation. This is a valuable way to examine site stability in response to disturbances like drought, and the influence of management decisions over time. Lastly, we used a global climate model to determine projected vegetation production trends in this area due to climate change and used these to project results into the future. This provides an additional tool for the BIA and Ute Tribe to plan future management of Reservation lands.

Germination Thresholds of Grass and Crop Species in Response to NaCl and Brine Induced Salinity

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Oil development in western North Dakota has resulted in the production of large volumes of hazardous byproduct referred to as produced water or "brine". Brine is a saturated solution of dissolved salts, primarily NaCl, which can exhibit electrical conductivities (EC) upwards of 200 $dS \cdot m^{-1}$ and sodium adsorption ratios exceeding 300. Accidental spills of brine occur frequently in this region, severely degrading soil health through salinization. Germination of plant species in brine contaminated soils can be severely inhibited due to phytotoxicity, osmotic stress, and induced seed dormancy. We tested the germination of four crop species: *Hordeum vulgare* (barley), *Helianthus annus* (sunflower), *Carthamus tinctorius* (safflower), *Beta vulgaris* (sugar beet) and four perennial grass species: *Pascopyrum smithii* (western wheatgrass), *Elymus hoffmannii* (AC saltlander), *Leymus triticoides* (beardless wildrye), and *Elymus trachycaulus* (slender wheatgrass). An equivalent of 20 pure live seeds were placed on substratum saturated with NaCl or brine solutions at EC levels of 0, 4, 8, 16, 24, and 32 $dS \cdot m^{-1}$. Seeds were then placed in germination chambers as specified by the Association of Official Seed Analysts guidelines for testing seeds. No significant difference ($P>.05$) in final germination was found between NaCl and brine solutions across perennial grass species or the crop species barley, sunflower, and sugar beet. Safflower was the only species with a significant difference in germination ($P<.05$) between solutions. The perennial grass species, AC saltlander, had the highest final germination (81.9%) at the maximum EC level (32 $dS \cdot m^{-1}$), compared to 47.2% and 0.8% for western wheatgrass and beardless wildrye, respectively. Slender wheatgrass exhibited no germination at or above 24 $dS \cdot m^{-1}$. Within crop species, safflower exhibited the highest germination (10-30%) across both solutions at 32 $dS \cdot m^{-1}$. Other crop species tested had very low germination at 32 $dS \cdot m^{-1}$, barley (0-2.9%), sugar beet (4.9-7.67%) and sunflower (0-1.4%).

Germination Thresholds of Riparian Graminoid Species in Response to $MgSO_4$ Induced Salinity

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Information on germination of perennial riparian graminoids adapted to the northern Great Plains exposed to high saline conditions is limited. Big bluestem (*Andropogon gerardii*), prairie cordgrass (*Spartina pectinata*), switchgrass (*Panicum virgatum*), Kentucky bluegrass (*Poa pratensis),* slender wheatgrass (*Elymus trachycaulus*), green needlegrass (*Nassella viridula*), woolly sedge (*Carex pellita*), and barley (*Hordeum vulgare*) were analyzed to determine saline tolerance during the fragile stage of germination. Twenty pure live seeds of each species were exposed to electrical conductivity (EC) values of 0, 4, 8, 16, 24, and 32 $dS \cdot m^{-1}$, respectively in the form of $MgSO_4$. Tolerance differences were observed only among species. Seeds were monitored for a varying number of days and placed in their respective growth chamber based on guidelines for seed testing set up by the Association of Official Seed Analysts. Seeds were observed to determine final germination percentage. Significant differences ($P \leq 0.05$) were observed between species, EC levels, and species x EC interactions. The perennial grass species, switchgrass had the highest final germination (44.9%) at the EC level of 24 $dS \cdot m^{-1}$. Germination was also observed for barley and slender wheatgrass at the EC level of 24 $dS \cdot m^{-1}$ at 2.87% and 9.07%, respectively. Germination was observed for barley (92.87%), slender wheatgrass (68.17%), switchgrass (86.97%) and big bluestem (14.93%) at the EC level of 16. Kentucky bluegrass had a value of 89.53% at the control EC level (0) but significant germination percentages were not observed at higher EC levels. Successful germination was not documented for woolly sedge and prairie cordgrass regardless of treatment. Results from this study suggest riparian graminoid reestablishment from seed on variable saline soils and electrical conductivity is dependent on species germination threshold.

GF-3850 – A New Herbicide for Noxious and Invasive Weed Management

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GF-3850 is a new herbicide developed by Corteva Agriscience for managing noxious and invasive plants in rangeland, pasture, rights-of-way, and other non-cropland sites. GF-3850 controls over 100 susceptible herbaceous broadleaf plants including yellow starthistle (*Centaurea solstitialis*), Canada thistle (*Cirsium arvense*), musk thistle (*Carduus nutans*), wild carrot (*Daucus carota*), horse nettle (*Solanum carolinense*), purple loosestrife (*Lythrum salicaria*), silverleaf nightshade (Solanum elaeagnifolium), squarrose knapweed (*Centaurea squarrosa*), spotted knapweed (*Centaurea maculosa*), and poison hemlock (*Conium maculatum*). Research trials were initiated in 2015 on rangeland, pasture, and non-cropland sites to assess the efficacy of GF-3850 on noxious and invasive weeds and weeds that negatively impact forage-livestock productivity or wildlife habitats. In these experiments GF-3850 at 75 to 126 g active ingredient·ha^{-1} was applied with CO_2-pressurized backpack sprayers in spray volumes of 10 to 20 GPA. Percent visual control assessments were made and are reported for a selected number of species. GF-3850 provided excellent control of these noxious and invasive species with low use rates compared to some products currently used for this purpose. GF-3850 will control all the weeds currently controlled by Milestone® herbicide and many additional species. Based on these efficacy data, GF-3850 will be a useful tool in the management of these difficult to control noxious and invasive weeds in rangeland, pastures, rights-of-way, and other non-crop sites.

GF-3850 – A New Herbicide for Use in Rangeland, Pastures, and Other Non-Crop Sites

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GF-3850 is a new herbicide developed by Corteva Agriscience for control of broadleaf weeds, including invasive and noxious weeds, and certain woody plants on rangeland, permanent grass pastures, Conservation Reserve Program (CRP) acres, non-cropland areas and natural areas such as wildlife management areas, recreation areas, campgrounds, trailheads and trails. GF-3850 represents an innovative new tool that is a non-ester, non-2,4-D containing, low odor, low use rate formulation that provides postemergence and preemergence residual control of susceptible broadleaf plants and seedlings and some woody plants. It will provide control of all species controlled by Milestone® herbicide plus many additional species and offers flexibly in application (ground, aerial, broadcast, or spot treatment). A key component of GF-3850 is a novel new active ingredient never before used in rangeland and pastures and is an EPA Reduced Risk Pesticide just like Milestone. In trials over multiple years across the United States, GF-3850 provided excellent control of weeds such as Canada thistle (*Cirsium arvense*), musk thistle (*Carduus nutans*), wild carrot (*Daucus carota*), poison hemlock (*Conium maculatum*), wild parsnip (*Pastinaca sativa*), spotted knapweed (*Centaurea maculosa*), silverleaf nightshade (*Solanum elaeagnifolium*), horse nettle (*Solanum carolinense*), woolly croton (*Croton capitatus*), annual marshelder (*Iva annua*), common broomweed (*Gutierrezia dracunculoides*), common caraway (*Carum carvi*), and many more. GF-3850 has excellent compatibility and can be mixed with Urea Ammonium Nitrate (UAN) 28% or 32% or impregnated on dry fertilizers for combined application on rangeland or pasture.

GIS Tools & GPS Data for Rangeland Management Planning: A Rancher's Perspective

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Recent advances in geographic information system (GIS) tools has made rangeland management planning affordable and effective. An example of a free, user-friendly GIS tool is Google Earth Pro (GEP). It provides users with satellite imagery and robust GIS tools to allowing them to maintain records, implement projects, and then objectively evaluate land management outcomes. The objective of this presentation is to highlight a rancher's experience using GIS tools and GEP for rangeland management purposes. It will provide examples of how the Cunningham Ranch has used GIS tools for land management planning over the last four years. Furthermore, it will highlight the rancher's perspective on the applied use of GPS collars for managing rangelands. Over the last year, the Oregon State University Extension Service and the Cunningham Ranch have collared cows with 20 Mobile Action igot-U GPS collars. The rancher will provide his perspective on how the data have been an invaluable tool to understand grazing distribution and create rangeland management plans.

Grazer Type Impacts Flower and Pollinator Abundance in Former CRP Fields Managed With Patch-Burn Grazing

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Grazing lands promote biodiversity in agroecosystems. Consequently, livestock management can influence the extent to which grazing lands provide quality habitat for native species. Management decisions on grazing lands typically focus on stocking rate, grazing duration, and grazing season, but choices about livestock species are also important. Species-mediated grazing preferences result in different distribution patterns, which in turn affect how, where, and when vegetation structure and composition vary across the pasture. We compared how sheep versus cattle, both under moderate stocking, affected floral resources and butterfly and bee communities in low-diversity, post-CRP pastures managed with patch-burning. We sampled bees and butterflies three times per season in 2017 and 2018 and counted all flowering stems within 1 m of transects. During our 2017 field season—which coincided with a severe drought (14 cm below-average rainfall) — there were notable differences in floral resources between pastures grazed by different herbivores. In 2017, we detected 34 forb species and 28,468 flowering stems in the cattle pastures, but only 12 species and 3,567 flowering stems in the sheep pastures. These trends persisted in our 2018 season, which had near-normal rainfall. In 2018, we detected 43,117 flowering stems and 47 forb species in cattle pastures, while sheep pastures had 2,470 flowering stems and 17 forb species. Furthermore, native bees were 9-16 times more abundant in cattle pastures than sheep pastures over both years. Butterfly responses were mixed, with species richness and abundance similar across grazer treatments. Continued monitoring of how different herbivores in a patch-burn grazing framework affect butterflies, bees, and floral resources will inform range management decisions to better support pollinators, especially in low-diversity grasslands where sheep are the dominant herbivores.

Grazing Management Practices in the Rangelands of Nepal

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Rangelands are part of Nepal's historic as well as religious heritage. They are a means of livelihood for the people residing in the Himalayas. They occupy 22.60% of the total area of the country and occur in each of three ecological zones, comprising high, mid and Terai regions of the country (Rangeland Policy, 2012). Out of the total area of 3.326 million hectares occupied by the rangelands, 94% of the rangelands are situated in the hills and mountain regions while only 6% rangelands are in the Siwaliks and Terai regions of the country. About 57% of the country's population resides either in rangeland ecosystems or adjacent areas, and are directly or indirectly dependent for their economic development on rangeland resources. Rangeland policy endorsed in 2012 recognizes the rangelands of Nepal as a rich source of biodiversity of food and forage crops, animals, medicinal plants, and its conservation and utilization has been given a high priority. However the productivity of these rangelands has been adversely affected due to overgrazing, human encroachments and tourism has also lead to the deterioration of these rangelands along with the loss of valuable diversity. Only 37% of the forages produced in rangeland are being utilized at present. Production and productivity of these rangelands however vary from 0.65mt DM/ha/Yr to 3.60 mt DM/ha/Yr (Rangeland Policy, 2012). Thus, a proper management and utilization strategy of rangeland is necessary to improve the livelihood and income generation opportunity of Nepalese people through traditional knowledge in the management of rangelands for centuries.

Grazing Phenology of Migratory Geese is More Impactful than Early Green-up in Coastal Alaska

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Arctic coastal ecosystems are heavily impacted by migratory geese that graze grasses and sedges for much of the short northern summer. These grazer-forage systems are experiencing rapid advancement of spring due to considerable warming over the past several decades and changes in the arrival timing of geese. Altered timing of green-up and grazing can lead to 'phenological mismatch' where geese consume tissue that is more mature and of lower quality. Consequently, these changes influence plant growth with implications for ecosystem processes such as greenhouse gas exchange. For three summers we conducted an experiment altering timing of spring green-up using open-top warming chambers (OTC) in the spring and early summer, and timing of grazing using exclosures and captive Pacific black brant. We also examined the consequences of removing grazing from the system because goose populations have declined recently. We monitored aboveground and belowground tissue growth, soil N pools, tissue C:N, and net ecosystem exchange. Advancing the growing season resulted in taller vegetation during late spring and early summer, but had little impact on aboveground and belowground biomass, soil N pools, and tissue C:N. Advancing the growing season enhanced instantaneous ecosystem respiration and reduced daily net carbon uptake only when the OTCs were installed. Conversely, changing the timing of grazing had substantial impacts on the system. Grazing early reduced aboveground and belowground biomass, enhanced soil NH_4^+, and reduced leaf tissue C:N and net carbon uptake. Delaying grazing resulted in more biomass, higher C:N, and greater carbon uptake in the system. Removing grazing, however, resulted in less stimulation of growth and carbon uptake than delayed grazing. These data highlight the importance of plant-animal interactions in determining how ecosystems will likely respond to future climate scenarios.

Grazing Season of Use Effects on Sagebrush-Obligate Avian Habitat

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Extensive sagebrush steppe reduction and declines in some sagebrush-obligate species has generated an intense focus on the management of the remaining sagebrush habitat in the Great Basin ecosystem. As the predominant land use in the sagebrush ecosystem, livestock grazing is a central factor considered in most sagebrush habitat conservation planning efforts. Surprisingly, a dearth of information is available for understanding the influence of common contemporary grazing practices on sagebrush habitats and associated sagebrush-obligate wildlife species over both short and long time scales. We are in the second year of implementing a replicated grazing experiment to assess the influence of two grazing regimes (winter and spring-defer rotation) at moderate utilization of native grasses (30-40% by weight) and grazing exclusion using nine 15-20 acre pastures of sagebrush habitat on (1) abundance, nest density, and nest success of sagebrush-obligate songbirds, including Brewer's sparrows (*Spizella breweri*), sagebrush sparrows (*Artemisiospiza nevadensis*), and sage thrashers (*Oreoscoptes montanus*); (2) potential nesting habitat for sagebrush-obligate birds; and (3) plant community composition and structure. This research will fill important knowledge gaps that currently exist around the effects of grazing on plant community and habitat characteristics of sagebrush rangelands and the influence of grazing on sagebrush-obligate songbirds.

Grazing Strategies Indices for Range Quality Assurance

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While most pastures are not overgrazed, many undermanaged pastures would benefit from various grazing management strategies. While many discuss overgrazing, reduction of animal numbers rarely solves problematic animal distribution, grazing season, duration of grazing, or timing of recovery periods. Yet reduction of animal unit months (AUMs) of livestock grazing has been common on public lands and megafires have increased. The Grazing Response Index (GRI) scores frequency (duration for repeated grazing of regrowth during the grazing period); intensity (leaf area remaining for regrowth); and opportunity for growth or regrowth (when grazing is not occurring). We thought rotation of use among years and possibly other strategies would help ranchers score their grazing each year. Western Sustainable Agriculture Research and Education funded GRI workshops on five ranches asked a series of questions before convening the many ranchers for a larger conversation. All ranchers felt GRI was very useful for evaluating grazing management. The best time for scoring is when livestock leave a pasture or a use area. Every rancher managed for grazing in different seasons in different years, so that through the years, animals would therefore go to different places and eat different plants, and plants would have an opportunity to perform all life functions and stay healthy. However, the ranchers did not feel that the GRI should be changed by adding a point for grazing rotation. Rather other simple metrics could evaluate grazing management depending on the strategies employed for success. The Nevada Rangeland Monitoring Handbook (3rd. Edition; Swanson et al. 2018) emphasizes that short-term or implementation monitoring should focus on strategy(ies) for meeting objectives. GRI scoring suggests that actual use records (date and duration of use and non-use periods in the growing season) would be more useful for monitoring and adapting grazing management than intensity of grazing or utilization.

Guide to Co-Developing Drought Preparation Plans for Livestock Grazing on Southwest National Forests

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The First Edition of the "Guide to Co-Developing Drought Preparation Plans for Livestock Grazing on Southwest National Forests" was recently published by the University of Arizona (UA) Cooperative Extension. It is available to the public to download for free at: https://extension.arizona.edu/pubs/guide-co-developing-drought-preparation-plans-livestock-grazing-southwest-national-forests. The Guide is one output from a project funded by the National Oceanic and Atmospheric Administration (2014-2017) where researchers and extension professionals from the UA partnered with Forest Service manages and livestock grazing permittees from the Tonto National Forest to explore and resolve drought-related challenges for managing national forest livestock grazing allotments. The purpose of this Guide is to assist Southwest Region 3 Forest Service managers and livestock grazing permittees to work together to co-develop and implement a Drought Preparation Plan for a national forest livestock grazing permit. A Drought Preparation Plan identifies strategic, proactive livestock management practices that can be implemented ahead of time in order to increase management flexibility to respond and cope with possible future drought conditions. Planning ahead is essential because: 1) Region 3 Policy defines drought as a Standardized Precipitation Index value of minus 1 or lower (i.e., drought) which occurs on average one in six years, and; 2) new practices on national forests must first be approved by through the National Environmental Policy Act (NEPA) review process, which can often take several years to complete. This Guide uses a series of seven simple worksheets to walk the two parties through a scenario planning and strategic planning process and emphasizes the importance of adaptive management. Working together has the benefits of a shared vision and expectations, improved trust, co-learning, and more efficient management.

Habitat Management: One Path for Dakota Skipper Recovery

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The Dakota skipper (*Hesperia dacotae*) is a prairie dependent butterfly that was listed as threatened under the Endangered Species Act in 2014. The U.S. Fish and Wildlife Service and conservation partners recently developed a Draft Recovery Plan that provides the recovery goals and objectives anticipated to be necessary for the future delisting of the species. Recovery efforts will focus on maintaining Dakota skipper viability across four Conservation Units and achieving recovery will be highly dependent on the cooperation and contributions of conservation partners. Specifically, recovery will require the cooperation and dedication of native prairie managers, conservationists, ranchers, farmers, agencies and those with expertise needed to design and evaluate the effects of land management actions on the species. Recovery of the species will also require flexibility throughout the range and across management actions to ensure partner buy-in and the creation/maintenance of diverse prairie grasslands while allowing for continued management of the land. As part of recovery planning, USFWS will be developing Conservation Unit-specific recovery implementation strategies that will include partners interested in maintaining high quality native grasslands in areas where Dakota skipper can benefit from and we will work together to identify specific recovery actions to achieve long-term success.

Habitat Variables across Multiple Scales Influence Female Sharp-Tailed Grouse Brood Habitat Selection and Brood Survival in a National Grassland Grazed by Livestock

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Sharp-tailed grouse occur across much of the Great Plains of North America. Though their populations have remained somewhat stable since European Settlement, population declines have been reported for recent years. Grassland loss to urbanization and agricultural practices, over grazing, and fragmentation are a few catalysts thought to be responsible for these declines. Lesser and greater prairie-chicken populations have received greater interest by the scientific community in recent years, with less attention focused on sharp-tailed grouse ecology across its range. In an effort to provide land and wildlife managers concerned with grouse additional information to help guide management decisions, we studied hen sharp-tailed grouse during the brooding season to determine habitat selection and factors that influenced the daily survival rate of broods. We conducted our study on the Grand River National Grassland in South Dakota where cattle herbivory is the primary form of disturbance and management option deployed. We monitored 42 broods from 2013-2015. Using conditional logistic regression, we found brooding hens selected habitats based on the distance to the nearest grassland and choose sites with less litter cover and bare ground relative to random sites at a microhabitat scale. Variables responsible for variation in survival did not align with those shown to influence habitat selection. We found that as the relative slope of a site increased, brood survival decreased and likewise as the distance a hen kept her chicks from a fence line increased the greater survival her brood experienced. At the microhabitat scale, survival was a function of the quadratic form of visual obstruction and the linear version of vegetation height. Our findings demonstrate the importance of numerous variables across multiple scales to brood rearing sharp-tailed grouse. Managers of grouse populations should manage for heterogeneity, as many factors appear to shape sharp-tailed grouse brood ecology in the Great Plains.

Harvesting Effects on Wild Bee Communities in Bioenergy Grasslands Depend on Nesting Guild

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Conversion of annual crops to native perennial grasslands for bioenergy production may help conserve wild bees by enhancing nest and food resources. However, bee response to the disturbance of biomass harvesting may depend on their nesting location, thus their vulnerability to nest destruction, and the response of the forb community on which they forage. Moreover, because bees have long foraging ranges, effects of local harvesting may depend on the amount of natural habitat in the surrounding landscape. We performed a large-scale experiment in Michigan and Wisconsin, USA to examine how grassland harvesting and landscape context affect above- and belowground-nesting bee communities and their forb resources. In Wisconsin, harvesting increased forb richness, cover, and evenness compared to unharvested control sites. Harvesting negatively affected aboveground-nesting bee richness and emergence from trap nests, possibly because of nest destruction during the previous harvest. By contrast, harvesting positively affected belowground-nesting bee richness, possibly because of the greater food resource availability and reduced thatch allowing greater access to nesting sites in the soil. We did not find a harvest by landscape context interaction, suggesting that harvesting can affect local populations rather than simply affecting forager aggregation in different resource environments. Similarly, in Michigan, belowground-nesting species also responded positively to harvesting, which was more pronounced in sandier soils that are preferred for nesting. Overall, our study demonstrates that harvesting grasslands can positively affect the 80% of bee species that nest belowground by enhancing nest and/or forage resources, but that conserving aboveground-nesters may require leaving some area unharvested.

Heavy Winter Patch Grazing as an Alternative to Fire on the Northern Great Plains

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Considerable research has focused on patch-burn grazing (PBG) as a means of creating heterogeneity on the landscape by altering vegetation structure and livestock grazing patterns. Though fire is seen as a healthy disturbance in grassland ecosystems, many landowners in the Northern Great Plains have an aversion to fire due to concerns over loss of forage and property. A study was conducted in 2016-2018 at the Cottonwood Research Station in southwest South Dakota to test the effectiveness of heavy winter-patch grazing (WPG) to simulate fire. Within each pasture, patches were created by intensively grazing cows during the dormant season in winter 2015 and 2016 to reduce standing dead forage and vegetation structure to mimic the effects of fire. Following a wildfire in October 2016 at the research station, the study was continued to also include a PBG treatment. Three pastures each contained a WPG patch, a PBG patch, and an ungrazed control patch. Height measurements of standing live and dead vegetation were taken along transects in spring to assess the impact of each treatment on vegetation structure. Satellite imagery was also acquired to compare NDVI values across each treatment to assess differences in greenness of vegetation. Livestock grazing patterns were assessed using GPS collars outfitted with motion sensors on a subset of steers within each pasture. Results indicate WPG was effective in creating structural heterogeneity on the landscape. Livestock showed a higher preference for PBG areas over WPG when given the choice, however they preferred WPG in the absence of fire. Given the unlikelihood of having both treatments in a management strategy, results of this study show WPG can be used as a surrogate for fire to create heterogeneity and shift grazing on the landscape.

Heterogeneous Forage Quality Determines Livestock Use When Implementing Patch Burn-grazing on Kentucky Bluegrass-invaded Rangeland

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Disturbance-driven heterogeneity is essential in maintaining rangelands that evolved with disturbances like fire and grazing, and especially important in maintaining forage diversity in Kentucky bluegrass-invaded rangelands. By combining season-long grazing with a yearly rotation of dormant-season or growing-season fires, patch burn-grazing creates contrast in forage quality and quantity between burned and unburned patches within a pasture. This heterogeneity can optimize rangeland value for both livestock and wildlife, and can attract grazers to the most recently burned patches. High forage quality in recently-burned patches should attract livestock and this attraction should maintain forage quantity contrast over the season. We sought to increase forage heterogeneity by applying a rotational patch burn-grazing treatment to pastures with season-long grazing. We have monitored forage quality, forage biomass, and grazer occupancy over two years of a four year patch burn rotation. We determined forage biomass by clipping 25 cm^2 quadrats in burned and unburned patches once per month through the growing season. At each point, we counted fecal pats within 5 m of the point to determine grazer usage of each patch. All clippings were dried, weighed, and ground, then run through near infrared spectroscopy (NIR) to determine crude protein and fiber content to quantify forage quality. Forage biomass was lower in recently-burned patches than in unburned patches. Biomass in burned patches increased over the growing season while biomass in unburned patches was stable. Forage quality (represented by crude protein percentages) was higher in recently-burned patches. Average fecal pat counts were high in burned patches and low in unburned patches. This attraction was reduced by the end of the growing season, likely due to decreasing forage quality. As the study progresses, we expect continued grazer attraction to the most recently-burned patches, and a developing gradient of forage quality and quantity as the burn patches shift.

Heuristics and Fire: Decision-Making Processes and Prescribed Fire Implementation in the Southern Great Plains

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The Southern Great Plains of Texas and Oklahoma, once predominately grassland biome, have undergone a slow conversion to a grassland-savanna matrix due to woody encroachment following European settlement. The suppression of fire in this once fire-driven ecosystem is partly to blame. Prescribed fire is a powerful management tool capable of mimicking historical fire regimes and maintaining the integrity of these rangelands. Despite the extensive history of prescribed fire use in the Southern Great Plains of Texas and Oklahoma, consistent usage of the tool on a landscape scale is impeded by a variety of policy, legal, and sociocultural factors. While significant research has been conducted into the policy and legal impediments to more widespread prescribed fire use, the sociocultural barriers represent an understudied area of research. Barriers and opportunities are shaped by both macro institutional and policy variables down to micro-level individual decision-making processes. Based on a mixed-mode web-based and mail survey, this research explores key variables that shape an individual's decision to use prescribed fire as a land management tool. The results indicate bifurcated modes of cognition that influence decision makers' choices regarding fire. On the one hand, the choice to implement prescribed fire is a conscious, analytical decision-making process. On the other hand, rather than solely utilizing analytical calculations of risk versus reward, our findings suggest that the decision to use prescribed fire is influenced by affective reasoning and heuristics that are more intuitive than analytical. Our research seeks to better understand these barriers as well as other obstacles not yet noted in the literature that inhibit more widespread use of prescribed fire in the Southern Great Plains. The results have implications for the ways that policy incentives are framed as well as the information communication strategies for advancing prescribed fire.

History and Legacies of Crested Wheatgrass Seedings on Rangelands in the Intermountain West

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Across the Intermountain West, millions of hectares of abandoned fields and shrublands were converted through discing or herbicide treatments and seeding with introduced perennial grasses with the intent to stabilize erosion, control invasive species, and increase forage production for livestock. Within land managed by the Bureau of Land Management (BLM), rangeland seeding has been the most widespread management treatment employed by the agency. Crested wheatgrass (*Agropyron cristatum* (L.) Gaertn. and *Agropyron desertorum* (Fisch. ex Link) Schult.) was one of the most widely seeded exotic species in the western United States and is now ubiquitous throughout western rangelands. As priorities for rangeland management changed in the 1970s and 1980s, efforts increased to understand how these practices affected wildlife and vice-versa. Much of this research has tended toward all or none comparisons (e.g., unconverted sagebrush stands vs. crested wheatgrass monocultures), and largely ignored stand variability (e.g., successional sagebrush occupation of crested wheatgrass seedings) and its associated effects on wildlife. Now, there is growing awareness that these now decades-old crested wheatgrass seedings may require diversification to provide important ecosystem services such as species diversity, wildlife habitat and watershed function, in addition to forage production. Priorities for rangeland management are shifting again and understanding the history and legacies of our past actions is even more important as we move into an era of climate uncertainty.

How Do Grasses Do That? Linking Anatomical Structure to Freezing and Drought Tolerance in C3 Grasses

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Grasses occupy some of the harshest environments on earth, from the cold environments to species that provide forage in desert grasslands. Despite the variety of environmental conditions occupied by this functional group, we don't have a grasp of the defining characteristics that allow perennial grasses to survive and dominate such diverse ecosystems. In order to provide some explanation for the widespread distribution of this growth form, we measured anatomical characteristics of the leaf vascular system to determine if the internal leaf structure contributed to drought and freezing stress tolerance in ~25 species of grasses. Further, we investigated whether there were trade-offs associated with stress tolerance, such as reduced growth rates and/or photosynthetic capacity. We will present results from our study showing the tight coupling between cell dimensions changing vein density that has implications for a species' ability to tolerate drought and/or freezing conditions. Finally, we will discuss the implications of trade-offs between leaf structure and growth rate that help explain the specific rangeland environments that can be occupied by different grass species.

How Does Patch-Burn Grazing Affect Forage Production, Plant Diversity, And Carbon Dynamics in Subtropical Humid Grasslands?

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Research has shown that mimicking the fire-grazing interaction using patch-burn-grazing (PBG) management benefits biodiversity, enhances soil nitrogen, and can reduce invasive plants, in temperate regions. However, little work has been done on how PBG affects ecosystem services in subtropical grasslands. The objective of this study was to determine how PBG affected forage production (ANPP), forage quality, plant diversity, and greenhouse gas regulation in a subtropical grassland. A randomized block design experiment was established in 2017 with 16 pastures (16 ha each) in two different pasture-types (intensively-managed (IM) vs. semi-natural (SN)) at Archbold Biological Station's Buck Island Ranch in FL, USA. In 2017, eight pastures were completely burned ("full-burned": FB). The remaining eight pastures were partially burned ("patch burn grazing": PBG) under a fire regime of one-third burnt yearly with the first third burnt in 2017. Statistical comparisons are between PBG pastures and FB pastures, or within PBG comparing burned and unburned sectors. This experiment is part of the USDA Long-term Agroecosystem Network's cross-site common experiment to assess the impacts of different management practices on ecosystem services. Plant species richness (SR) and diversity (H') were greater ($F(1,14)=10.07$, $p<0.007$) in SN pastures (SR: 36.2±10, H': 20±7.2) compared to IM pastures (SR: 21.2±8.9, H': 9.9±5.1) but did not differ among burn treatments (FB vs. PBG) the first year after fire treatments. Within PBG pastures, burned sectors had higher SR and H' compared to unburned sectors, but only for SN pastures (Burned: SR=29±12, Unburned: SR=19.8±7.7; $F(1,3)=16.2$, $p=0.03$). Overall, ANPP did not differ between PBG and FB or pasture type. Preliminary analyses of net ecosystem exchange and carbon dynamics will also be presented. It is expected that as time-since-fire increases in FB pastures, structure and function of grasslands will diverge between FB and PBG treatments.

How Many Collars Do We Really Need to Understand Grazing Distribution of Cattle Herds?

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In the past, the number of global positioning collars (GPS) used in research projects was determined more by budgetary constraints than sample size and power analyses. The goal of this research was to estimate the number of samples that should be used to detect differences in cattle grazing distribution patterns. Tracking data from nine ranches in the western United States were used to estimate appropriate sample sizes to detect 10% changes in terrain use metrics. Nine to 26 cows were tracked at each ranch. Means of elevation use, slope use, distance from water and distance traveled per day were calculated for each tracked cow. Sample size was estimated using the standard deviation of terrain use metrics from each ranch assuming that alpha equaled 0.05 and power was 80%. Sample size varied greatly among ranches for all terrain use metrics except elevation. Less than 10 samples were required for elevation at all ranches. In contrast, sample size required to detect a 10% change in means for slope use, average distance from water, and distance traveled per day varied from six to over 100. Fewer samples were required for slope use on ranches with gentle terrain and more ranches with steep terrain. Similarly, samples required for distance from water was greater for more extensive pastures than smaller pastures or pastures with more water sources. Until the recent advent of lower cost GPS collars, scientists have relied on obtaining large differences among treatments rather than obtaining precise measures from larger samples sizes.

How Many Prairie Dogs Are Too Many? One Bird's Perspective

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Burrowing mammals serve as ecosystem engineers and keystone species in rangelands across the globe. In many cases the disturbance they engender, so crucial for associated wildlife, is perceived as detrimental from a traditional rangeland condition and economic perspective. No species has spent as much time in the crosshairs of this debate as the black-tailed prairie dog (*Cynomys ludovicianus*). Many species rely on habitat constructed by prairie dogs, including the endangered black-footed ferret (*Mustela nigripes*), and imperiled mountain plovers (*Charadrius montanus*). Conversely, prairie dogs and livestock can compete for forage, especially in dry years. Further, where black-tailed prairie dogs overlap sagebrush (*Artemisia* spp.) steppe, they may degrade habitat for sagebrush birds. We examine these issues from a bird's perspective in the Thunder Basin National Grassland (TBNG), at the ecotone between the Great Plains and sagebrush steppe. After four years, we confirmed that without prairie dogs mountain plovers become nearly absent on the landscape. More surprisingly, mountain plovers show a "goldilocks response" to colony size, with densities increasing up to 500 m from an interior colony edge, then declining such that colony "cores" provide little suitable habitat. Further, sagebrush bird densities are low on colonies, indicating that some undisturbed habitat is necessary to maintain avian biodiversity in this landscape. Forage availability (measured as total herbaceous biomass) for livestock and wild ungulates was also reduced by prairie dogs in large colonies and in dry years. The TBNG and other national grasslands are expected to sustain viable populations of wildlife while simultaneously meeting the economic requirements of livestock grazing. Stakeholders with diverse, and sometimes conflicting, perspectives are working to balance these objectives within this landscape. Here, we examine the prairie dog debate in light of economic, social, and ecological perspectives to begin to identify sustainable goals for prairie dog management in the TBNG landscape.

How Much Grass Will I Have This Summer?

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Decisions about summer grazing plans during and after extended drought would be much easier if somehow ranchers knew how much forage would be available during summer. Reliable estimates can be made by comparing this year's amount of precipitation to the long-term average or long-term median. In Montana, one method compares the amount of precipitation received in a "crop year", while another method compares the combined total precipitation received in April, May, and June. A third method (my preferred method) averages the estimates provided by the crop year precipitation and the April+May+June precipitation. For example, if precipitation during the crop year from 1 September 2018 to 30 June 2019 equaled 80% of the 30-year average or 30-year median, then forage production will likely be about 80% of normal in summer 2019. Similarly, if the combined total precipitation received in April, May, and June 2019 were to equal 70% of the 30-year average or median for April+May+June precipitation, then forage production will likely be about 70% of normal in summer 2019. The average of the two methods would predict 75% of normal forage production. Estimates derived from either the crop-year method, the April+May+June method, or the average of these two methods also can be used to manage risk. For example, if an area normally receives 4 inches of precipitation in April+May+June, and no moisture is received in April, the long-term weather records can be examined to gauge the likelihood that 4 inches will be received in May+June. These methods do not provide perfect estimates, of course, because they do not account for the many other factors that also affect range forage growth such as air temperature, humidity, and wind. However, these simple procedures provide reliable estimates that can help ranchers make informed management decisions.

Hydrogel Rate and Depth: Impact on Soil Water and Seedling Establishment

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Revegetation of disturbed rangeland is often hindered by low precipitation. Invading annual grasses germinate earlier, thus depleting water resources. Using hydrogel's (HG) super absorbency to create a wider establishment window is a possible solution. Previous glasshouse studies indicated banding HG buried at 7.5 cm increased soil moisture and seedling longevity under drought conditions. These results were field tested with bottlebrush squirreltail [*Elymus elymoides* (Raf.) Swezey] and Vavilov II Siberian wheatgrass [*Agropyron fragile* (Roth) Candargy] at two Great Basin locations established November 2017. HG bands were applied at rates of 0, 1500, 3000, and 6000 $kg \cdot ha^{-1}$ at 7.5 cm depth at both locations and also 2.5 cm at one. Soil moisture was measured monthly spatially (in every plot) and temporally (every 2 h in select plots at one location). Similar to the glasshouse studies, deep HG placement increased soil moisture an average of 17.4 and 13.7% in April and May, respectively. The differences disappeared by June. Shallow HG placement initially had similar results with a 14.9% increase in moisture in April, but the trend reversed with the non-HG treatments having 2.2, 6.3, and 2.4% more moisture than HG treatment in May, June, and August, respectively. Buried sensors corroborated these findings. Useable soil moisture existed for six d longer in HG plots during spring, but the trend reversed with these plots being well below the permanent wilting point in the summer while controls were not. Despite initially higher soil moisture, HG negatively affected longevity of both species. We attribute these findings to the HG causing extreme cracking in the soil that, despite initially holding onto more soil moisture, resulted in eventual moisture depletion and poor seed establishment conditions. Future work will evaluate lower HG rates and deeper placement to prevent soil cracking – possibly increasing both moisture retention and seedling longevity.

Identifying Landowner Tipping Points for Ecological Transformation in the Southern Great Plains

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Responses to ecosystem transformation depend largely on how people experience, perceive, and accept changing conditions. Combining sense of place and beliefs about consequences of change, we explored private landowners' thresholds of acceptability for woody plant encroachment (WPE) in the Southern Great Plains as a first step in understanding how people and social systems adapt. Based on mail survey responses from 877 private landowners in Texas, Oklahoma, and Kansas, we examined the acceptability of *Juniperus* spp. using a photo analysis approach in which landowners rated the acceptability of three photos showing successively encroached landscapes. Sense of place, measured through place meanings, represented the symbolic connections landowners have with their land. We used K-means cluster analysis to group landowners based on their sense of place and employed a series of mixed regression models to explore the pathways by which sense of place, beliefs about consequences, and perceptions of threat relate to landowner thresholds for juniper. Most landowners believed that juniper leads to negative outcomes and had low thresholds of acceptability for it; however, sensitivity varied across six landowner groups. Group membership was directly related to threshold of acceptability; landowners who emphasized production-oriented and heritage meanings expressed the greatest sensitivity to WPE. Sense of place was also indirectly related to thresholds via beliefs about consequences and perceived threat. Beliefs about beneficial outcomes (e.g., wildlife habitat) were associated with lower sensitivity to WPE while high threat perceptions were associated with higher sensitivity. By examining acceptability thresholds, critical tipping points that drive adaptive, place-protective behavior can be identified. This is important to understand the trajectory of ecological transformations. The drivers of landowners' perceptions of and thresholds for WPE provide the underlying context for management actions that either sustain grasslands or enable further encroachment.

Identifying Smooth Brome Elongation Using the Correlation of Mean Stage Count and Accumulated Growing Degree Days

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The US Fish and Wildlife Service (USFWS) uses the five-leaf developmental stage as a signal to the initiation of elongation in smooth brome (*Bromus inermis*). In areas where certain plant community criteria are met, conducting a prescribed burn at elongation onset has reduced smooth brome populations. However, leaf stage identification presents USFWS managers with challenges, due to the variability of smooth brome development in tallgrass prairies of the northern Great Plains. The objective of this research was to develop an alternative method to determine when smooth brome populations reach the targeted 50% elongation by linking growing degree days and population level plant phenological stages (mean stage count). At sites in North Dakota, South Dakota, and Minnesota smooth brome phenological stages were determined, as well as the corresponding number of growing degree days, calculated using the base temperature of 0 °C. Linear regression models, correlating phenological stage and growing degree days, determined onset of elongation in the smooth brome population, regardless of leaf stage variation. The average accumulated growing degree days (1,256 AGDD) and corresponding standard deviation (±155 AGDD) predicts when 95% of smooth brome populations in northern tallgrass prairies reach 50% elongation. As part of USFWS Native Prairie Adaptive Management, results will be used to assist management decisions regarding the timing of control in an effort to enhance native plant communities where smooth brome is the dominant invader.

If You Want Something to Die, Make It Be Still: Pyric Herbivory Promotes Pollinator Diversity

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Fire created and maintains grassland ecosystems around the world, with the pattern and processes in these systems maintained by fire driven grazing – an ecological process called pyric herbivory. Pyric herbivory creates a patchwork of habitat types across space and time at local, regional, and continental scales. This diverse and shifting mosaic of habitat is what native grassland wildlife evolved with, and most species in these systems need more than one type of habitat to complete their life cycles. Rangelands are the last stronghold for wildlife in North America, with grassland ecosystems making up the majority of these rangelands. However, conventional rangeland management practices in the United States strive for uniform animal distribution and forage utilization, which in turn selects for uniformity in habitat structure and plant species composition across vast landscapes. This uniformity in habitat across both space and time is in direct contrast to the patterns and processes of patchy habitat that wildlife evolved with in these rangeland systems. This research examines native pollinator responses to rangeland management practices in the Central Great Plains, including patch-burn grazing – a management practice that strives to effectively mimic pyric herbivory. Results indicate a twofold increase in relative pollinator abundance in patch-burn grazing pastures as compared to annual-burn grazing pastures, with a threefold increase in native bee species richness in patch-burn grazing pastures and a twofold increase in butterfly species richness. Moreover, 93% of all VHF-tagged bumble bee queens nested in 2-years-since-fire patches, yet foraged 65% of the time in the year-of-fire patches and 32% in the 1-year-since-fire patches. These findings indicate that patch-burn grazing has significant potential to restore one of North America's most endangered groups of wildlife – grassland pollinators – with one of its most dominant land-use enterprises – cattle grazing.

Immersive Co-Production to Inform Ranch Management in the Gunnison Valley, CO US

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To be successful, producers must interpret environmental stimuli and respond with management actions that help match their production operations to the ecosystem services they depend on. Climate change, and the increased variability that will likely result, may lessen the relevance of historical rules of thumb and management heuristics by altering environmental conditions and giving rise to novel systems that feature more frequent and intense periods of stress. To meet this challenge, rapid knowledge production is necessary at the ranch-level. We propose immersive co-production, wherein a student researcher is embedded within the production operations of a working ranch while studying and conducting research, as one method of quickly developing the knowledge resources necessary to sustain livestock production in the context of environmental change and present a case study involving a ranch near Gunnison, Colorado as evidence of the effectiveness of this approach. This project was collaboratively designed and conducted by the landowner and a student and faculty mentor from Western Colorado University and sought to understand the potential of supplemental feeding to augment the development of soil organic matter in historically overgrazed shrublands with the intent of enhancing the future drought tolerance of these landscapes. Sustaining livestock production in the face of climate change depends on the rapid production of knowledge to inform adaptation to novel systems. Involving producers in research is often discussed as a strategy to help accomplish this goal. Immersive co-production employs this strategy while also involving aspiring researchers in production to develop useful ranch-level management insights and a new generation of interdisciplinary range professionals with intimate knowledge of the complexity faced by producers.

Impacts of Different Disturbances on the Performance of Clonal Plant Buffalograss

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Clonal growth and reproduction is one of the universal traits of plants, but is achieved by various morphological forms, such as stolons, rhizomes, and roots. They play critical roles in vegetation recovery, colonization and resilience following disturbance by resource sharing and clonal integration among connected ramets. In perennial grassland ecosystems, the vegetative reproduction via bud bank is responsible for over 99% of new tiller growth. Buffalograss (*Bouteloua dactyloides*) is one of the two dominant of short grasses species in the Northern Great Plains. Besides sexual reproduction, buffalograss reproduces clonally through aboveground stolon growth with buds. Multiple factors can affect bud production and subsequently clonal growth. At the SDSU Cottonwood Research Station the impacts of three disturbances including: patch-burn grazing (PBG), winter-patch grazing (WPG), and continuous summer season-long grazing (CG) on the performance of clonal plant buffalograss were evaluated. The experiment was a randomized complete block design with three treatments in each of the three pastures (as blocks). Five samples with 10-cm dia. and 10-cm depth were randomly collected from a buffalograss patch from each treatment in each block for three times during the growing season two-year post disturbances. Samples were separated into crown tillers, stolon tillers based on the generations, the number of stolons, length of stolon, number of buds axillary buds, and stolons buds, tiller height and mass were examined. Data were analyzed to evaluate buffalograss bud banks and clonal growth traits in response to different disturbances. The results will provide useful information for better understanding the underlying mechanisms driving the systems resistance and resilience to disturbances.

Impacts of Patch-Burn Grazing and Winter-Patch Grazing on Arthropod Community Heterogeneity

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Since winter-patch grazing and patch-burn grazing managements create different environmental conditions during and after the disturbances, we hypothesize that patch-burn grazing and winter-patch grazing will have different impacts on arthropod communities in order richness, abundance, composition, and diversity compared to summer season-long grazing. The objective of the experiment was to evaluate and compare the impact of patch-burn grazing and winter-patch grazing on arthropod community abundance, diversity and richness. Arthropod samples were collected from three patches of typical mixed-grass prairie; each of which had been subjected to either patch-burn grazing, winter-patch grazing or conventional grazing. Three pastures were used as replicates. Sampling was conducted through sweep-netting with the intention of collecting samples from the greatest number of arthropod orders. Sampling occurred twice over the summer season (June, July). Preliminary results indicate that order richness is greater in plots treated with winter-patch grazing and patch-burn grazing. Two more orders (Ephemeroptera, Odonata) are present in both variable treatments (winter, burn) than are present in the contemporary treatment (summer-long) and one order (Neuroptera) is unique to only the winter-patch treatments. Furthermore, data indicates that both variable treatments result in greater total arthropod abundance than contemporary treatments. Many arthropods make up a large portion of the ecosystem's secondary trophic level. Their role as the primary consumers of vegetation as well as the main source of food for many birds and other species makes arthropods an important and valuable part of functioning ecosystems. Furthermore, arthropods that serve as pollinators are essential to preserving the abundance of vegetation that relies on pollination. The information from this experiment could aid in the development and promotion of management practices that preserve natural arthropod communities.

Impacts of Simulated Trampling on Regrowth of Yellow Flag Iris (*Iris pseudacorus* L.)

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The impacts of exotic invasive species on biodiversity, ecosystem processes, soil properties, and local economics have been, and continue to be major concerns. One of the most complex challenges associated with invasive species is how best to manage their impacts and remove them from a landscape if practical. Yellow flag iris (YFI) is a non-native, invasive wetland species that forms extensive monocultures along water courses and adjacent to water bodies. While chemical and mechanical treatments can be effective, trampling may also be a viable YFI treatment method. Our study aims to address two questions: (1) Does simulated trampling of YFI impact shoot density, shoot height, and carbohydrate reserves stored in YFI rhizomes? (2) Does inundation with water affect the impacts of simulated trampling on YFI? These questions are being addressed in a simulated trampling study conducted on potted plants in a greenhouse. Six treatment groups consisting of all possible combinations of inundation (inundated and not inundated) and trampling (untrampled, trampled early and trampled late) were studied. Inundation was achieved by maintaining the water level in the pots consistently 5-7 cm above the crowns of the iris plants. Trampling was simulated by the researcher applying concentrated pressure with the blunt end of a hammer to the plant crown. Prior to implementing treatments, and again at the conclusion of the study, shoot height and density were recorded and rhizome samples were collected for carbohydrate assays. We expect that the YFI plants exposed to both trampling and inundation will show the greatest reduction in height, density, and rhizome carbohydrate concentrations. Final results are pending, but initial observation supports this prediction.

Importance of Soil Health to Successful Restoration

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The better condition a soil is in when it is seeded as part of a restoration project, the greater the chances the project will be successful. A well-designed soil management plan is an essential part of any restoration project, but is even more important if the project requires soil lifting, stockpiling and replacement. Familiarity with soil properties and function prior to disturbance is required for their maintenance. Knowledge of the presence of factors limiting to plant growth in the soil profile, such as salty or sodic horizons, are critical to determine how much soil to lift from a site before a planned disturbance. An understanding of soil macronutrient levels and nutrient requirements of species used for revegetation is helpful. It is important to realize that levels of inorganic nutrients, especially N, may increase in a soil as a result of aggregate destruction during soil lifting and soil replacement. We have found that fertilization of disturbed soil benefits weeds more than desirable native plants. Use soil amendments with care and specific objectives in mind. One of the most commonly used soil amendments in Wyoming, gypsum ($CaSO_4$), is effective in preventing soil crusting but is also a salt that lowers the soil water potential and makes it more difficult for plants to extract water from soil. Healthy soils capture and store water, provide essential nutrients, are resilient to disturbance and support large populations of microorganisms, including mycorrhizal fungi that can help plants grow.

Improvements in Disturbance and Reclamation Tracking

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The BLM manages 247 million acres (12.5% of U.S.) and 700 million acres of subsurface mineral estate (30% of U.S.). We manage nearly a million energy and mining authorizations. Our databases did not always require surface disturbance acres, nor was reclamation criteria recorded in a manner that can be queried. We are working to change that. There are two problems that must be solved. #1 start tracking disturbance and reclamation for the authorization that will be built tomorrow in the most efficient and effective manner possible. #2 digitize our legacy authorization into one database. During the past 10 years the industry has switch from one well on a pad to directional drilling, which may now have approximately 60 wells as a single massive pad, where better tracking of topsoil, soil management, pit and water management and interim reclamation will help enable responsible energy development. We have rethought our database management to better track these surface disturbances polygons of pads, pipelines, roads, electrical lines, and production facilities. We are creating data standards for 42 feature services and 37 external datasets, which will include Resource Use Designation Decisions (RUDD), ownership, and resource data, so that we can intersect these datasets with proposed disturbance in an efficient web app. We are also switching to ESRI Survey123 and Collector to verify the permit is in compliance. Via a USGS contract, we have made customizations to track disturbance thresholds in the sage grouse plans to the Desert Renewable Energy Conservation Plan (DRECP). We have QA/QC'd and ingested state's data, and digitized disturbances. We will be creating a national reclamation database that will track how reclamation is conducted, monitoring protocols and survey data, and standards.

Improving Analytics for Forage and Livestock Risk Management Using Remote Sensing, Simulation Models, and Forecasting

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Because of the large land areas occupied by rangelands, characterization of the extent and intensity of drought poses challenges for land managers and producers. Monitoring networks for climate are generally sparse and large distances can occur between sensors or gauges. Therefore, the evaluation of forage quantity and forage quality over large landscapes cannot always be completed on a near real-time basis, thus increasing risk for producers during times of drought and other disasters. Increased availability, resolution, and quality of climate and remote sensing products are improving capabilities for assessing drought impacts on rangelands through the use of early warning and forage monitoring systems. The products include rainfall, temperature, and vegetation greenness imagery (NDVI) that can be used for local and regional analyses, as well as inputs to simulation models and statistical forecasts. Integration of remote sensing products, simulation models, and other available data streams (e.g., forage quality, livestock prices, hay availability) within a GIS framework provides capabilities for identifying anomalies and trends on a near real-time basis and provide a more holistic assessment of risk. An overview of the specifications and limitations of remote sensing, climate, and forecast products that are currently available for use in early warning systems and risk management assessments will be presented. Information on lower cost sensors and instruments that could provide new data streams and sensor networks for next generation early warning systems for risk management will be discussed.

Improving Rangeland Seedling Recruitment Using Fungicide Seed Coatings

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Reseeding rangelands following disturbances is oftentimes unsuccessful. One of the demographic processes limiting seedling recruitment is fungal attack. A possible solution to this problem is to coat seeds with fungicides. We tested this hypothesis by developing a fungicide coating for *Pseudoroegneria spicata* seeds that included four fungicides that address specific fungal pathogens known to attack *Pseudoroegneria spicata* seeds. We tested germination and seedling biomass of seeds coated with a range of fungicide rates in a complete randomized block laboratory experiment. We found that coating seeds with fungicides at 5/3 of the recommended rate for (*Triticum aestivum*) produced seedlings with the highest biomass without reducing germination. We planted a fully randomized split plot design experiment using seeds coated with the 5/3 fungicide rate to evaluate germination and emergence in the field. We found that although fungicide coatings did not improve germination against the control, fungicide coatings improved emergence by 48.3%. The results suggest that fungicide seed coatings may improve success of rangeland seedings by increasing seedling emergence. Fungicide seed coatings may also reduce seeding cost by reducing the seeding rate necessary to reach target plant densities.

Improving Reclamation Success on Western Public Lands

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Successful reclamation of highly disturbed western US public lands remains challenging. Improvements in systems for capturing data and information related to reclamation practices and associated outcomes have the potential to greatly increase our understanding of best management practices (BMPs) for a given soil and climate context. A variety of environmental factors contribute to reclamation challenges in the west, including problematic post-disturbance soil conditions, often low and variable precipitation, and invasive species. Despite these challenges, we do see some successful reclamation outcomes and understanding the practices and circumstances under which success was achieved is critical. Similarly, identifying practices that are not often successful, or environmental settings that are especially challenging, can serve to minimize reclamation costs and environmental risk. Finally, current standards for defining successful reclamation are highly variable across the west, both within and among land management agencies, leading to uncertainty for producers and lands that are not on a pathway towards providing habitat and other ecosystem services. Here, we provide 1) an overview of the current management of oil and gas as it relates to reclamation, 2) a vision for an adaptive management framework for oil and gas reclamation, and 3) ideas for approaches to standardizing reclamation standards.

Improving Seeding Success in the Sagebrush Steppe with Seed Priming and Deep Furrow Plantings

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Seeding of native perennial species commonly fails in the presence of invasive annual weed species. The ability of weeds to deplete soil moisture by early germination and rapid growth gives them a competitive advantage over native species. A possible solution to help native species compete with invasive weeds is to enhance their germination rate and growth. We primed seeds of *Pseudoroegneria spicata* and *Linum lewisii* in a matrix of compost, clay, and biostimulants for 4-7 days. For the priming duration that had the quickest germination, we conducted an additional study where the priming matrix and seed was formed into pellets through extrusion. We evaluated the primed pellets at two field sites against unprimed seed in pellets and untreated seed. Seed treatments were planted in shallow (2 cm) and deep (15 cm) furrows, in a complete factorial design, with the expectation that the deep furrow would sidecast weedy seeds in the surface soils and provide an enhanced microsite to improve plant growth by collecting additional moisture. In the first month after planting, primed pellets in deep furrows increased seedling emergence of *P. spicata* and *L. lewisii* by 128% and 303%, respectively, compared to untreated seed in shallow furrows. The following growing season, plants resulting from primed *P. spicata* seeds in deep furrows increased plant biomass by 158% compared to untreated seed in shallow furrows. Priming did not improve biomass production in the following season for *L. lewisii*, but the deep furrow treatment did increase biomass by 100%, compared to shallow furrows. Overall this study indicates that the rapid germination of primed seeds and the use of deeper furrows may assist seedlings in establishing earlier in the growing season, which may allow them to better compete with invasive annual weeds.

Improving the Establishment of Pollinator Mixes on Semi-arid Conservation Reserve Program Lands

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Conservation of pollinating insects has garnered significant attention in recent years. In 2010, the USDA Farm Service Agency (FSA) started incentivizing landowners to establish pollinator plantings through its Conservation Reserve Program (CRP). Since that time, restoration practitioners and habitat management professionals in northeastern Colorado have accumulated practical knowledge on pollinator planting establishment through trial and error. Lessons learned include the importance of proper weed control and site preparation prior to planting, correct seed selection, proper equipment, and the value of skilled operators. By 2016, FSA recognized that although CRP pollinator plantings were gaining steam, their success still remained relatively low, particularly in western drylands. FSA therefore funded a research program focused on further enhancing pollinator planting success across three regions: the Great Basin, the Northern Great Plains, and the Central Great Plains. Rangeland scientists from each region developed alternative planting treatments which included “business as usual”, nutrient alteration, alternating grass and forb strips, and alternative seed mixes. In the Central Plains, the alternative seed mix treatment was developed in association with local NRCS restoration practitioners and was geared towards the use of drought-tolerant species found in local native rangelands. To make the research applicable to real-world situations, large research plots were co-located with non-research CRP plantings on widely variable, privately-owned fields. First-year results suggested that all three of the alternative treatments produced higher densities of planted species and more abundant floral resources than the “business as usual” option. Researchers will repeat the entire experiment again in 2019 to investigate how weather variability influences the success of different planting treatments. For both local practitioners and restoration researchers, identification of successful CRP pollinator planting strategies involved throwing out “the book” – or the local traditional planting paradigm – and planning projects based on a working knowledge of plant ecology combined with practical experience.

In Pursuit of Better Rangeland Management, 3rd Edition Nevada Rangeland Monitoring Handbook

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For adapting public and private rangelands management based upon short- and long-term monitoring, we seek a common voice among State and Federal agencies and key stakeholders. Specific measurable, achievable, relevant and timely objectives for long term or effectiveness monitoring focus on priorities. Strategies for meeting objectives focus short-term or implementation monitoring. If the rangeland is not overgrazed – but inappropriately managed, monitor the management strategies that matter. Ecological Site Descriptions provide a foundation for knowing what is needed and effective. Adaptive management uses principles for flexibility with responsibility. Flexibility is needed because rangelands change with weather and trends. A Cooperative permittee monitoring template steps through a common sense process focused on priorities, objectives, strategies, and agreement. Appendix F – Scales in Monitoring addresses questions related to AIM, “objectives” tables for sage-grouse habitat, land-use plan “objectives,” etc. It is fundamentally important to set objectives at the scale of the issue and to monitor at the scale of the objective and management strategy. Appendix I – Statistical Considerations helps consider variations in data for artful informed management. The Handbook is posted at http://www.unce.unr.edu/publications/sp_2018_03.aspx. Important concepts are illustrated with color photos or fillable forms. This work is designed to support ROGER (Results Oriented Grazing for Ecosystem Resilience), Outcome Based Grazing, fine fuels management, riparian functions, and other efforts to address real and important management challenges.

Incipient Tree Invasions Signal Heightened Vulnerability of an “Uninvadable" Grassland Region

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Empirical studies suggest that some arid and semi-arid grassland regions are exempt from tree invasion and encroachment due to environmental constraints. This hypothesis is often used to justify tree cultivation (e.g., agroforestry) in grassland regions. However, despite justifications, tree cultivation can results in invasion; sometimes it does not, and sometimes invasion occurs years or decades after establishment. Rangeland managers are faced with this uncertainty. The Nebraska Sandhills was originally hypothesized to be exempt from eastern redcedar (*Juniperus virginiana*; hereafter redcedar) invasion and today redcedar’s invasion potential is unknown. We use the plant invasion ecology framework to assess incipient spread of redcedar throughout the Nebraska Sandhills, USA. Our objectives were to (1) classify redcedar invasion potential in the Sandhills and (2) test the assumption in invasion ecology that native species do not disperse via cultivation pathways. We mapped redcedar cultivation and dispersal on 44 public properties in the Sandhills using satellite imagery and field sampling. These data were evaluated against Richardson et al. (2000) invasion framework to assess objective one. For objective two, we used a resource selection function to compare expected and observed proximities of redcedar dispersal to redcedar cultivation. Invasion potential was interpolated based on mean annual precipitation (MAP) associated with redcedar invasion. Redcedar invasion occurred throughout the Sandhills and field sampling identified additional dispersal in the herbaceous layer. The driest instance of invasion had a MAP of 423 mm. Given these findings, 97% of the Sandhills is vulnerable to redcedar invasion. Redcedar dispersal occurred significantly closer to cultivated redcedar than expected at 87% of public properties with >5 redcedar dispersers. We show that, despite sparse redcedar cover, the Sandhills is vulnerable to invasion and redcedar cultivation contributes to invasion. Preventative and proactive policies and management of redcedar are merited in the Sandhills to maintain this regions rangeland resources.

Incorporating Black-Tailed Prairie Dog (*Cynomys ludovicanus* Ord) Occupation into State-and-Transition Models

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Black-tailed prairie dogs (*Cynomys ludovicanus* Ord) are a native rodent to the mixed grass prairie of the Northern Great Plains and their occupation can affect production, standing crop, and species richness of an ecological site compared to the same ecological site located off-colony. Prairie dog occupation is considered a natural disturbance similar to large herbivore grazing, fire, and drought. Colonization by prairie dogs on a given ecological site will impact soil properties, hydrology, vegetation, and biotic interactions (e.g., grazing of large herbivores) that are uniquely distinctive than other disturbance drivers of the mixed grass prairie. Ecological site descriptions (ESD’s) are defined as “a distinctive kind of land with specific characteristics that differs from other kinds of land in its ability to produce a distinctive kind and amount of vegetation” (NRPH 2003) and contain four major sections: site characteristics, plant communities, site interpretations, and supporting information. State-and-transition models (STM’s) located in the plant communities section of ESD's communicate the ecological dynamics within a given ecological site through the primary components: states, transitions, and pathways (Stringham et al.). We propose that incorporating a prairie dog occupation within a given ecological site should be addressed within the STM on ecological sites where colonies are known to exist to better describe the resulting changes to the ecological processes due to this unique disturbance. This poster illustrates how prairie dog occupation can be incorporated into STM’s.

Incorporating Pasture States in Ecological Site Descriptions

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An ecological site is a conceptual classification of the landscape. It is a distinctive land type based on a recurring landform with distinct soils (chemical, physical, and biologic attributes), kinds and amounts of vegetation, hydrology, geology, climatic characteristics, ecological resistance and resiliency, successional dynamics and pathways, natural disturbance regimes, geologic and evolutionary history including herbivore and other animal impacts; and response to particular management actions. Ecological site classification and descriptions (ESD's) are fundamental to USDA-NRCS conservation planning and management, and communication with other agencies and land users. In USDA-NRCS, ecological site descriptions, including state and transition models (S&TM) represent a culmination of knowledge about ecosystem dynamics and changes in response to natural events and management applications. They are diagrammatic portrayals of predictable pathways with narratives and identification of specific environmental and various disturbance drivers, but do not necessarily explain the mechanisms or processes or advance theories of plant succession. Within the S&TM, vegetative states change as a result of natural or anthropogenic disturbance events, or lack of a natural events. Land uses such as cropland and pastureland emerged at some point in past history from clearing timber and/or plowing grasslands and are now identified in NRCS ecological site S&TM's. In order to understand specific land dynamics; address ecological status/soil health/rangeland health; or evaluate and prescribe management, a working knowledge of ecological origins, site potentials and dynamics is needed. Including converted states in S&TM's fosters a general understanding of ecological parameters and response to management actions; thereby, leading to more efficient and effective allocation of management efforts. In this paper we review classification of pasture groupings, describe the methodology of developing pasture states and present a S&TM showing converted state dynamics with recommended narratives and content.

Incorporating Region-Wide Outcomes of Pinyon-Juniper Reduction Treatments into Generalized STMs for Sagebrush Ecosystems

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The expansion and infilling of pinyon pine (*Pinus* spp.) and juniper (*Juniperus* spp.) species into sagebrush (*Artemisia* spp.) ecosystems of the western United States is actively counteracted by vegetation treatments to reduce tree density, increase understory perennial vegetation, and promote a transition from a conifer-dominated state to a state dominated by shrubs and grasses. Specifying how tree reduction treatments influence transitions and incorporating this information into generalized state-and-transition-models (STMs) could greatly enhance the accuracy of STMs and their adoption as a tool for making land management decisions. We assessed pre- and post-conifer reduction vegetation cover at 168 sagebrush sites that encompassed three ecoregions across Utah. Plant responses were analyzed by functional group using meta-analysis of effect sizes (ln[Post/Pre]) with phase of tree dominance, sagebrush community type, and treatment type (i.e., chaining, mastication, cutting) as covariates. The dataset was also partitioned into post-treatment timeframes ranging from 1 to 15 years to evaluate temporal dynamics of vegetation change. Perennial grasses increased for all comparisons, especially for chained sites with the highest tree dominance. Perennial forbs also increased in most situations except in cutting treatments and at sites with high initial values and low conifer density. Sagebrush increased in most cases except within Wyoming big sagebrush (*A. tridentata* ssp. *wyomingensis*) communities treated with chaining or cutting or when mastication was applied at sites with low initial conifer density. Over time, sagebrush generally increased, while perennial forbs declined, but outcomes varied depending on treatment type. We address how underlying ecological site characteristics strongly interact with treatment options and incorporate treatment outcomes into generalized STMs for black sagebrush (*A. nova*), Wyoming big sagebrush, and mountain big sagebrush (*A. tridentata* ssp. *vaseyana*) ecological sites. Our synthesis offers a validation mechanism for STMs and provides a platform to discuss the adoption of STMs for project planning.

Increasing Sector Adoption of AC Saltlander Green Wheatgrass

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Severe soil salinity affects an estimated 2.2 million hectares on the Canadian Prairies. It can severely reduce forage plant establishment resulting in unproductive land and significant economic losses to producers. Agriculture and Agri-Food Canada (AAFC) developed AC Saltlander green wheatgrass (ACS), a perennial forage, to use in areas where soil salinity is a major limiting factor. AAFC plot-scale research has shown that ACS can reclaim unproductive saline soils for increased forage production and potential economic gain – it has superior establishment and persistence, has suitable nutritional forage quality and provides good weed suppression. However, producer uptake has been less than expected. The objective of this project is to improve sector adoption of ACS on saline soils by scaling up recommended management practices to field scale studies in Alberta, Saskatchewan and Manitoba. Demonstration sites were seeded in 2017 to five forage mixes (ACS at 2 rates, ACS+slender wheatgrass, ACS+alfalfa, and a commercial saline forage mix). The following parameters were monitored: forage establishment, weed species and cover, forage yield, forage quality, and soil salinity levels. Information products such as videos, factsheets and presentations will be developed to communicate the results and help increase the uptake of ACS by showing producers that it is a good option for managing saline soils.

Indaziflam Effects on Seed Production for Established Perennial Grasses

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Annual weeds, like cheatgrass (*Bromus tectorum* L.), negatively impact grass seed production by directly competing for resources and contaminating seed lots. Herbicide options in grasses grown for seed are relatively limited, and for one to be useful it must provide acceptable weed control with little reduction in seed production and viability. Indaziflam controls annual grasses and other weeds, but we know little about how it affects seed production and germinability. Our objective was to evaluate the effects of indaziflam on grass seed production and germinability across a range of plant materials. Eighteen different grass species (or varieties) were seeded in a randomized complete block design with four replicates at Wyarno, WY in 2013. We applied indaziflam (73 g ai·ha^{-1}) and glyphosate (420 g ai·ha^{-1}) to one half of each plot on March 27, 2017. Cheatgrass was actively growing and some of the perennial grasses had broken dormancy at the time of application. We harvested, counted, and weighed mature inflorescences early July 2017 and mid to late July 2018 from three bunchgrasses per plot or from within a 0.25 m^2 frame for rhizomatous grasses. We evaluated cumulative germination using 50-seed lots in petri dishes with filter paper in a growth chamber set at 21° C daytime and 10° C nighttime temperatures for one month. We analyzed data as a two-way ANOVA with plant material and herbicide as the two treatments. Two years after herbicide application, indaziflam provided nearly 100% cheatgrass control. Herbicide treatment affected seed production ($p<0.001$) in 2017 and 2018, though directionality and magnitude of effects varied among species and across years. Our initial findings suggest indaziflam may provide acceptable annual weed control in desirable rangeland grasses grown for seed production, if appropriate labeling is approved.

Inducing Phenotypic and Genetic Variability Through Gamma Irradiation in Lehmann Lovegrass (*Eragrostis lehmanniana*)

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Lehmann lovegrass (*Eragrostis lehmanniana*) is a species used for the restoration of highly degraded grasslands. However, using species may implicate an ecological risk because it could disperse and displace the native vegetation. Thus, it is recommended to improve its nutritional quality in order to increase its acceptance by the cattle, and therefore reduce its invasiveness. This study assessed the morphological, nutritional and molecular diversity in Lehmann lovegrass, as it was induced through gamma irradiation. That, within the framework of a genetic improvement program. Seeds were exposed to gamma radiation (60Co) at doses of 100, 200, 300, 450, 600, 900 and 1400 Gray (Gy). A control treatment (0 Gy) was also included. Ten plants per dose were produced under greenhouse conditions and they were evaluated during two years through eleven agronomic traits related with high forage quality. The outstanding individuals (M1 mutants) were selected and characterized, nutritionally through near-infrared spectrophotometry, and molecularly through AFLP markers. Gamma irradiation induced morphological variability, which allowed to select six mutants. Three mutants (200-6, 300-7 and 1400-10) presented lower ($P<0.05$) lignin and higher ($P<0.05$) protein contents than the control plants. Results from the molecular analysis showed significant differences ($p<0.05$) among the control genotype and the mutants 200-6 and 300-7, which presented genetic similarities to the control (Dice's coefficient of 0.49 and 0.48, respectively). The phenotypic and genetic variability induced by gamma irradiation allowed selecting the first generation of mutants with nutritional quality. Thus, it is recommended to assess the following generations of these materials until fix the chosen characteristics.

Influence of Grassland Management Systems on Fine-Scale Distribution of Lesser Prairie-Chickens and Their Habitat

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The lesser prairie-chicken is an imperiled species that faces range and population declines due to declines in quality and mismanagement of its remaining grassland habitat. Female lesser prairie-chickens use diverse grassland resources across their life stages; most important for population growth are nesting and brood-rearing periods. Historically, climate and interactions between fire and free-roaming bison drove this configuration of resources. However, current management seeks to shape lesser prairie-chicken habitat by grazing domestic cattle restricted within pastures, often not in conjunction with prescribed fire. Because much of the species' eastern range occurs on privately owned land, understanding the influence of grazing management on lesser prairie-chicken habitat is crucial to conservation. We collected data on patch-burn grazed and rotationally grazed treatments, representing two widely used cattle management techniques. We tested how these systems alter fine-scale cattle distributions and subsequently influence vegetative resources for lesser prairie-chickens. We used Brownian bridge movement models to map the distribution of GPS-collared cattle within pastures on both treatments. We used conditional logistic regression to model resource selection by GPS-tagged female lesser prairie-chickens during nesting and brooding, relative to factors such as elevation, time-since-fire, tree density, and fine-scale distribution of cattle. We used generalized linear models to determine how factors within each system influenced visual obstruction and percent composition of plant functional groups. We used the relationship between fine-scale grazing and vegetative resources to determine how much nesting and brooding habitat was available to lesser prairie-chickens within each treatment. These data will inform future grassland management on the mixed-grass prairie relative to which grazing systems and stocking rates provide the optimal proportion of nesting and brooding habitat for lesser prairie-chickens.

Influence of Precipitation on Plant Production at Different Topographic Positions in the Nebraska Sandhills

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Several studies have evaluated the spatial distribution of cool- and warm-season grasses across different topographic positions in the Nebraska Sandhills, but limited research has explored topographic differences in total plant production or production of plant functional groups in relation to variable amounts of precipitation. This study evaluated how spring and growing season precipitation influenced plant production at four topographic positions common in the eastern Nebraska Sandhills. Plant production data were collected from annually moved grazing exclosures in mid-June (peak cool-season grass production) and mid-August (peak warm-season grass production) during a 17 yr period from 2001 to 2017. Total plant production and precipitation use efficiency were 35 to 58% greater on interdune positions and precipitation marginal response for total plant production was more sensitive to increases in spring and growing season precipitation on interdune compared to dune positions in both mid-June and mid-August. The greater precipitation marginal response of total plant production on interdune positions was driven primarily by greater increases in cool-season grass production with increasing spring or growing season precipitation. Warm-season grass precipitation marginal response was not different among the topographic positions, but production was 23 to 70% greater on interdune compared to dune topographic positions in mid-August. When differences in the amount of each topographic position at the study location were accounted for, growing season precipitation explained 49% of the variation for total plant production in mid-August, but spring precipitation only explained 23% of the variation for total plant production in mid-June. Because of the differential response of plant production at dune and interdune positions, incorporating the relative amount of each topographic position into estimates of plant production at the pasture or ranch scale will provide better information for adjusting stocking rates to more accurately match animal demand with forage availability.

Information Is Power to Get from Seeds to Successful Prairie Every Time!

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Prairie reconstruction (establishing prairie from seed) is essential to conservation goals. It is frequently used to buffer or enlarge existing prairie remnants, build a semblance of historic prairie where it no longer exists, improve water quality or create habitat. Many conservation organizations and landowners attempt to reconstruct diverse prairie, but through time, quality among such plantings can range from highly diverse, functional prairies to disappointingly weedy places with few native species. The question is why? To bridge knowledge gaps and benefit through collective learning, a network of researchers and practitioners from over 30 conservation organizations have joined forces in a group called the Prairie Reconstruction Initiative (PRI). PRI uses tools such as the newly-released PRI monitoring protocol and reconstruction and management database to improve collective learning and inform future decisions. Furthermore, PRI reaches beyond the data to share the knowledge generated from these products. PRI supports a wide range of informational products, person-to-person interactions and knowledge exchanges through field days, webinars, workshops and discussion forums.

Integrated Monarch Monitoring Program: Evaluating Habitat and Use by Monarchs to Guide Conservation

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Monarch butterflies (*Danaus plexippus*) have declined more than 80% during the past 20 years, spurring rapid conservation action to increase their numbers and decrease their risk of extinction. A loss of breeding habitat, milkweed and nectar plants, is implicated in their decline. More complete information regarding monarch distribution and abundance, habitat availability and use, and reproductive rates across seasons and regions is needed to guide these efforts. The Integrated Monarch Monitoring Program was designed by the Monarch Conservation Science Partnership to monitor monarch butterflies and evaluate their habitat nationally. A network of coordinators, resource practitioners, and citizen scientist volunteers collect data on milkweed density, frequency and diversity of nectar plants, and egg, larval, and adult monarchs. Sites include randomly selected locations across land types (grasslands, rights-of-ways, developed, and agricultural) and conservation sites to describe enhanced habitat conditions and learn more about management efforts. I will present habitat profiles from grassland sites, explore management evaluation scenarios, and talk about opportunities for involvement in the program.

Intensity of Perception and the Influence on Information Acceptance Related to Prescribed Fires

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Prescribed fire is an important management tool on many rangelands. However, evidence that this tool is effective for mitigating a number of problems faced by landowners has not led to substantial increase in its adoption. Lack of knowledge about the safe application of this tool has often been cited as a reason for not applying it, which has led to calls for more education and outreach efforts to fill this knowledge gap. However, even when such education is provided to landowners, adoption rates often do not increase substantially. When examining education improvement strategies, credibility often comes up as a primary driver to information acceptance. However, credibility does not solely explain why information is not accepted from credible sources and mediums providing such information. Other facets of information influence the acceptance and implementation of prescribed fire. Previous research indicates that the relationship users have with a particular source and medium of information heavily influence their acceptance of the information. My research attempts to identify facets of information other than credibility that potentially influence that relationship; these include reliability, clarity, relevance, accessibility, and shareability, on information acceptance. This research explores how these factors affect landowner perceptions about information sources and mediums used to disseminate information about prescribed fire. The hypothesis is the appearance of information and the users' relationship with that source/medium plays a more significant role than previously thought. This hypothesis is tested using a mixed methods web and mail survey. The results of this study will provide guidance for government agencies and landowner entities, such as prescribed burning associations, how to improve their information dissemination practices in order to enhance landowner perception and adoption of prescribed fire.

Introduced Forage Species on Native Rangeland: Friend or Foe - An Introduction

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Introduced forage species have been a cornerstone of pasture production since the 16th century. And the debate as to the benefits or detrimental effects of these species is almost as dated. This symposium will investigate the attributes that make these forage species so dependable and such aggressive invaders in native systems. Corteva Agriscience, the agriculture division of DowDuPont is proud to host the symposium to encourage active conversations and solutions to the mounting issues of forage grasses nationwide.

Introduction to the US National Vegetation Classification (NVC)

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The National Vegetation Classification (www.usnvc.org) is a framework required of all federal agencies to enable aggregating information about existing vegetation communities across land ownership. The National Vegetation Classification (NVC) is a hierarchical system which aids in describing, inventory, monitoring, and study of vegetation across all lands in the United States. The NVC was developed using plot data and has eight levels. The plots provide critical information about the underlying concepts of ecological context and plant community. The public can have a better understanding of the vegetation in the United States when all agencies, states and NGOs describe vegetation and track vegetation changes using a standard classification. Federal land managers can more easily collaborate to manage vegetation by using shared knowledge to determine the best actions, and to monitor effects and outcomes. The Forest Service has a key role in supporting and adopting the federal standard. Several approaches are being tested to crosswalk national and regional existing vegetation classifications to NVC. By using one standard existing vegetation classification, federal land managers will engage in vegetation management and planning across all lands and at all scales. Everyone will use the same language to talk about existing vegetation and desired conditions, and to discuss treatments and effects across large landscapes.

Investigating Factors that Influence Northern Bobwhite Chick Survival

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Research on northern bobwhite brood ecology is extremely limited, especially for neonate chicks. Furthermore, basic life-history information such as cause-specific mortality for the first six weeks of life, post-hatch is deficient in the literature. What little survival information exists on bobwhite chicks is often based on flush counts which are subject to detection issues resulting in biased estimates and untenable inference. Data concerning bobwhite brood resource use is also very limited. Given these shortcomings in the literature, our objective is to estimate bobwhite chick survival and resource use in the Rolling Plains of west Texas. We are using a combination of GPS-equipped radio-transmitters fitted to hen parents and VHF radio-transmitters sutured to backs of chicks. Tracking parent hens using GPS tags provide fine-scale movement information while suture-tags of chicks provides individual vital rate information and more accurate estimation of individual and group-specific survival. Additional factors potentially influencing survival and resource use such as predator abundance, weather conditions, insect availability, and vegetation composition and structure will be incorporated as covariates in future analyses. During 2017 and 2018 we monitored 25 broods and 101 chicks using a combination of patagial tags and radio-tags, 2-4 times a day to determine movements, survival and cause of mortality based on evidence at the mortality site. We will report daily survival of chicks and cause of mortality. These data will provide much needed insight to management practices that will help maintain or increase bobwhite populations in the Rolling Plains of Texas as well as help to fill a gap in the literature on bobwhite ecology.

It Depends on Goals: Fire and Grazing Are Both Needed for Prairie Butterfly Management

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Land managers seek to conserve endangered prairie ecosystems by reinstating natural, pre-settlement disturbances such as fire and grazing. The Minnesota tallgrass prairie is home to many butterfly species that are sensitive to disturbance. Although the effects of fire on prairie ecosystems are well documented, much less is known about the effects of conservation grazing on prairie butterflies or how these management practices interact with species traits and environmental characteristics. We address this knowledge gap by documenting direct and indirect effects of fire vs. grazing on tallgrass-prairie butterflies and by exploring the interactions between species traits and environmental characteristics. Butterfly surveys were conducted at 20 remnant prairies in Minnesota during the summers of 2016 and 2017. Overall butterfly abundance was higher at burned sites. However, large, grazed sites were correlated with higher abundance of prairie-dependent butterflies, particularly those in the Hesperiidae family. Host-plant frequency was an important indicator of abundance for the regal fritillary (*Speyeria idalia*) but not the monarch (*Danaus plexippus*), for which forb frequency was a significant indicator. Additional butterfly-trait and environmental characteristics explain patterns in prairie butterfly observations and can be used to develop conservation plans.

Juniper Recovery Following Initial Restoration with Extreme Fire

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Woody plant invasion threatens the persistence of grassland biomes globally and their unique suites of ecosystem services. Eastern redcedar (*Juniperus virginiana*: hereafter juniper) is invading Great Plains grasslands due to changes in fire regime components, (e.g., frequency, intensity), human facilitated spread and planting of juniper trees, changes in climate, and greater grazing intensities by domestic livestock. In response to increased woody abundance, citizens of the Great Plains are forming cooperative burn associations. Some burn associations have been successful at restoring grassland dominance through the use of high intensity prescribed fire capable of collapsing juniper woodlands. However, the reinvasion rates of juniper following initial restoration and the appropriate management regimes required to maintain restored grasslands remains unclear. The objective of this study was to quantify the rate of juniper reinvasion following initial restoration with high intensity prescribed fire. This study was conducted in the 133,546 ha Loess Canyons Experimental Landscape, Nebraska, USA. Sampling occurred in a randomly selected collapsed juniper patch in 22 burn units ranging from 0-16 years since fire. We also sampled in three unburned juniper patches to serve as reference woodland conditions. In each burned juniper patch, we sampled for juniper canopy cover, height of juniper trees, and juniper density. Results showed that juniper seedlings re-established within one year after initial restoration by fire. Juniper trees outgrew the herbaceous layer and were readily visible four years after initial restoration by fire. Adult juniper trees (>1.8m) were visible nine years after initial restoration. Based on juniper recovery, guidance on adaptive juniper management is provided, including management phases with biological cues, a timeline, and management options.

Juniper Sapling Regrowth Following Targeted Grazing Treatments in Relation to Terpenoid Concentration

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Chemically defended woody plants are expected to grow at slower rates compared to less-well defended counterparts. The objective of our study was to determine whether regrowth of browsed one seed juniper saplings (*Juniperus monosperma*) was related to initial terpenoid concentrations. Targeted grazing with small ruminants was applied on 16 10 x 30 m sapling-infested rangeland plots at NMSU's Corona Range and Livestock Research Center in the summer of 2006 (n=8) and spring of 2007 (n=8). Immediately after grazing, foliage of approximately 10 saplings in each plot was harvested and subsequently analyzed using gas chromatography/mass spectrometry. In 2017, we returned to the plots to measure sapling survival and regrowth. We hypothesized that sapling regrowth rate would be inversely related to terpenoid concentration measured in 2006/07. We used linear regression to explore this hypothesis using PROC REG in SAS 9.4. Plot averages were used in two separate regression analyses (summer and spring). Crown height of saplings increased 20.1 ± 1.4 cm and 19.9 ± 2.2 cm, and terpenoid concentration was 0.30 ± 0.01 mg/gDM and 0.26 ± 0.01 mg/gDM in spring and summer plots, respectively. Terpenoid concentration explained 52% of the variation in sapling regrowth in spring plots (β=-88.2; P=0.04) and 81% of the variation in sapling regrowth in summer plots (β=-227.6; P<0.01). As predicted, we found an inverse relationship between initial terpenoid concentration and one seed juniper sapling regrowth 10 y after applying targeted grazing treatments with small ruminants. Since sheep and goats preferentially browse saplings with low terpenoid levels, our results suggest that heavily browsed saplings that survive are likely to exhibit the highest regrowth rates after treatment.

Laboratory Evaluation of Abscisic Acid and Gibberellic Acid Seed Coatings to Improve Germination Timing of Low Sagebrush

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Catastrophic wildfires, invasive species, tree encroachment, and anthropogenic disturbances are degrading sagebrush ecosystems in North America and threatening the survival of sagebrush obligate and associated species, as well as decreasing rangeland ecosystem resources. Low sagebrush (*Artemisia arbuscula*) is an important shrub species in the sagebrush biome. The reestablishment of this species through seeding has been limited in success. Germination timing can have a strong influence on the ability of a plant to establish, and altering the timing of germination for sagebrush may improve establishment success. Seed enhancement technologies offer a novel approach to controlling germination timing. The plant hormone abscisic acid (ABA) can be applied to seeds to delay germination. Gibberellic acid (GA) plant hormones can be used to accelerate germination. Our objective was to understand how planting date and application of ABA and GA treatments influence germination timing of this sagebrush species. Seed was left untreated, treated with two separate concentrations of ABA, or treated with two separate concentrations of GA. Hydrothermal germination models were developed for each seed treatment and applied to field soil moisture and temperature data to predict germination timing. Simulated planting dates were tested at monthly intervals from October-April on eight different years at six different Wyoming big sagebrush sites. Results indicate that planting date, ABA concentrations, and GA concentrations can have a strong influence on seed germination timing and could alter this timing to occur in windows that have more favorable temperature and moisture conditions for plant establishment.

Land Management Strategies to Reduce Invasive Cool-Season Grass in the Northern Great Plains

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The conservation of biodiversity in working landscapes requires understanding the response of vegetation to different land management practices, especially where biological invasions threaten biodiversity. Kentucky bluegrass (*Poa pratensis*) invasion in the northern Great Plains is currently homogenizing mixed-grass rangelands. Burning and grazing in grassland landscapes has been successful for managing invasive species and increasing native biodiversity, but it is unclear how specific strategies improve restoration practices in novel ecosystems where invasive plants have a similar growth phenology to native plants. We investigated grazing strategies and prescribed fire as a restoration practices to decrease the cover of Kentucky bluegrass, a perennial cool-season invasive grass phenologically similar to dominant native cool-season grasses, by 1) evaluating season of burn (early-growing season, late-growing season, and dormant season) in a field experiment to test differences in plant community composition and 2) manipulating fine fuels (3,000-5,000 kg·ha^{-1}) in an experimental approach to determine the effects of fire on plant survivability of selected native grasses and bluegrass, and 3) investigating season-long, early-intensive and patch-burn grazing on vegetation species composition and cover, specifically Kentucky bluegrass. Bluegrass decreased 27% on all field burned plots the first year post-fire. Three years post-fire, late-growing season and dormant-season treatments had 35% less bluegrass, whereas the early-growing season treatment was not significantly different from the control. Native grasses and bluegrass experienced high rates of mortality (40–50%) at fuel loads above 4,000 kg·ha^{-1} and heat dosages above 30,000 °C·sec, features commonly associated with early-growing season burns. Bluegrass, in grazed pastures, was least in PB and highest in SL pastures. The consequences and control of bluegrass invasion remain largely unknown but understanding how different management strategies impact invaded pastures aids the advancement of research to mitigate its deleterious effects and conserve biodiversity.

Landscape Changes, Land Management, and the Endangered American Burying Beetle in Nebraska

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The Loess Canyons of Nebraska are a biologically-unique landscape (BUL) consisting of steep loess-sand hills that support mixed-grass prairie. This area sustains several endangered species, including the American burying beetle (*Nicrophorus americanus*). Cattle grazing is the primary use of land with some agriculture on the more level areas. After decades of fire suppression and intentional cultivation, eastern redcedar (*Juniperus virginiana*) has expanded from the riparian zones and invaded the prairies. Local prescribed burn cooperatives have used fire to combat this spread since 2002. We aim to pinpoint how landscape changes have affected the stability of beetle populations in the Loess Canyons. Additionally, we aim to find the spatial scales relevant to beetle stability. Using 10+ years of beetle sampling data provided by the Nebraska Game and Parks Commission, we can determine the stability of beetle populations in the Loess Canyons. Spatial analysis will provide information on changing land cover ranging from small scales (~1 hectare) to large (~10,000 hectares). With this, we may find what land cover types are better suited to the beetle and if land cover changes at small or large scales are more important. Our results show that beetles are more frequent in the eastern half of the Loess Canyons, an area less invaded with redcedar. We expect to find that beetle populations are more stable in areas with less eastern redcedar. Also, we expect that the largest scale of land cover (10,000 hectares) will be too large to detect beetle preferences. This research can inform land managers who are combatting regime shifts and attempting to bolster populations of endangered species.

Landscape Evaluation of a Managed Disturbance Regime: A Case Study Texas Coastal Prairie Rangeland

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Woody encroachment can be regulated and reduced with the application of disturbance regimes. A managed grazing and prescribed fire regime (managed pyric herbivory) was implemented with The Grazing Manager on the Duncan Spade Ranch, Wharton County, Texas in 2012 with to control McCartney rose (*Rosa bracteata*) encroachment. The managed disturbance regime was evaluated with three questions: 1) Does the managed disturbance regime reduce McCartney rose on the Spanish Camp?; 2) Do reclamation burns break up large McCartney rose patches into multiple smaller patches?; and 3) Do repeated burns reduce McCartney rose patch size? Classification of aerial photographs show that McCartney rose cover decreased from 21% to 15% from 2012 to 2016. Measurements taken using landscape metrics show that McCartney rose patches are decreasing in size and fragmenting into multiple small patches (weighted average patch size 1.17 to 0.24). Landscape metrics also show that multiple fires produce greater fragmentation and a decrease in patch size in comparison to single fires. The continuity of McCartney rose decreased in response to multiple fires. This rangeland study has demonstrated that managed pyric herbivory is capable of reducing woody encroachment on the Texas Coastal Prairie.

Large Scale Resilience Planning

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The global human population has placed greater demands on the natural environment in recent decades than at any other point in human history, resulting in surprising and often unforeseen scales of collapse and reorganization in ecosystems. Innovations in technology and land use classification are now making it possible to detect complexities in ecological change that are unaccounted for in traditional rangeland inventory and monitoring approaches. New concepts and metrics have also emerged within resilience science to quantify cross-scale order in ecological systems and corresponding spatial complexities of change over time. These resilience metrics are now being put into practice to help guide improved decision-making in the face of rapid environmental change and heightened uncertainty. We have developed a new geospatial product that incorporates a metric of cross-scale resilience to the Rangeland Analysis Platform, a new decision-support tool that provides continuous, annual inventory of rangeland functional groups that correspond to known transitions in rangelands. We provide examples of how this product can increase planning horizons and help avoid common mistakes when prioritizing investments meant to sustain rangeland resources in regions experiencing large-scale transitions to ecosystems with lower ecosystem service provisioning.

Learning from the Past: Identifying the Historical Significance of Plant Functional Research on Rangeland Management

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Mechanistic research searching for explanations to the patterns and processes of natural and managed ecosystems has provided important information in developing management plans for these natural resources. Plant ecophysiology and functional ecology are two disciplines that have identified fundamental mechanisms that explain plant responses to dynamic environmental conditions. The field of plant ecophysiology, in particular, developed from research focused on explaining how plants in alpine zones could survive the cold, harsh conditions in these high-elevations ecosystems. But scientists focused on rangeland ecosystems worked to identify similar mechanisms of growth and survival in grasses and shrubs that dominate rangeland ecosystems. I will begin by presenting a brief history of plant ecophysiology and functional ecology in rangeland ecosystems, highlighting the important impact this research has had on understanding the ecology and management of natural ecosystems. After summarizing some key historical results, I will discuss some promising areas of research that will help us to continue improving our management of rangeland ecosystems.

Lessons Learned: Scale and Functional Heterogeneity are Foundational Concepts

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Our understanding of rangelands has been transformed over the past several decades by recognition of the fundamental importance of scale and functional heterogeneity that emerged from the equilibrium-nonequilibrial debate that began in late 1980's. Spatio-temporal heterogeneity is now considered to be foundational to the utility of our modern dynamic conceptual model of rangelands because rangelands are heterogeneous in both space and time. Scale and heterogeneity are tightly coupled concepts that are critical in understanding and managing rangelands for both production of food and fiber, as well as conservation of goods and services. Rangeland management was founded on the steady state management model that emphasized the optimal and efficient production of a small number of services by reducing variability and diversity to increase predictability in natural systems. Range science was founded on the premise that fencing and predator elimination programs, along with wildfire suppression, were superior to herding as a livestock production strategy that is common to pastoral systems. The consequences of spatial scale also went unrecognized as data collected in small plots was linearly applied to entire communities. A primary objective of range science until recently has been to minimize the consequence of spatio-temporal heterogeneity, rather than to optimize its value. The concept of carry-capacity has often been applied to stocking rates with a goal of optimizing livestock production with little recognition of scale and functional heterogeneity. The highly dynamic nature of rangeland primary production, through time and space, has increasingly been met with supplemental feeding, water developments, and livestock relocation. Future management needs to recognize heterogeneity and scale as a functional characteristic of rangelands that can be critical to successfully considering them as socio-ecological systems. Heterogeneity and scale are fundamental concepts to achieving multi-functional landscapes capable of providing food and fiber and other ecosystem services.

Livestock Water Quality Varies across 10 Years in Eastern Montana

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Concentrated dissolved minerals in naturally occurring water accessible to livestock grazing semi-arid landscapes can negatively influence animal productivity and wellbeing. Twelve indicators of water quality (Ca, Cl, F, Fe, Mg, Mn, Na, Nitrate-N, pH, SO_4, total dissolved solids (TDS) and temperature) were sampled from four sources: springs, reservoirs, ground water, and flowing surface water accessed by livestock over 10 years from 2009 through 2018 at the 22,257 ha USDA-ARS Fort Keogh Livestock and Range Research Laboratory, Miles City, Montana to estimate variation. Samples were collected twice yearly in two seasons, May (wet) and September (dry). Year, source, season, and their interaction were analyzed as a 10x4x2 factorial arrangement of treatments. A year by source interaction ($P<0.05$) was found for Na, Mg, SO_4, TDS, and temperature. A year by season interaction ($P<0.05$) was found for Na, TDS, and temperature. Concentrations of Ca, Cl, Fl, and NO_3, differed by source ($P<0.05$). Concentrations of Ca were different between years ($P<0.05$). SO_4 levels are generally higher in the dry season. Three years received below normal precipitation, three years received normal precipitation (316 mm) and four years received above normal precipitation. Solute concentrations such as TDS and sulfates were higher ($P<0.05$) in below and above normal years compared to normal. Average concentrations of Ca, Cl, Mg, nitrate-N, pH and TDS levels across sources did not exceed the upper maximum intake level for beef cattle. In contrast, concentrations of F, Fe, Mn, Na, and SO_4 exceeded upper levels for beef cattle, implicating these minerals may negatively impact range beef cattle performance.

Long-Term Trends in Perennial Grass Production, Precipitation and Temperature in the Chihuahuan Desert

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Rising temperatures and more frequent droughts are posing new challenges to livestock producers in the Southwest. Our objective was to evaluate long-term perennial grass production (PGP) in the Chihuahuan Desert in relation to ambient temperature and precipitation. PGP was correlated with precipitation (mm) and ambient temperature (°C) over a 49-year period (1969-2017). Increasing precipitation in December through September was associated with higher PGP (r=0.74, n=49) whereas rising maximum average temperatures in March through September were associated with a reduction in PGP (r=-0.54, n=49). Two-sample t-tests comparing averages of each variable for the first and last 25 years of the study period (1969-1993 vs. 1994-2017) revealed that mean PGP decreased by 35% (220.7 ± 12.5 vs. 143.92 ± 15.89 kg DM·ha^{-1}; P<0.01), precipitation was more variable and decreased by 21% (264.88 ± 1.30 vs. 211.13 ± 16.67 mm; P=0.01), whereas mean maximum temperature (24.48 ± 0.14 vs. 25.22 ± 0.13°C; P<0.01) and mean temperature (14.45 ± 0.13 vs. 15.04 ± 0.13°C; P<0.01) increased by 0.7°C and 0.6°C, respectively. Over this 49-year period, Chihuahuan Desert rangelands at our research site lost 35% of grazing capacity (approximately 84 AUMs/1,000 ha [7 AUYs/1,000 ha]). Our research shows that increased temperatures and more frequent droughts are severely impacting forage and range livestock production in the southwest.

Long-term Wyoming, USA Precipitation-Biomass Relationships and Cattle Gains as Triggers for Drought Decision Making

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Drought has been a persistent challenge to livestock production on western North America rangelands. The most common way that drought impacts livestock production is the reduction of forage quantity and carrying capacity relative to animal demand; an effect that typically leads to herd reduction or complete liquidation. The development of triggers to predict or more proactively mitigate drought-induced consequences could assist in reducing risk for producers. I present two long-term data sets from Wyoming, USA that offer insight on potential triggers for drought decision making: (1) precipitation-biomass relationships from a sagebrush-grassland from 2005-2018 using samples stratified across varying sagebrush cover levels, and (2) calf weaning weight data from two ranches from 2011-2014 – a period with some of the worst drought years (2012) on record. For the precipitation-biomass relationships, I summarized the three replications stratified across sagebrush cover of 16%, 20%, and 24% using data from 2005-2018. Within each plot, we have clipped six quadrats that are positioned in exclosures, thus, this represents herbaceous biomass production with no grazing removal. The total quadrats generating this data set are 36. For each plot, we calculated the mean of the quadrats, and then calculated the mean of the plots per sagebrush cover class. To generate standard errors, we used the three replications across sagebrush cover classes (n=3). I also generated growing season precipitation data from PRISM. We ran precipitation models using single months and month combinations to determine the most predictive indicator of growing season biomass that can be used a drought decision trigger. For the calf weaning weight data, we used linear regression, stratified by steers and heifers, for the two ranches separately to determine the reductions in weight gains associated with escalating drought conditions and generate gain thresholds that could be evaluated early in the drought development process.

LRU Development and the Creation of Abiotic Driven Ecological Site Keys

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NRCS-SSD has focused on the development of Land Resource Units (LRU) and provisional ecological sites across the US. LRUs are subdivisions of Major Land Resource Areas (MLRAs) that have one or more unique features making them more homogenous than the surrounding area, making them useful for land management. LRU determinations are made only after considering factors like dominant topography, geology, soil moisture and temperature regimes and amount of effective precipitation. Concepts are spatially delineated and described based on the specific group of contrasting characteristics. Ecological site concepts (ESCs) are then assigned to each LRU based on the set of dominant controlling abiotic factors. Working closely with soil scientists, we narrowed the central soil-site concept and identified the key relationships (abiotic factors) that provide a good generalization of site interactions. The abiotic relationships were then used to develop dichotomous keys for each of the resulting LRUs. ES keys will help our partners reliably identify ecological sites and are in the process of being tested. As we move past the Provisional Ecological Site Initiative, revision and narrowing of ecological sites, state and transition models (STMs), and soil-site relationships using tools such as RHEM, R, and partnerships will continue. The process of refining ecological site concepts will result in a product that has a vast array of uses outside of the obvious grazing management and restoration implications. By incorporating as many sources and models as practical, we hope to create important soil survey interpretations not only for localized management questions but a resource that can be utilized on whole landscape scales.

Machining a Solution to Data Heavy Rangeland Research: Case Study with Camera-trap Photo Processing

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Time-lapse cameras are increasingly being used to assess wildlife and livestock interactions on rangelands. The use of camera-traps is an inexpensive, unobtrusive, and relatively real-time method to estimate various metrics of range use, but extracting information has proven to be costly and time consuming to process collected data. Researchers and managers are in need of new methods for streamlining the digestion of these large datasets. One such problem appears in the quantitative processing of photos from time-lapse camera traps used to estimate frequency of site use by grazing species. Time-lapse cameras collect hundreds of thousands of photos that need to be individually sorted and classified by human observers. Processing time can exhaust months to years of effort, distract from data analysis, and limit the prospective scope of the research. We are testing the use of machine learning techniques via deep neural networks such as Visual Geometry Group to automate photo processing and data extraction. Through the use of deep learning, large datasets of thousands of photos can be processed in a matter of days rather than months, greatly reducing the time invested by hired personnel while matching accuracy. Machine learning methods have the potential to provide detailed and current results allowing resource managers to make up-to-date decisions regarding the proper management of rangelands given prevailing conditions. By negating the burden of photo processing time, resource managers can tackle increasingly complex problems across various environments and land ownerships.

Making Rangeland Education & Careers Accessible for Native American Youth: How Can We Do Better?

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Erin Boyd, Society for Range Management, White Cone, Arizona
Diana Doan-Crider, Amino Partnership in Natural Resources, Medina, Texas
Kelsey Ducheneaux, Intertribal Agriculture Council, Billings, Montana
Jessica Orozco, Hualapai Tribe, Peach Springs, Arizona

It is clear that we need to expand access to rangeland education for Native American youth to recruit the next generation of rangeland managers. Even for students who may not pursue a career in rangeland management, it is important that Native youth understand the general importance of rangelands and their significance in tribal land management (agriculture, wildland management, wildlife management, recreation). In 2015, we held a meeting with tribal college instructors, students, agency personnel, and extension agents to identify disconnects in natural resource education for tribal students. We pinpointed over 100 distinct barriers that keep Native youth from entering into the career path and workforce. During this forum, we will highlight several successful programs with Native youth, and identify key components that contributed to their effectiveness. Native youth will also learn about career paths and options in Agriculture and Natural Resources. We will also facilitate discussion with Native youth regarding some of the more serious disconnects in natural resource education and allow them to provide input on how they should be solved.

Making SRM More Inclusive

Joel Brown, USDA NRCS, Las Cruces, New Mexico
Amy Ganguli, NMSU, Las Cruces, New Mexico

The SRM BoD has identified a need to make our Society a more inclusive place. The first interaction with SRM that perspective members have is frequently the Annual Meeting. As with any large public gathering, our premiere event is a chance to showcase how passionate we are about the profession of rangeland management and a great opportunity to share that enthusiasm with prospective new members. This training workshop will be facilitated by the USDA Civil Right Office and will focus on improving communication in a workplace environment. The course will be open to all SRM members, and can be used by federal employees to meet training objectives.

Making Technology Work for You - Apps, Drones, and Satellites that Actually Work

Christine Su, PastureMap, San Francisco, California

How can you use technology to help you save time on the ranch, instead of adding tasks? We will demonstrate how to use apps on your phone or tablet to manage your ranch from your pocket, even without cell reception. There are apps that help you plan fencing in the field, keep animal and grazing records, and take GPS photos of forage and infrastructure. We'll also discuss how to get value out of drone and satellite imaging.

Management Impacts on Dynamic Soil Properties of a Pacific Northwest Bunchgrass Prairie

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Soils are a critical resource for sustaining productivity, maintaining ecosystem resilience, and preserving overall ecosystem function. Some soil properties (e.g., soil resistance and moisture) are dynamic and can be affected by management decisions such as livestock grazing and prescribed fire. Unfortunately, in the Pacific Bunchgrass Prairie, our understanding of how management decisions impact soil parameters is limited to one study related to livestock grazing. In this study, we further explored the effects of management in this grassland on dynamic soil properties as they relate to livestock grazing, prescribed fire, and their potential interaction. Specifically, we aimed to determine if prescribed fire and/or livestock grazing influenced the dynamic soil properties of soil penetration resistance and moisture. The soil data were collected from 16 plots established in 2004 by The Nature Conservancy to examine long-term effects of livestock grazing and prescribed fire on their Zumwalt Prairie Preserve. Soil penetration resistance values, based on the number of strikes, were collected with a dynamic cone penetrometer at four depths. Soil moisture was measured with a Campbell Scientific Hydrosense II soil moisture meter. Contrary to our expectations, we only found significant differences with the main effect of prescribed fire on moisture and resistance at the shallowest (0-5 cm) depth. Soils exposed to prescribed fire had significantly less moisture and lower soil penetration resistance than soils in sites that were not burned. Our findings suggest that livestock grazing at the current stocking rates did not have a detectable effect on soil penetration resistance or moisture. In addition, prescribed fires (in the fall every 10 years) may help reduce soil penetration resistance in this grassland system. More work should focus on soil dynamic properties to aid in the management and conservation of this unique grassland ecosystem.

Managing Grazing in Riparian Areas to Maintain Multiple Rangeland Ecosystem Services

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In arid US rangelands, riparian areas generate ecosystem functions and services important to wildlife and people. For example, riparian ecosystems provide livestock forage and habitat for sage-grouse. These areas are also expected to maintain water quality that meets state and federal thresholds. Due to the multi-use mandate on public lands, managers are tasked with balancing these different demands. One solution is to manage the duration of grazing. This can alter cattle disturbance of stream-side vegetation and limit waste inputs into streams. To test whether grazing can be managed to increase the provision of multiple ecosystem services, we conducted a two-year study (2016-17) that examined the effects of different grazing durations on water quality (*E. coli* levels (MPU/100 ml)), two of many indicators of sage-grouse habitat (grass/forb height (cm)), and stream-bank stability (% bare ground). The grazing durations investigated are all employed in our study area: 4 months/pasture (continuous turnout), 1.5-2 months/pasture (4-pasture rotation), and 2-4 weeks/pasture (multi-pasture rotation). We measured water quality along 13 rangeland streams via grab samples collected twice monthly from May-November, and grass/forb height and % bare ground along nine streams monthly from May-August. We found that controlling the duration of grazing in Intermountain West rangelands is an important tool for managing multiple riparian ecosystem services. Shorter grazing durations resulted in fewer violations of Utah and EPA critical water quality thresholds. Shorter grazing durations also led to taller forb/grass height, which early in the season can increase sage-grouse habitat quality, and less bare ground, which can reduce stream-bank erosion. Overall, our findings suggest that although active grazing can negatively affect all ecosystem services studied, when the disturbance caused by grazing is limited by cattle rotation, livestock production can be balanced with the provision of a suite of ecosystem services in rangeland riparian areas.

Managing Invasive Cool-Season Grasses with Grazing, Fire, and Herbicides in the Eastern Tallgrass Prairie

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The efficacy of different grazing strategies for preserving or enhancing the utility of patch-burn grazing (PBG) management remains mostly untested. Season-long stocking (SLS) is the primary grazing strategy employed in PBG yet how a modified grazing regime such as intensive early stocking (IES) affects PBG is unknown. Stocking at twice the normal season-long rate for the first half of the season with no grazing during the last half, IES takes advantage of early summer high-quality forage and may provide an ecosystem service in the form of invasive plant species control. To determine the efficacy of IES within PBG pastures to both 1) maintain or enhance the utility of PBG and 2) control an invasive plant, we compared pasture heterogeneity (i.e., variance in vegetation structure among management patches) and tall fescue (*Schedonorus phoenix*) cover between IES and SLS pastures in the Grand River Grasslands of southern Iowa and northern Missouri. In addition, we report on the usefulness of IES under PBG management for controlling invasive grasses relative to IES control pastures that are burned in their entirety every third yr and treated with herbicide. July vegetation structure and tall fescue cover collected among IES and SLS pastures under PBG management revealed patch contrast (heterogeneity) of IES pastures (initiated in 2014) reached SLS levels by 2016, whereas tall fescue cover in IES pastures was 4% lower than SLS by the end of the three-yr PBG cycle. From 2015 to 2017, tall fescue cover in IES PBG sites declined from 30 to 19%, whereas fescue cover remained at ~12% on pastures managed with herbicide, IES, and uniformly burned every third year. Thus, fescue cover, after 3 yr of IES PBG management without herbicide application, spanned from 18% to only 7% greater than IES control pastures.

Mapping Cross-Scale Transitions in Rangelands

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New theory-technology linkages have emerged for quantifying complexities in ecological change unaccounted for in traditional vegetation mapping or the delineation of spatial regimes (or states). These linkages are increasingly important for studying and managing rangelands in an era of uncertainty and change. Moving forward, couplings between feedbacks and plant communities are potentially non-analogue in many rangeland systems, so knowledge of mechanisms linking past form and function becomes less useful for decision-makers. We present cross-scale maps of spatial regime boundaries (transitions) among six plant functional groups in rangelands of the Western United States from 2000-2017. A major advantage of our approach is its objectivity, in that it does not require *a priori* knowledge of which state variables drive form and function; nor does it require that spatial or temporal locations of regime shifts be known. This avoids bias inherent in traditional rangeland vegetation state mapping. Instead, our approach extracts cross-scale signals of change from a state-of-the-art dataset and applies expert knowledge and subjective judgement to the interpretation of results.

Mapping Residual Dry Matter: Evaluating Grazing Patterns and Compliance with Vernal Pool Easement Mitigation Goals

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Residual Dry Matter (RDM) is the previous season biomass remaining on the ground (standing or litter) before the next growing season starts. RDM is predominantly used to evaluate impacts of grazing and previous season forage production on annual rangelands and is an indicator of subsequent year potential forage production and species composition. RDM was monitored and mapped from 2013 through 2015 on the 2,656 hectares Merced Vernal Pools and Grassland Reserve (MVPGR), in Merced California. The MVPGR is a multiple use mitigation easement that was established in 2001 close to UC Merced. One core goal is to maintain sustainable rangelands and vernal pools function through proper grazing management. A 1,600 herd of dairy cattle grazed the Reserve for about six months each year. Triplicate RDM samples and standing vegetation height were collected at 55, 67 and 71 sites in 2013, 2014, and 2015, respectively. Mean overall RDM was 760 lb/acre in 2013; 430 lb/acre in 2014; and 956 lb/acre 2015. Lower RDM levels in 2013 and 2014 can be attributed to low precipitation rather than high grazing intensity and high RDM levels in 2015 is attributed to lower grazing pressure. Mean grass height was about 2.7 inches (6.9 cm) over the three years. RDM monitoring took place during the historic drought (2013-2015) in California in which annual precipitation in eastern Merced County was 29% to 67% of the long-term mean. Mean RDM levels were 5% below the recommended target of 800 lb/acre in 2013 and about 20% above the target in 2015. The maps show high spatial variation in RDM across the reserve and within pastures, mostly associated with pasture size, stocking rates and distribution of water points. Adaptive stocking and tools to improve livestock distribution will be critical to promote sustainable rangelands and vernal pools function on the MVPGR.

Meadow Health and Grazing Utilization Monitoring on Public Lands

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Riparian meadows provide an array of ecosystem services, including clean water, flood attenuation, and wildlife habitat. In addition, riparian meadows serve as a critical resource for summer cattle grazing. It is important that monitoring for meadow health take place at the meadow scale rather than the allotment scale to ensure the continued provision of these services. Research has shown that meadows are vulnerable to disturbance and that "adaptive, site-specific management strategies are required to meet grazing pressure limits and safeguard ecosystem services within individual meadows, especially under more variable climate conditions" (Oles, 2017). Therefore, an efficient monitoring protocol to assess meadow health and grazing utilization is critical. To meet this goal, a rapid field assessment method was adapted from USFS meadow monitoring protocol, resulting in a monitoring scheme that can be conducted in an average of 29 minutes per meadow. The goal of this research is three part: (1) assess meadow health on National Forest grazing allotments in Northern California; (2) develop a rapid field assessment to ensure meadow monitoring protocols are efficient; and (3) collect riparian meadow utilization data to inform sound, long-term management decision-making on public lands. We will present results and outcomes from this research.

Mediating Science and Culture: Prey Behavior and Predation Theory Informs a Land Management Paradigm for Reducing Large Carnivore-Livestock Conflict

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Olivier Larocque, A7 Ranch, Galiano Island, British Columbia
Charles Mamo, Southern Alberta Conservation Cooperative, McBride, British Columbia
Jim Pissot, Wild Canada Conservation Alliance, Canmore, Alberta
Ron Davis, Nelson Ranch, Claresholm, Alberta
Cam Gardiner, Bluebird Valley Ranch, Longview, Alberta

Waning public trust mirrors a widening dissent over deception and politics that conflate large carnivore-livestock conflict management. This westward growing impasse belies ranchers' search for science-based help to avoid economic loss, while a long-term and socially acceptable solution to large carnivore-livestock conflicts remains unmet. We redress this deficiency with land management paradigm led by a ranch community for preventing and reducing livestock conflict with wolves and grizzly bears. We share research advances in prey behavior and predation theory to benefit ranchers' evolving awareness and understanding for conflict cause and avoidance and mediate ranchers' reluctance to modify practices for reducing livestock vulnerability. Using economic measures identified by ranchers for report of damage from large carnivore-livestock interactions (2007-2009), we deployed and evaluated a land management-conflict avoidance model across an agriculture economy and public-private land environment where ca. 27,000 primarily cow/calf pairs graze a 726 km^2 wolf home range occupied by a resident wolf pack and grizzly bears with depredation histories. We appropriately-scaled our systematic vigilance to the home range and rotated across allotments related to stocking and behavior to intercept carnivore-livestock interactions and interrupt harassment and pursuit of livestock as prey. Single or paired area ranchers on horseback and foot consistently attended all pastured cattle within wolves' home range every ≤4 days ($\bar{x}$=3.6 days; range 2-7) during consecutive seasons in 2011 (June-October) and 2012 (July-November). Wolves and grizzly bears frequented or traversed pastures occupied by cattle during three of every four days in 2011 ($\bar{x}$=74%; n=134 ride days) and every two of two days in 2012 ($\bar{x}$=67%; n=127 ride days). Livestock associations and cooperatives reported complete counts, no damage requiring additional management and profitable weight gains for both years. We recorded only single conflicts during respective grazing seasons (calf wounding in 2011; calf depredation in 2012). Economic grazing benefits far exceeded vigilance costs. Our results show that livestock

vulnerability can be managed amidst resident wolves and grizzly bears during grazing to avoid economic loss. Avoidance of indiscriminant large carnivore turnover where livestock interact can yield long-term land stewardship benefits in reducing conflicts, delivering economic profits and improving urban values in working ranch communities.

Medusahead: A Potential Livestock Forage on Rangelands?

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Livestock tend to avoid medusahead rye (*Taeniatherum caput-medusae* (L.) Nevski) due to its high silica content, low digestibility, and inferior nutritional quality. Emerging information on grazing behavior and the application of a glyphosate-containing herbicide has been shown to increase preference for this invasive plant species. Several experiments have been conducted to determine why this increased preference occurs and what techniques can be used in order to maximize medusahead control. Initially, the salt contained in the herbicide (Roundup RT 3®) was thought to increase grazing preference; however, application of the salt further reduced medusahead preference by cattle. An additional study was conducted with cattle to determine if the adjuvant within the herbicide was responsible for enhancing medusahead palatability, but this treatment did not increase the consumption of medusahead. Chemical analyses revealed that Roundup RT 3® promoted a decrease in silica content and an increase in water-soluble carbohydrates in medusahead tissues, thus improving the nutritional quality of the plant. An *in vitro* digestion kinetics study showed that Roundup RT 3® nearly doubled the rate of medusahead digestion. The practical aspect of rate, type of herbicide, and timing of application were explored in ensuing studies. It was observed that 788 g ae·ha^{-1} was the optimal rate of application that enhances medusahead palatability, while there was no difference in preference between the application of a generic glyphosate herbicide and Roundup RT 3®. Another study determined that cattle preferred medusahead that was treated during the late vegetative stage to that of the earlier or later phenological stages. In summary, these studies show that the application of a glyphosate-containing herbicide in combination with targeted grazing can be used to reduce medusahead invasion, provide a forage of improved nutritional value for livestock, and facilitate potential restoration methods.

MEGA FIRE! Collaborative Emergency Stabilization and Rehabilitation after Nevada’s Largest Wildfire: The Martin Fire

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On July 7th, 2018 the Martin Fire was started, and consumed 435,569 ac. of northern Nevada. Rapid growth continued for days due to hot and windy weather conditions. 153,698 ac. of priority sage grouse management area was burnt, and nearly 18,000 acres of mule deer habitat across the Owyhee high plateau. Federal Policy allows only 21 days for BLM to plan emergency stabilization and rehabilitation (ESR) efforts. BLM Elko District ESR team organized and led collaboration amongst BLM resource specialists, permittee’s and stakeholders, the USFWS, Nevada Department of Wildlife, Nevada Department of Agriculture, and the University of Nevada Reno’s Rangeland Ecology and Restoration Laboratory. Field Visits and follow-up phone conversations were held including all participants to plan a solution that involved interests from all and was guided by science. The process can be considered an example by which other large scale land management planning efforts can follow. The poster graphically highlights planning tools, information sharing, and collaboration throughout this effort.

Mesquite Has Its Uses: Moving from Eradication to Beneficial Management

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The dominant conception of mesquite (especially *Prosopis velutina* and *P. glandulosa*) in the southwestern US is as an invasive shrub that reduces forage production and ecosystem services in grasslands. Scientific literature and popular discussion frequently present mesquite invasion as having only negative consequences. Vast sums of money have gone into controlling/eradicating mesquite by both private and governmental landowners, generally with unsatisfactory results. Interviews in 2017 with 82 private and ejido landowners in the Chihuahuan Desert, in the US and Mexico, told a different story. Only a small number (<5) of interviewees reported that mesquite was a definite problem and that they would eradicate all of it from their land if they could. The vast majority reported that mesquite was helpful in moderation, particularly by offering crucial forage before the summer monsoon and during droughts when little other forage is available. Some refuted the idea that less grass grows in mesquite-dominated areas, claiming that mesquite-grass relationships are highly variable. Additionally, respondents pointed out that mesquite has two different growth forms; tall, tree-like mesquite offers more shade, produces more beans, and inhibits grass growth less, while the low-growing, multi-stemmed form offers fewer benefits. Crucially, mechanical shrub control tends to replace 'good,' tree-form mesquite and with the 'bad,' multi-stemmed form. Interview results suggest that more research should be devoted to managing mesquite and livestock grazing in a manner that maximizes benefits to ranchers. Results also suggests that current efforts at mesquite eradication may have negative consequences beyond cost. New research and outreach efforts devoted to helping livestock owners utilize mesquite as an integral (unavoidable) part of their range would be welcome.

Mesquite Sap Flux Following Fire in a Semi-Arid Savanna

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Tian Zhang, Texas A&M AgriLife Research - Vernon, Vernon, Texas

Honey mesquite (*Prosopis glandulosa* Torr.) responses to fire are variable, ranging from complete above ground mortality (top-kill) to little or no effect, and are related to age, plant condition, and/or fire intensity. Most fire research with mesquite has measured effects on whole plant mortality, and less is known about physiological responses to variations in foliage reduction in partially top-killed plants. A study to examine differences in mesquite sap flux responses following wildfire was conducted in one burned and one unburned site at the Smith-Walker Research Unit near Vernon, TX, USA. Objectives were to determine relationships between climatic conditions and foliage reduction on mesquite water use and recovery after fire. Sap flux density (Js) was continuously measured using 10-mm long Granier-style (1987) heat dissipation sensors that were installed in 12 trees at each site approximately seven weeks after a June 2018 fire. Fire reduced the leaf area:basal area ratio (LA:BA) of burned trees (73 $cm^2 \cdot cm^{-2}$) compared to unburned trees (91 $cm^2 \cdot cm^{-2}$), but leaf area:basal area ratio was unrelated to sap flux rates (r^2=0.02). During the first month after sensor installation, average daily sap flux rates were similar between the burned and unburned sites. On average, individual burned mesquites lost 14.2 ± 0.7 liters·$dm^{-2} \cdot day^{-1}$ through transpiration, while unburned mesquites lost 15.9 ± 0.4 liters·$dm^{-2} \cdot day^{-1}$. Mesquite sap flux at the burned site was more responsive to changes in vapor pressure deficit (r^2=0.59) than sap flux at the unburned site (r^2=0.30). Total soil moisture from 0-1.5 m deep was similar at the two sites. Transpiration at both sites was likely reduced due to low soil moisture availability during the study period.

Methods for Improving Re-Vegetation Success in the Sagebrush Steppe using Solid Matrix Priming

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Catastrophic wildfires have occurred more frequently and at larger scales than in previous decades in the American west, causing mass degradation to the sagebrush steppe and other rangeland ecosystems. Due to this, there is a need to develop cost-effective techniques for re-establishing native vegetation on degraded sagebrush (*Artemisia* spp.) steppe ecosystems. This study used the concept of solid matrix priming (priming is accomplished by partially hydrating seed and maintaining it under defined moisture and temperature conditions for a prescribed period of time) as a seed technology for reducing overall time to germination, and seed pelletizing for improving re-vegetation success of three native perennial bunchgrasses: bluebunch wheatgrass (*Pseudoroegneria spicata*), Idaho fescue (*Festuca idahoensis*), and prairie junegrass (*Koeleria macrantha*). This project addressed two issues with solid matrix priming which have been identified as barriers to success: 1) it is difficult to separate the seed from the solid matrix material once priming is complete, and 2) as the technology scales up to landscape level applications it becomes increasingly difficult to maintain consistent water potentials throughout the priming process. These issues were remedied by combining solid matrix material and seed together in a pellet, and then using the pellet itself to prime the seed. This involved the formulation of seed priming medium, the identification of specific water potentials to correlating moisture contents, and the determination of optimal seed priming durations and water potentials for each bunchgrass species. The end goal of this project was the development of a method using solid matrix priming to prime seeds within pellets for large scale applications, as well as increasing germination rate, uniformity and establishment of wildland seedings for three native perennial bunchgrass species.

MezaVue for Pricklypear Control and Oak Tolerance when applied by Ground and Aerial Broadcast

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Charles Hart, Corteva Agrisciences, Abilene, Texas

Pricklypear cactus (*Opuntia* spp.) is a native and invasive plant found throughout western and central Texas. Pricklypear spreads rapidly across the landscape limiting forage production and forage access for grazing animals. For years the standard in chemical pricklypear control has been Tordon 22K (picloram) or Surmount (picloram and fluroxypyr). While these herbicides obtain a high level of control for pricklypear they can take a long period of time to visually see any sign of desiccation or sickness on the treated plant. Surmount while it does deliver a high rate of mortality on pricklypear it is also damaging to live oaks (*Quercus virginiana*) which are desirable to many landowners in Texas. In Spring of 2019 Corteva Agrisciences will release their new herbicide MezaVue (picloram, fluroxypyr and aminopyralid) for pricklypear control in Texas, New Mexico and Oklahoma. Prior to MezaVue being released, rate studies were established in 2017 and 2018 to determine what rate provided the most consistent and highest level of pricklypear desiccation when applied by ground broadcast. In three ground broadcast trials MezaVue at 32 ounces product per acre delivered an average desiccation rating of 80 percent at 12 months after treatment. Live oak tolerance studies were also established in 2017 and 2018 to determine how MezaVue compared to the current standards for oak tolerance when applied aerial over the trees. When applied by air over live oaks MezaVue did cause visual damage at the time of application, however; at one year after treatment the live oak trees in the MezaVue plots had less damage than live oaks in the Surmount plots.

Minimize Ecological Impact - Maximize Power Output - How?

Jim Truax, New Hope, Minnesota
Jennifer Hildebrand,New Hope, Minnesota
Dwayne Stenlund, New Hope, Minnesota
Jeremy Duehr, New Hope, Minnesota

The demand for energy from both solar and wind is challenging our ability to deliver without impeding the landscape in ways that are environmentally unfriendly. Pro-solar and wind farm from a legal perspective. Legal and regulatory requirements impose significant constraints on siting solar and wind farms. This presentation will focus on legal framework and environmental considerations that limit deleterious impacts to the landscapes with proposed solar and wind farm energy production facilities. Proper footprint siting of energy facilities can co-exist and compliment multiple use of landscapes from grazing, perpetuation of water quality to maintaining wildlife connectivity. Anti-solar and wind farm. Legal and regulatory requirements impose significant constraints on siting solar and wind farms. All permanent energy facilities impose changes and impacts to landscapes that cannot easily or inexpensively be mitigated. This loss of ecological services, recreation, aesthetics, habitat and impacts to migratory wildlife are permanent and must be understood.

Mobile Action i-gotU GPS Collar Data Processing & Visualization Using R

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Colt Knight, University of Maine, Orono, Maine
Dylan Mikesell, Boise State University, Boise, Idaho
Joe Champion, Boise State University, boise, Idaho

Mobile Action i-gotU GPS data can be processed, analyzed, and visualized with a combination of R and MATLAB software. These two software environments require unique code and installation packages to evaluate GPS comma-separated values (.csv) data files associated with livestock behavior. Participants will first become familiar with the layout of RStudio, an integrative development environment for R. Afterwards, participants will modify code provided by the presenter to create an R project before installing relevant packages. Next, participants will learn how to read in multiple .csv files and establish geospatial borders for a dataset. Subsequently, participants will learn to implement rules to identify suspicious data, such as excessive rate of travel and extreme course changes. Afterwards, participants will learn to correct for elevation, further identify bad data using elevation parameters, and obtain behavior data in R. Finally, participants will visualize data using the Shiny app, allowing participants to see location, elevation data, and GPS fix rates for a combination of animals. The coauthors created a video library with instructions for how to download the necessary software environments and installation packages. The video library will also explain R so participants will have reference material after the presentation.

Modeling Land Resource Units to Inform ESD Development in Central California's Coast Range

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Developers of Ecological Site Descriptions (ESD's) increasingly rely on moderate-scale ecoregion designations known as the Land Resource Unit (LRU) to resolve differences in vegetation communities that arise from localized climatic effects. Hierarchically, the LRU is nested within the Major Land Resource Area (MLRA) and specifies ranges for a specific climatic zone that can accommodate a suite of similar ESD's from a management perspective. The implications of LRU development can be monumental; if developed with robust criteria, LRU's may inform stakeholders in areas such as range management plans, wildlife habitat restoration, forestry, and recreation. The Central California Coast Range (MLRA 15) has been heavily utilized for a wide variety of resources over past centuries and today is recognized for its cultural resource hotspots, recreational opportunities, productive rangelands, specialty crops, and forestry potential. However, extreme climatic variability due to marine areas, rain shadow-effects, and large latitudinal and elevation gradients, has made designating LRU's particularly challenging. The 1987 EPA Ecoregion assessment delineated 28 Level IV climatic zones which are overlapping with MLRA 15. This number of divisions may be excessive for identifying ecological site concepts, and could result in unnecessary duplication of ESD's. Our objective is to identify the main abiotic drivers of vegetation patterns across this region, and to designate the appropriate level (and number) of LRU's in the Central California Coast Range. We plan to implement topographic, climatic, and vegetation indices in a GIS environment to generate unsupervised classifications (clustering) using the freeware R, and compare with an unsupervised ISODATA algorithm in Erdas Imagine. Accuracy assessments will be performed for all R and Imagine outputs. The model(s) yielding the most accurate and usable information will be utilized in creating LRU maps of the region, which will facilitate updating ESD's, thus resulting in informed decision making on the ground.

Moderating Stocking Rate Stabilizes Forage Availability More Than Patch-Burning in Low-Stature Grassland

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Livestock production is an important industry in the eastern US Great Plains but invasion by non-native C3 grasses (e.g., tall fescue *Schedonorus arundinaceus*) and overgrazing have caused substantial rangeland degradation. Lower plant diversity and overgrazing might increase temporal variability in forage availability thereby reducing the stability of ecosystem services provisioning. While prescribed fire is common on conservation lands, most of which are ungrazed, grazing land managers need to understand how fire regime and grazing intensity on stability of forage availability in invaded grasslands. Here, we examine the stability of forage availability and test for diversity-stability mechanisms in southern Iowa, USA, through three periods of grazing intensity: heavy stocking rate, light stocking rate, and moderate stocking rate. All pastures were treated with one of two different fire regimes: patch-burning, with one-third of the pasture burned each year, or complete burns every third year. Moderate stocking rates had the least temporal variability in forage availability, regardless of fire regime. Likewise, we found statistical evidence for the portfolio effect under moderate stocking rates, and beta diversity among plant functional groups was greatest in pastures stocked moderately. Together these results suggest that low temporal variability in forage availability is associated with diversity-stability mechanisms that underlie ecosystem function. Our results provide novel ecological evidence for a decades-old principle of range management: moderate stocking rates enhance diversity and stability, which might help livestock producers mitigate livestock productivity loss caused by climatic variability.

Monitoring and Assessment: Evaluating Reclamation Success of Surface Coal Mine Reconstructed Rangelands

Edward Vasquez, Office of Surface Mining Reclamation and Enforcement, Denver, Colorado

Evaluation of surface coal mine reclamation is ultimately based on the specific requirements of the reclamation plan and the functional requirements of the post-mining land use. The scope of this discussion focuses on monitoring and evaluating the successes of reclamation following surface coal mine disturbances. The Surface Mining Control Reclamation Act of 1977 regulations require bonding by the operator prior to mining activities. An assessment of reclamation is conducted by the regulatory agency prior to bond release for three Phases of reclamation. For Phase I, the performance of the reconstructed landform topography is evaluated; Phase II assesses attributes such as topsoil depth, vegetative cover, soil/site stability, and hydrologic function. Final bond release for Phase III requires the reclaimed plant community(s) meet specified criteria indicative of diverse, effective, and permanent plant communities for their intended post-mine land use. Vegetation success standards for Phase III bond release having a post-mine land use of rangelands are largely based on indicators such as foliar and ground cover, shrub density, plant diversity, and biomass production compared to either a reference area(s) or technical standards. Reclaimed rangeland watersheds must capture, store and release water effectively into reconstructed watersheds. Indicators such as vegetative cover and composition may suggest successful reclamation. Process-based indicators such as water-flow patterns, rills, soil compaction, and plant community composition and distribution relative to water infiltration and runoff may suggest the opposite. The graded spoil in all reclaimed mining areas must be systematically sampled to identify the extent, nature, and location of unsuitable materials for plant growth. Effectively linking remotely sensed data with site-based data can help to address ecological questions across a gradient of spatial scales. Monitoring program design should be an integral part of the reclamation planning process and indicators reflecting landscape-scale processes can be adapted to monitor reclamation project success.

Monitoring Daily Livestock Foraging Activity with Accelerometers: Calibration, Formula Discovery, and Final Data Processing

Jim Sprinkle, University of Idaho, Carmen, Idaho
Jameson Brennan, South Dakota State University, Rapid City, South Dakota

The objectives of this hands-on training are: 1) introduce workshop participants to the mechanics, operation, and mounting of 3-axis accelerometers for determining daily livestock grazing behavior; 2) provide electronic templates and processes for recording field calibration data in order to differentiate grazing, walking, and resting activity at 5 second intervals; 3) demonstrate and provide example datasets, electronic templates, and data coding (e.g., Python, R) necessary for compiling large datasets; and 4) formula discovery (using such tools as quadratic discriminant analysis with data plotting) necessary to obtain data signatures of observed calibration data processed against the full dataset. Real life example datasets, both problematic and well behaved, will be used in this workshop setting to demonstrate how to migrate raw accelerometer data files to a finished file for importation into a statistics program. Participants will receive a flash drive containing the presentation, instruction manual, and all the example electronic templates, data coding, and example data files used in this training. To obtain maximum benefit from this workshop, participants should bring a portable laptop computer to the workshop and will be encouraged to load software and preview content from a shared cloud directory prior to this training.

Monitoring Restoration Outcomes in the Southwestern U.S. to Improve Future Treatments

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David Pilliod, U.S. Geological Survey, Boise, Idaho

Restoration and reclamation treatments are widely practiced but their outcomes are infrequently monitored to increase the effectiveness of subsequent treatments. Monitoring outcomes can be especially informative in the southwestern U.S., where low precipitation and high topo-edaphic variability create large challenges for promoting ecosystem recovery. We synthesized over 5,000 treatments (1940s-present) and conducted restoration field trials across grasslands, shrublands, and low-elevation woodlands to better understand trends in restoration treatments and subsequent outcomes. We found that in the last 70 years, the cost and size of treatments has steadily risen, with a higher number of species and more native species used in seed mixes, and a growing number of herbicide and prescribed burn treatments implemented across the region. High precipitation following treatments had a positive effect, while high temperature had a negative effect, on total vegetation recovery. Native perennial cover increased after disturbance but was not always affected by seeding and was negatively affected by non-native perennial cover. Seed germination was positively affected by treatments that encouraged water retention, and plant survival was higher if their traits (e.g., specific leaf area, seed mass) matched the environmental conditions of the restoration site. Our results highlight opportunities to improve future restoration and reclamation treatments across environmental gradients in the southwestern U.S.

Monitoring Vegetation Changes on Abandoned Energy Development Sites Using Time-Series Remote Sensing

Miguel Villarreal, U.S. Geological Survey, Menlo Park, California

Energy development in the western US has increased substantially in recent decades, contributing to habitat fragmentation, dust emissions, and accelerated soil erosion. Oil and gas well pads are often developed and then abandoned when they are no longer sufficiently productive. Information on the type and rate of vegetation changes after abandonment is important for assessing reclamation progress as well as landscape and ecosystem integrity after disturbance. We used Landsat satellite data and cloud computing to develop dense time series (1984-2011) of vegetation cover for 365 abandoned well pads and undisturbed reference sites on the Colorado Plateau, and analyzed change in vegetation cover relative to climate and other spatial variables. There was a wide range of re-vegetation among the sites: After five years of recovery, average vegetation cover on well sites was 36 percent of that found on reference sites, and about half of the well sites in the study contained less than 26 percent vegetation cover found on reference sites. We found that climate conditions and the year of abandonment played a role in vegetation cover changes, with increased cover in later years associated with a wetter period. However, high-resolution aerial imagery and Landsat-based phenology indices indicate that abandoned pads where vegetation increased rapidly were often dominated by exotic grasses and annual forbs. These remote sensing time series models have the potential to provide land managers with tools to assess reclamation efforts over large landscapes, and when combined with spatial and temporal environmental data can help restoration practitioners identify site and climate conditions that are favorable for reclamation.

Monitoring, Evaluating, and Targeting Rangeland Conservation through Advanced Riparian Sensitivity Mapping

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Riparian vegetation plays a critical role in rangeland ecosystems by protecting water resources and providing habitat for fish and wildlife. Unfortunately, many of these areas around the Western United States have experienced large amounts of disturbance, emphasizing the need for regular monitoring and evaluation of their health in addition to targeting key areas for rehabilitation. The ecohydrologic function of riparian corridors provides benefits far greater than the sum of its parts, suggesting that in order to accurately assess the health of these areas we need to do so at spatial extents that incorporate the whole watershed. To accomplish these needs, we provide a new, satellite based state-of-the-art tool to monitor, evaluate, and prioritize riparian areas around the Western United States. The tool maps floodplain areas for all perennial, ephemeral, and intermittent stream reaches in the Western U.S. and then calculates a standardized sensitivity index of vegetation to climatic water deficit within the floodplain area. These values are ranked within HUC 10 watersheds to provide relative sensitivities for each watershed. We anticipate this tool to be used by practitioners in a number of ways: (1) monitoring riparian health after restoration or disturbance to better understand system response to impacts, (2) evaluating resiliency of riparian areas to climatic conditions to inform drought management, and (3) targeting/prioritizing areas for rehabilitation that exhibit relatively high sensitivities to maximize conservation benefits. We will provide real-world examples of these three potential uses and discuss the procedure for applying the Riparian Sensitivity Index to rangeland ecosystems.

Movement and Cow-Calf Proximity Patterns of Raramuri Criollo Vs. Angus-Crossbred Nursing Cows Grazing Chihuahuan Desert Rangeland in Summer

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The objective of this study was to compare cow-calf proximity patterns of Angus X Hereford (AH) and Raramuri Criollo (RC) cows with nursing calves in large Chihuahuan Desert pastures during the summers of 2016 and 2017. Eleven cow-calf pairs of each breed grazed two adjacent pastures (1,190ha, 1,165ha) separately in a crossover design, for four weeks per deployment. Within each breed, a group of seven to nine randomly selected cows were fitted with GPS collars which recorded animal position at 10-min intervals. Proximity loggers configured to record number and duration of contact events (<1m distance) were also fitted on a subset of five cow-calf pairs. Data from the dam's proximity loggers were used for analysis. The effect of breed (AH vs. RC) on duration and number of contact events, as well as distance traveled, path sinuosity, velocity, area explored, and time spent resting, grazing and traveling by the dams was determined via ANOVA. All variables were calculated for four daily periods: midnight to sunrise (AmNight); sunrise to noon (AmDay); noon to sunset (PmDay); and sunset to midnight (PmNight). Breed (Pasture*Year) was treated as the experimental unit and differences were declared significant at $P \leq 0.05$. Number and duration of cow-calf contacts was highest during PmDay and lowest during AmNight and no breed-related differences were observed. RC cows traveled farther at higher velocities during AmNight, AmDay and PmDay and explored an area almost three times larger than the area explored by AH counterparts (152 vs. 57 ha). RC cows spent more time traveling during AmNight, AmDay and PmDay, more time grazing during AmNight and PmDay and less time resting during AmNight and PmDay than their AH counterparts. Our data suggest that RC calves impose fewer constraints on their dams' grazing patterns compared to commonly-used British crossbreds when grazing the Chihuahuan Desert during summer.

Multicriteria Decision Analysis and GIS to Prioritize Grasslands Areas in Chihuahua, Mexico

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The conservation of biodiversity is compromised in terms of the demand for natural resources. Conservation programs that are designed and executed effectively can be used to rationally manage the use of natural resources for the benefit of societies. Maps of zoning grasslands conservation are essential for the prevention or mitigation of the disturbance of these areas. In this study, four conservation scenarios of grassland zones were generated for the semiarid ecoregion of Chihuahua, Mexico by using multicriteria evaluation techniques with weighted overlay (MCE-WO) and fragmentation analysis. The analysis was performed in a geographic information system (GIS). The proposed scenarios were: Non-Intensive Agriculture, Intensive Agriculture, Urban and Rural. The areas defined were: Good, Acceptable, Moderate, Bad and Very Bad. The results showed that the acceptable zone was the one that covered the largest area in the four scenarios with an average area of 37,804 km^2. The bad and very bad areas were concentrated mainly in the central region of the semiarid ecoregion of Chihuahua. The landscape metric Number of Patches (Nump) showed that, at the landscape level, the Non-Intensive Agriculture scenario and the Rural scenario have the highest number of patches, with 54,640 and 46,210, respectively. Our results showed that grassland conservation zones are fragmented, which can be assessed visually on the map as agricultural areas and rural localities. The integration of GIS with MCE-WO is useful and effective for areas with little or no information on the state of the grassland. This approach can also provide a solid source of information for decision makers regarding planning use of land cover to mitigate the vulnerability of grasslands.

Native Bee and Honey Bee Patch Occupancy in the Great Plains: Evidence of Resource Partitioning?

Clint Otto, USGS, Jamestown, North Dakota
Larissa Bailey, Colorado State University, Ft. Collins, Colorado
Matthew Smart, US Geological Survey, Jamestown, North Dakota

Habitat loss and competition with non-native, managed bee species have been implicated in the decline of native bees in the US. The Northern Great Plains (NGP) supports over 40% of all managed honey bee colonies and the number of colonies brought to this region continues to grow. Concurrent with the increase in honey bee colonies, land-use conversion of grassland to cropland in the NGP threatens habitat for native bees and honey bees alike. Loss of habitat and a burgeoning population of managed honey bees makes the NGP an ideal setting to investigate potential resource competition between native bees and honey bees. We will use site occupancy modes to estimate seasonal occupancy of native bees and non-native honey bees in relation to floral resource abundance or richness on managed grasslands, while accounting for species imperfect detection. We will also use two-species occupancy models to estimate how the presence of honey bees is related to the presence of wild bees and how co-occurrence patterns are related to floral resource availability. We will explore how our research can be integrated into existing decision-support tools to improve management efforts for native bees and honey bees in the NGP.

Natural Resource Users Law and Policy Center

Sarah Noelle, University of Arizona, Tucson, Arizona
Barbara Hutchinson, University of Arizona, Tucson, Arizona
George Ruyle, University of Arizona, Tucson, Arizona

The Natural Resource Users Law and Policy Center is a unique partnership between the University of Arizona's College of Agriculture and Life Sciences, Cooperative Extension, and James E. Rogers College of Law that strives to address the underrepresented law and policy needs of the natural resource community in Arizona and the West. The Center promotes innovative approaches to working with stakeholders and in creating the next generation of natural resource professionals, lawyers, agency heads, politicians, judges, etc. – those who will be making natural resources policy and legal decisions in the coming years – by creating an environment where students learn in real time by actively working on the needs of natural resource users and the community. This poster presents an overview of the Center's student programs, current projects, and communications outlets including the Center's website: https://extension.arizona.edu/nrulpc

Navigating Rigidity Traps at the Nexus of Law, Policy, and Science to Foster Resilient Rangelands

Conor Barnes, University of Nebraska-Lincoln, Lincoln, Nebraska
Dirac Twidwell, University of Nebraska, Lincoln, Nebraska

While rangelands are critical to the economies of many states, wide open spaces of grass were not always so highly valued; in the past much of the interior was viewed as the "Great American Desert." To make these areas more habitable, federal and state governments established laws and policies to encourage the widespread planting of trees on rangeland. Many of these laws and policies continue to influence management actions today. Yet these laws and policies were created in an era when few thought ecosystems could switch to an entirely different regime with different goods and services. Modern ecological resilience holds this is not the case – instead, there are multiple alternative stable states to which a system might "flip" should the system's adaptive capacity be overcome. Scientists and land managers are paying great attention to woody plant spread in rangelands to prevent just such a flip. Unfortunately, with past laws and policies still in place, land managers have been forced into situations where they must plant trees to satisfy one directive, then turn around and remove trees to satisfy another. Such doublethink is evidence of "rigidity traps", situations where institutions become self-reinforcing and inflexible. This poster examines two case studies where the law, science, and policy of past values have created rigidity traps. In the first case, nineteenth and twentieth century science led to laws and policies that inhibit modern management efforts. In the second, laws and policies of the prior two centuries have led scientific disciplines to research better ways to implement those laws and policies, which can also undermine modern management efforts. The poster concludes by proposing methods for escape from such rigidity traps and thereby promote consistent, modern management practices.

Needles in a Haystack: Identifying Thresholds in Annual Grass-Dominated Rangelands

Clay Wood, University of Wyoming, Laramie, Wyoming
Brian Mealor, University of Wyoming, Laramie, Wyoming

Invasive species have an ever-increasing impact on the ecological and economic functions of ecosystems. Cheatgrass (*Bromus tectorum*) is an invasive annual grass that is widely distributed throughout most of the western United States. Cheatgrass produces high amounts of fine fuels that can increase fire frequency, altering vegetation composition and structure. Determining thresholds within cheatgrass-invaded rangelands may help conserve native plant communities. The objective of this research is to determine if there is a direct, predictable relationship between pre-treatment vegetation condition and post-treatment increases in perennial grass biomass following treatment with two formulations of imazapic (liquid and granular). We sampled locations representing a gradient of cheatgrass to perennial grass ratios prior to, and following, herbicide application across multiple sites. At the Saratoga and Pinedale, Wyoming field sites, we collected pre-treatment data in 2015, aerially applied herbicides in September 2015, and collected post-treatment data in 2016 and 2017. Prior to treatment, perennial grass biomass decreased with increasing cheatgrass cover ($p<0.001$). Post-treatment cheatgrass cover was reduced by both herbicide treatments two years after treatment (YAT) at Pinedale ($p<0.001$) and Saratoga ($p=0.017$). In Pinedale 1 YAT, perennial grass biomass response to herbicides depended on relative cheatgrass cover prior to treatment ($p=0.038$), but we did not observe this interaction 2 YAT. Herbicide treatment increased perennial grass biomass 2 YAT at Pinedale ($p<0.001$), but not at Saratoga ($p=0.949$). Inter-annual variability in vegetation and herbicide efficacy makes identifying thresholds difficult in these systems.

New Rangeland Production and Phenology Monitoring Services

Charlie Schrader, USDA, USFS, Prineville, Oregon
Matt Reeves, USDA Forest Service, Florence, Montana
Iric Burden, USDA, NRCS, Flagstaff, Arizona

In this session we describe two new services available for managers and producers. These services include an assessment of annual production and phenology for US rangelands. Users will be able to query the datasets for their pastures, Ecological Sites, allotments, or other areas of interest. The annual production database from the Rangeland Productivity Monitoring Service (RPMS) will enable users to learn a lot about areas under their management because the estimates span from 1984 to present, seamlessly and consistently, for all coterminous US rangelands. Trends, inter-annual variability, and recovery after drought and wildfire can all be quantified with these services. This new service will help inform risk management strategies and enable better allotment management plans for federally managed rangelands. The data can be found publically at: https://www.lankstonconsulting.com/data-warehouse and elsewhere. Likewise the Phenomap products (https://www.fs.fed.us/wwetac/threat-map/TRMPhenoMap.php) quantify past and in-season estimates of phenological velocity. Users of this novel information will be able compare the current week's phenology with 16-year baseline values and estimate how many days that rangeland phenology is behind or ahead of seasonal norms. Like the productivity service, Phenomap will enable improved allotment management plans by potentially increase flexibility on federally managed allotments and simultaneously inform grazing management solutions by producers. We have partnered with private industry to develop and freely offer these and other tools but they are maintained by the USDA Forest Service.

North Dakota Soil Recovery Program: Innovative Northern Great Plains Program Aims to Accelerate Adoption of Forage and Soil Enhancing Grazing

Marshall Johnson, Audubon Dakota, Fargo, North Dakota

The North Dakota Soil Recovery Program (NDSRP) is a state-based incentive program that encourages North Dakota producers and ranchers to adopt adaptive and holistic management on their native and cover crop pastures and croplands. Audubon Dakota has partnered with NDSU Extension to deliver the program in high priority North Dakota counties within key soil health recovery geographical areas, as determined by North Dakota Web Soil Survey. Over the next four years, NDSRP will enroll 100,000 acres of private lands with the goal of improving soil health, forage quality, and wildlife habitat through the implementation of rotational grazing on enrolled acres, designed by NDSU and Audubon staff. In addition, Audubon Dakota and NDSU Extension have begun to develop an educational program for the enrolled North Dakota producers to learn of the importance of soil health and the role of holistic management in improving soil quality. Audubon Dakota and partners will provide participating landowners access to cost sharing opportunities for grazing infrastructure through existing conservation partner cost share programming. The NDSRP not only aims to improve soil health on native/planted grass and cover crop pastures and croplands, but it will also become a viable option for private landowners who are faced with the inability to re-enroll their expiring CRP acres and for landowners who desire to incorporate and/or expand an adaptive management system within their operation. Audubon Dakota is a proud project partner of NDSU Extension, Natural Resources Conservation Service, and the North Dakota Stockmen’s Association.

Novel Approaches to Restore Degraded Grasslands in Canyonlands and Arches National Parks

Michael Duniway, U.S. Geological Survey, Moab, Utah
Rebecca Mann, U.S. Geological Survey, Moab, Utah
Stephen Fick, U.S. Geological Survey, Moab, Utah
Travis Nauman, U.S. Geological Survey, Moab, Utah
Liz Ballenger, National Park Service, Moab, Utah

Many upland grassland communities on the Colorado Plateau have undergone a shift to degraded states, characterized by extensive patches of bare ground and predominance of invasive annual species. These state shifts are associated with alteration of processes and feedbacks, including accelerated soil erosion, depleted native seed banks, and loss of surface horizons. Due to low and variable precipitation, traditional rangeland restoration practices in these areas are often unsuccessful and under some circumstances restoration failures can lead to catastrophic erosion. In Canyonlands and Arches National Parks, we have studied the potential of using small barriers (Connectivity Modifiers, ConMods), to overcome limiting physical site conditions and restore degraded grassland communities. Our small-scale experiment data show that application of ConMods can create microsites that favor seedling establishment. After four years, ConMods significantly increased the establishment of *Sporobolus* species, and 90% of seeded plots with a ConMod had successful establishment. In addition to improving native grass establishment, ConMods increased in soil fertility five years after installation, likely due to increased capture of surface litter. We initiated a broader study within four heavily degraded sites in Canyonlands and Arches National Parks to investigate the effectiveness of ConMods at broader-scales and in different settings. Over 2,500 ConMods have been installed as part of this adaptive management effort and restoration successes monitored for two years. Results show that effectiveness of ConMods in promoting plant establishment is highly dependent upon within ecological site variation, particularly soil surface texture. Overall, our research has shown that this novel technique can moderate harsh physical conditions, promote plant establishment, and can be an effective restoration method in highly degraded upland plant communities. However, the high variation in success, even within an ecological site, suggests integration of these approaches into ecological site descriptions and associated state-and-transition models will require accounting for within-site abiotic gradients.

Now Available: Version 5 of Interpreting Indicators of Rangeland Health (IIRH) Technical Reference

Mike Pellant, BLM, Boise, Idaho

A new version of the IIRH Technical Reference is now available. This version replaces the 2005 Version 4 and is the latest update of this protocol that was initiated in 1994. IIRH is a largely qualitative technique that uses 17 indicators that collectively provide a point in time assessment of three attributes of rangeland health: 1) soil/site stability, 2) hydrologic function, and 3) biotic integrity. Version 5 is a product of an interagency cadre and has received extensive field testing during Bureau of Land Management and National Resources Conservation Service classes, user applications, solicited comments and a peer review conducted by the SRM's Rangeland Assessment and Monitoring Committee. Changes in the protocol from Version 4 to Version 5 will be described and information on accessing Version 5 and obtaining the publication will be provided.

Old World Bluestems in the New World: Not Your Usual Bluestems

Keith Harmoney, Kansas State University, Hays, Kansas
Karen Hickman, Oklahoma State University, Stillwater, Oklahoma
Walter Fick, Kansas State University, Manhattan, Kansas

Old world bluestems (OWB) are warm-season grasses from Asia, Africa, and Australia first introduced into the US in the early 1900's. Since that time, selection programs with collections from around the globe have released multiple cultivars adapted to the southern Great Plains for soil conservation and forage. To this end, these programs were successful in developing grass releases that were capable of establishing, persisting, reproducing, and developing abundant dry matter, even in hot and dry climates. The widespread use of OWB has resulted in a source of introduction into some rangelands and pasture where OWB were not intended or wanted. Because OWB are perennial warm-season grasses, controlling them in perennial warm-season grass dominated native rangelands is difficult and often results in collateral damage to the native species. Therefore, a system approach to control OWB in rangeland and pasture is needed that reduces OWB populations over multiple years, yet remedies consequential landscape concerns derived from the use of herbicides that may decrease existing vegetative soil cover. Efforts to remove OWB from pasture should include three basic goals: 1) control the OWB, 2) protect existing native species, and 3) prevent soil exposure and erosion.

One Steppe: Efforts from Multiple Stakeholders in Wyoming to Streamline Disturbance, Reclamation, and Conservation Efforts

Michael Curran, University of Wyoming, Laramie, Wyoming
Peter Stahl, University of Wyoming, Laramie, Wyoming

Aside from being a leading producer of natural resources in the US, Wyoming is also the least populated state and provides habitat to a wide-array of wildlife species. The greater sage-grouse, a species of concern under the Endangered Species Act, is often thought to serve as an umbrella species to other sagebrush-steppe obligate species in Wyoming. Efforts to balance natural resource development while conserving wildlife habitat have been ongoing in Wyoming for over a decade. These efforts have included mapping disturbance, limiting development within critical wildlife areas, tracking reclamation efforts, and reporting to various state and federal government agencies. Multiple tools, which at one point were disparate, were developed in Wyoming as a result of the above efforts. Since 2014, researchers from University of Wyoming's Geographic Information Science Center (WyGISC) and Wyoming Reclamation and Restoration Center (WRRC) have been working with industry partners, state and federal government agencies, and private landowners to develop an integrated, central platform to combine these tools. OneSteppe is the result of these efforts. Lessons learned from the process will be discussed and the tools developed within OneSteppe will be demonstrated.

Open-access Geospatial Tools for Land Management on Google Earth Engine

Charlie Bettigole, Ucross High Plains Stewardship Initiative, New Haven, Connecticut
Sabrina Szeto, Ucross High Plains Stewardship Initiative, New Haven, Connecticut

Ucross High Plains Stewardship Initiative builds open-access tools for land managers that leverage the petabytes of satellite and climate data and cloud-computing power of Google Earth Engine. We will be demonstrating a few of the tools we have developed and describing the process that we have undertaken to work one-on-one with field partners in developing these tools. One of these is the Change Vector Analysis tool for mapping changes in indices that correlate with vegetation health and bare ground. Another is Stratifi, which is a tool that uses unsupervised clustering using user-defined characteristics like elevation or NDVI to generate stratified sampling points for field surveys.

Optimizing Productivity Models for Enhanced Rangeland Monitoring

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Brady Allred, University of Montana, Missoula, Montana
Matthew Jones, University of Montana, Missoula, Montana
David Naugle, University of Montana, Missoula, Montana

Monitoring and evaluating rangeland vegetation productivity is a critical component of rangeland management and conservation. Monitoring rangeland productivity across broad spatio-temporal extents and at appropriate scales however, is a significant challenge. While ground-based methods capture important local detail, they are essentially snapshots in space and time, difficult to effectively expand to broader scales. Remote sensing based approaches on the other hand, can capture dynamics at broader scales, but often miss the local detail necessary for effective decision making and management action. Here we capitalized on advancements in cloud computing technology and remote sensing product development to produce spatially and temporally continuous estimates of the productivity of key rangeland plant functional types. Integrating a new plant functional type percent cover product and remotely sensed vegetation indices, we produce estimates of the productivity of annual forbs and grasses, perennial forbs and grasses, shrubs, and trees, at a 30 m resolution across the western rangelands of the contiguous United States.

Outreach for Grass-Cast: A New Grassland Productivity Forecast for the Great Plains

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Every spring, ranchers face the same difficult challenge – trying to guess how much forage will be available for livestock to graze during the upcoming summer. How much risk are ranchers willing to take on if dry conditions emerge? Conversely, what opportunities would be missed if wet conditions occur? A team of researchers recently developed a new Grassland Productivity Forecast or "Grass-Cast" for ranchers in the Northern Great Plains region (Montana, Wyoming, Colorado, North Dakota, South Dakota, and Nebraska). Grass-Cast forecasts the productivity of rangelands, currently at the individual county level, using current climatic conditions to date and precipitation outlooks for the May-July period using above-normal, near-normal, or below-normal estimates, relative to the individual counties' 34-year history. Ranchers could use the early-May Grass-Cast maps to help inform their initial late spring grazing and marketing decisions, and updated maps for adaptive grazing strategies. Outreach emphases of Grass-Cast has included: (1) six state-level workshops with USDA-NRCS and University Extension, (2) a series of popular press articles and webinars, and (3) (a) an introductory video and an outreach-oriented diagram showing how Grass-Cast is made, (b) archived forecast maps (2018) that capture uncertainty and variability in growing season precipitation, (c) a practical example illustrating how Grass-Cast is interpreted and can be used to inform stocking decisions, (d) county-level historical estimates of above-ground net primary production, and (e) recorded webinars. These materials can assist ranchers and land managers with correctly interpreting and using Grass-Cast as it prepares to enter its second season (2019) in the Northern Great Plains and expands to the Southern Great Plains (Kansas, Oklahoma, Texas, and New Mexico) in spring 2019.

Phased Post-Fire Rehabilitation Effects on Plant Community and Soil Characteristics in the Great Basin

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Invasion by cheatgrass after fire has altered Great Basin ecosystem structure and function, resulting in costly fire suppression and rehabilitation efforts. Post-fire rehabilitation has the potential to reshape ecosystems for decades, yet there is little research on interactions between fire, rehabilitation, soil characteristics, vegetation, and biological soil crust (BSC). We examined how two phased rehabilitation treatments commonly applied in the Great Basin, herbicide and seeding, altered the post-fire successional trajectories of plants and BSC. Explicitly, we explored how soil characteristics and processes related to plant community composition and abundance. The field study was a full-factorial design consisting of two herbicide treatments (no herbicide and first spring glyphosate application), three seeding treatments (no seeding, pipe harrow, and hand seeding), and two seeding rates (9 and 13.5 lb./acre); unburned controls were established outside the fire perimeter. We measured plant species and biological soil crust cover, plant density and height, and canopy gap. Soil characteristics included stability, texture, moisture, temperature, N-pools, bulk density, surface roughness, and sediment erosion. Our results suggest that pipe harrowing promoted cheatgrass the first year after fire. This may be attributed to increased surface roughness and seed capture in harrow rows. Hand seeding had cheatgrass levels similar to unburned plots. By the second year, differences in cheatgrass cover between harrow treatments were undetectable. There was no difference in native perennial or cheatgrass cover between pre-emergent herbicide treated and untreated plots; however, herbicide application significantly lowered native annual forbs the first growing season after treatment. Post-fire BSC survival was low because of high soil erosion rates, and no treatment effect was detected. Soil erosion was greater on herbicide treated plots and decreased once vegetation was established.

Phenotypic and Genetic Variability of Blue Grama (*Bouteloua gracilis*) Populations from Northern Mexico

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Blue grama [*Bouteloua gracilis* (Kunth) Lag. ex Griffiths] is considered one of the most important species for restoration of grasslands in Northern Mexico. Due to a lack of seed availability, most of the blue grama seeds used for restoration in Mexico have been imported, increasing costs and establishment failures. This study assessed the phenotypic and genetic diversity of 41 blue grama populations from Northern Mexico, with the aim of identifying genotypes with potential for restoration and plant breeding programs. Three plants per population were collected and transplanted in a field nursery. To evaluate the phenotypic variation, 12 morphological variables were measured during the third and fourth years after plant establishment. Amplified Fragment Length Polymorphism analysis was performed to assess the genetic diversity. In general, wide phenotypic and molecular diversities were found. The morphological variables with the highest variation were forage yield [variation coefficient (VC)=59.9], number of stems (VC=45.1) and leaf length (CV=26.6). The molecular analysis differentiated the populations into four different groups. However, the partitioning of the total AFLP variation showed that 63.6% of the variation was present within clusters and just 36.3% was present among clusters, suggesting populations can be selected individually. The populations N75, N146, N646 and N695 showed the greatest productive potential. These populations could be used for the future development of a new blue grama variety, which can be used on restoration programs. In addition, the genetic richness found represents an opportunity to perform plant breeding on this species.

Physiological and Microanatomical Responses to Extreme Drought in *Andropogon gerardii*

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Current climate models project an enhanced risk of drought in the Tallgrass prairie over the coming century; which will alter productivity, ecosystem functioning, and may promote woody encroachment. To understand the role of reduced precipitation, rainout shelters were constructed at Konza Prairie LTER, to simulate an extreme multiyear drought (50% rainfall reduction). We measured species composition, aboveground net primary productivity (ANPP), species-specific physiology and microanatomy during the 2016-2018 growing seasons. Results indicate that prolonged drought will negatively impact species' leaf physiology and microanatomy, decrease productivity, and alter species composition.

Physiological Responses to Elevated CO_2 and Drought in Encroaching Woody Species

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Current climate projection of the Great Plains region predicts increased carbon dioxide concentrations [CO_2] and altered precipitation regimes that, in the southern Plains, reduce soil moisture. These climate predictions will likely favor deep-rooted woody plants over shallow-rooted warm season grasses and exacerbate woody encroachment. To test this hypothesis, we conducted a greenhouse study to determine how four woody seedling species (*Cornus drummondii*, *Rhus glabra*, *Gleditsia triacanthos* and *Juniperus osteosperma*) would grow under elevated [CO_2] and decreased soil moisture. We measured leaf gas exchange, leaf fluorescence and a suite of plant functional traits. After five months of monitoring we found that all species increased water use efficiency and increased their root growth under elevated [CO_2] and lower soil moisture. We found each woody species had a different physiological strategy to cope with the different environmental conditions. Broadly, elevated [CO_2] did ameliorate the stress of decreased soil moisture for the seedlings, suggesting that woody plant seedlings will be able to cope with the projected climate scenarios for the Great Plains region.

Plant Traits Predict Precipitation Sensitivity of Species and Communities in Semi-Arid Shortgrass Prairie

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Understanding how plant species and communities respond to precipitation allows for predictions of inter-annual variation and directional trends in ecosystem services, such as forage production and quality, biogeochemical cycling, and biodiversity, as well as reducing risks for land managers. In a US shortgrass prairie, we collected data describing plant abundance, functional traits related to growth rate and drought tolerance, and aboveground net primary productivity (ANPP) to identify (1) "response traits" indicative of species and community responsiveness to precipitation (i.e., precipitation sensitivity), and (2) "effect traits" that mediate spatial relationships between community-weighted trait values and ANPP. Across 32 plant species, we explained 68% of the variation in species-level sensitivity to temporal fluctuations of precipitation using leaf dry matter content (LDMC), specific leaf area (SLA), and leaf osmotic potential. Plant height was important for describing precipitation sensitivity of annual but not perennial species. SLA and LDMC were also identified as effect traits, both having negative spatial relationships with ANPP. These findings suggest that community traits may shift towards faster growing, less stress resistant states in wetter years and/or under chronically increased precipitation regimes and vice versa for drier years/trends. Additionally, trait shifts may cause emergent effects on long-term primary productivity and these shifts should be incorporated into predictions of ecosystem function under altered climatic conditions.

Policy and Practice for Sourcing Seed in Grassland Restoration: How are People Defining Local?

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Grassland restoration practices and policies have often been more focused on the past instead of the future, particularly when it comes to how seed is sourced for restorations. Although recommendations to diversify seed mixes in restoration projects to enhance genetic diversity and adaptability are pervasive in the literature, common practice and sometimes local laws dictate the use of exclusively local ecotype seed for restoration or reconstruction. Emerging climate change strategies for grasslands, such as enhancing genetic diversity in forb species, represent an advance that stretches the limits of the current dogma, i.e., that “local is always best.” This philosophy could be restricting the adaptability of our current and future grasslands. During the winter of 2017-2018 we conducted a survey of restoration practitioners to assess the variety of seed sourcing practices and strategies employed in grasslands across the continental U.S. and Canada. Through an online survey we investigated whether locally sourced seed was considered or required by law or policy across different agencies and organizations, and if local seed was used, we inquired about the parameters used to define local and the justification used to develop these policies. The survey reached a wide audience with 494 respondents from 40 U.S. States and five Canadian provinces. Very few states or provinces had laws regarding the use of local ecotype seed, but 85% of respondents considered local ecotype seed in restorations either because of organizational policy or practitioner preference. Parameters for defining local and justifications for strategies used will be presented.

Potential for Soil Amendments to Restore Belowground Function and Aboveground Vegetation on Severely Disturbed Abandoned Mine Sites

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Healthy soil is key to successful restoration of drastically disturbed lands. In addition, above- and below-ground components of ecosystems must be linked to ensure appropriate amounts and kinds of ground cover. However, restoration efforts sometimes ignore these linkages and target either soil processes or plants species. Restoration efforts may be hampered by poor soil physical or chemical properties or reduced soil microbial communities which may result in failure of planted or seeded species to thrive. To enhance degraded ecosystems, soil amendments may be necessary to promote increased soil organic matter, water holding capacity, and nutrient cycling. To facilitate abandoned mine land restoration, biochar, biosolids, and wood chips were used to build soil as single amendments or in combination. These soil building treatments were then planted with two grass species (*Bromus carinatus* Hook & Am. and *Elymus glaucus* Buckl.) on one-half of the treatment plots and were seeded with a native plant mix on the other half. After two years, soil cover on the seeded side and overall plant survival was highest in the biosolid + wood chip and biosolids + wood chip + biochar treatments. In general, *Bromus carinatus* had better survival after two years than *Elymus glaucus*. Improved *Bromus* survival may be associated with the nutrient and water needs of this species. Changes in soil properties from soil amendments meant to improve critical soil functions will change how plant species respond and highlights the need to match seedlings with site conditions to ensure adequate plant cover.

Potential Long-term Cheatgrass Seedling Reduction with Indaziflam in Sagebrush-grassland Communities in Sublette County, WY US

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The extent of cheatgrass (*Bromus tectorum* L.) invasion in the western US is now measured in millions of hectares, and by increasing fine fuel abundance and reducing fire return intervals, cheatgrass presence increases the likelihood of continued invasion and increasing dominance. Herbicides have proven an effective tool for reducing this threat, however it is often difficult to avoid harming native perennials and long-term control has proven elusive. Indaziflam (Esplanade®, Bayer CropScience) has demonstrated the potential to selectively reduce cheatgrass seedlings and achieve long-term control of the soil seed bank without harming established perennials. We present results from the first two years of a multiyear study to better understand the potential of indaziflam to reduce cheatgrass seedlings with minimal harm to native perennial species. We measured cover by species and cheatgrass seedling density in four sets of small plots that include controls, indaziflam treatments at three different rates (51, 73 and 102 g ai/ha), and imazapic (Plateau®, BASF) treatments (123 g ai/ha). Imazapic has documented, albeit limited long-term effectiveness for treating cheatgrass. We also collected similar data in four, one-acre aerial indaziflam treatments. The study sites are located at Boulder Lake, near Pinedale, Wyoming and feature sagebrush-grassland communities dominated by bluebunch wheatgrass (*Pseudoroegneria spicata* (Pursh) A. Love), needle and thread (*Hesperostipa comata* (Trin. & Rupr.) Barkworth), arrowleaf balsamroot (*Balsamorhiza sagittata (*Pursh) Nutt.) and mountain big sagebrush (*Artemisia tridentata* ssp. *vaseyana* (Rydb.) Beetle). Sites were treated in September 2016 and sampled in June 2017 and 2018. Indaziflam treatments showed significantly fewer cheatgrass seedlings and more native grass cover in 2017 relative to control plots, and this difference was even greater in imazapic treatments. Analysis of 2018 data is forthcoming, but visual data suggest that the effectiveness of indaziflam has increased in year two, while the opposite is true of imazapic.

Potential of Accelerometers to Monitor Cattle Behavior and Welfare

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On extensive rangelands, cattle may not be able to be observed on a daily basis. The ability to remotely monitor livestock behavior and its relationship to animal welfare would reduce labor costs and potentially decrease time for managers to respond to potential animal welfare concerns. Failure of livestock water delivery systems is one of the most critical animal welfare concerns in arid and semi-arid rangeland pastures. Eight Corriente cows were fitted with GPS tracking collars and accelerometers for four weeks in a 1,090 ha pasture at the Deep Well Ranch near Prescott, Arizona. Cattle were tracked at two-minute intervals and movements were recorded at a frequency of 12 Hz by ear tag accelerometers. Cattle behavior was visually observed and recorded with video, and random forests procedures were used to analyze and predict animal behavior. Distance traveled was the most important variable for predicting behavior followed by side to side and fore and aft accelerometer movements. However, using only accelerometer data, mean movements of x, y and z axes, and motion intensity may not be appropriate metrics for accurately predicting multiple behaviors on rangelands. Variation of metrics and other combinations of metrics may be more effective. Simulated water delivery failure was evaluated on three occasions in June 2018. Panels were used to keep cattle away from the water drinker for four hours at mid-day. Cattle remained near the water tank and displayed aggressive behavior during the period when water was not available. Preliminary analyses suggest that simulated water failure may be able to be predicted by remotely collected data from GPS tracking collars and accelerometers, but more research is needed to validate initial results.

Practicing a New Natureculture of Hope for Multifunctional Rangelands: Lessons from Collaborative Adaptive Rangeland Management

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In the US Great Plains, multigenerational ranching livelihoods and grassland biodiversity are both threatened by dynamic and uncertain climatic, economic, land use and regulatory processes. Working apart, agricultural and conservation communities face doubtful prospects of reaching their individual goals for multispecies sustainability, despite a common sense of urgency. This study documents the journey of a group of public lands managers, conservationists, ranchers and researchers re-imagining and practicing, together, a different future for the rangelands of the US Western Great Plains. Formed by invitation of researchers in 2012, the team manages an experimental yearling cattle ranch on the shortgrass steppe (the ~6,070 ha Central Plains Experimental Range in Nunn, CO) via collaborative adaptive rangeland management (CARM). We examine processes and outcomes of a series of meetings in which the team worked to revise their management objectives (2016-2018). We do so through the lens of the natureculture concept, which recognizes the 'inseparability in ecological relationships that are both biophysically and socially formed' (Fuentes 2010; Haraway 2003). In the early days of CARM, the team established locally-relevant multifunctional goals and objectives. Revisions to these objectives after four growing seasons reveal distinct changes in the team's conceptual understanding and related practice of rangeland management. We describe and discuss these changes as the beginnings of a new natureculture, grounded in hope, emerging from the CARM experience. We consider how insights from collaborations for multifunctional management in CARM inform broader regional efforts to create what Stegner described as "a society to match the scenery" (1997).

Prairie Reconstruction Guide Book for North Dakota

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The Prairie Reconstruction Guide Book focuses on prairie reconstruction, defined as the planting of a native seed mixture composed of multiple prairie species (graminoids, forbs and small shrubs) in an area where the land has been cultivated or anthropogenically disturbed. The purpose of the Guide Book is to provide prairie reconstruction guidance for land managers in North Dakota and surrounding areas. Described methodologies will allow for the proper planning, implementation and establishment of prairie reconstructions based on articulated goals. It brings together scientific research and land management experience to address important components of a reconstruction including objectives, site selection, seed mix, seeding method, management actions, and evaluation methods into one document. Reconstructing prairies on former cultivated areas provides opportunities to create sustainable and resilient grassland cover that reduces soil erosion and invasive species while creating habitat for a variety of native wildlife and re-establishment of ecological processes to the site. Careful consideration of each of the phases of reconstruction creates the strongest opportunity for success.

Precision Prairie Reconstruction (PPR): 15-Year Field Study Results for Sustaining Forb Richness & Density

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Precision Prairie Reconstruction (PPR) is a site specific, minimal disturbance, cost effective, low maintenance technique for addressing a notable problem in grassland reconstruction: the decline in species richness over time. The method consists of establishing native grass and native forb micro-communities in an existing grass matrix. The working hypothesis is that by installing and seeding specific quantities of small-scale-disturbances with native species, a self-sustaining community will be established that will generate a continuing source of propagules which in time will colonize the surrounding vegetation matrix (by taking advantage of suitable environmental conditions that can occur over the years) and thus increase native species diversity. The micro-communities in this experiment were created by broadcast seeding simulated small-scale-disturbances (8 m^2 in size) installed systematically over an empirically determined percentage of the site (5%, 25%, 50%). The PPR results were compared with two standard restoration techniques: herbicide application/drill seeding (H&D) and roto-till/broadcast seeding (R&B). Across all years sampled, the 25% and R&B treatments were statistically similar (P>0.05) in terms of total species richness (22 species for both), seeded forb richness (7 vs. 8 species), seeded forb stability (CV of 0.4 vs 0.5, where high CV represents low stability), and seeded forb density (10 vs 8 plants/m^2). All the other treatments were significantly different (P<0.05) with corresponding averages of: 16 species, 3 species, CV of 0.97 (the 50% was similar to the 25% and RB with CV of 0.4) and density of 3 plants/m^2. Outcomes from this field experiment after 15 years show that the PPR technique results in sustainable native forb species micro-communities visually comparable to a native prairie and offers an alternative approach for increasing native grass and forb density and richness in old fields dominated by an exotic grass matrix.

Predicting Forage Production in South Dakota: Important Trigger Dates for Drought Management

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Spring droughts, in the Northern Great Plains, have been known to reduce forage production from rangelands more than any other intra-annual dry period because plant composition is dominated by cool-season grasses. The objective of this paper is to present forage prediction models from two locations in South Dakota to identify important trigger dates for drought management. Data come from a long-term stocking rate study conducted in western South Dakota from 1945-1960 and a private ranch in east-central South Dakota from 2000-2005. Forage production from the western South Dakota site was best predicted by accumulated April-June precipitation and the east-central site by April precipitation. These data sets illustrate the importance that spring precipitation has on annual forage production of South Dakota rangelands. Extension specialists, technical service providers, and producers can use spring precipitation data to help take drought management actions, early in the grazing season, to avoid overgrazing rangelands and potentially reduce economic risks driven by drought-induced market fluctuations.

Projected Drought Effects on Ashe Juniper Populations Inferred from Remote Measurements of Tree Canopies

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Tree mortality from drought is anticipated to increase if climate change promotes more frequent or severe water limitation. Ecosystem impacts of woody mortality depend on both the number and sizes of trees that die, but a limited capacity to predict mortality risk for individual trees hinders the capacity to forecast drought effects on tree population demography and ecosystem processes. We remotely measured leaf area of living Ashe juniper trees at three savanna sites in central Texas, USA to characterize the frequency-size distribution (FSD) of juniper populations and evaluate mortality risk from drought as a function of tree size. Mortality risk of individuals was assessed from the deviation in leaf area per tree from that of a similarly-sized individual with near maximal leaf area using correlations among leaf area, growth rate, and mortality measured during a prior drought. We found that the FSD of juniper trees is bell-shaped at each site with most individuals of intermediate size. Mortality risk from drought exceeded 25% of emergent trees in savanna juniper populations, but was highest for largest trees. Mortality risk was greatest at a grazed savanna, exceeding 50% of trees with projected canopy area >20 m^2. Results imply that severe drought could kill a large fraction (18-85%) of intermediate- to large-sized Ashe juniper trees in central Texas savannas. Our analysis demonstrates a novel use of remote measurements of canopy foliation to link mortality risk from drought to the demography of Ashe juniper populations through properties of individual trees.

Projections of Climate-Induced Land Cover Change in the U.S. Great Plains

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The Great Plains climate is continental and characterized by dominant north-south temperature and east-west precipitation gradients. Future climate change is projected to be heterogeneous with greatest warming and increasing annual precipitation at high latitudes and warming and drying at lower latitudes. These changes are anticipated to modify land cover, plant community composition, primary production, and related ecosystem services. We assessed the rates and patterns of land cover change and NPP in the region from 2020 to 2100 with the global dynamic vegetation model (MC2), driven by projections from five global climate models (GCM's) considered most appropriate for the Great Plains region. We found an overall transition from C3 (cool-season) to C4 (warm-season) grasses in the Northern and Central Great Plains as well as major decreases, increases, and geographic shifts in the percentage of grassland cover throughout the entire region. The Northern and Central Plains showed strong responses to projected climatic change, although shifts in the proportion of grassland cover were not linear, but fluctuated through time. Land cover in the Southern Plains remained relatively stable in comparison. We found a notable redistribution of NPP among grassland, shrubland, and forest vegetation. However, total NPP had no clear signal and fluctuated by up to 50% throughout the century in some regions. Simulations without fire benefitted woody plants while its presence increased the percentage of grassland cover and in some regions the percentage of shrubland cover. Simulations run with representative concentration pathways 4.5 and 8.5 showed minimal differences for either land cover or NPP. Climate-induced changes in land cover may create both positive and negative consequences for social-ecological systems throughout the Great Plains. Woody plant expansion may increase C sequestration and redistribute soil nutrients, but a reduction in grassland cover and production may decrease livestock production and grassland obligate species.

Promoting Vegetation Heterogeneity with Alternative Grazing Strategies to Improve Ecosystem Services

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Northern Great Plains mixed-grass prairie evolved under fire and grazing, creating a variety of plant communities throughout the landscape that are essential for preservation of habitat and biodiversity. These heterogeneous landscapes are declining due to fire suppression and maximization of livestock production. At the SDSU Cottonwood Research Station, we evaluated impacts of patch-burn grazing (PBG), winter-patch grazing (WPG), and continuous season-long grazing (CG) on vegetation structure and aboveground and belowground composition for two years. The experiment was a randomized block design with three grazing treatments (PBG, WPG, CG) occurring in each of three pastures (blocks). Five exclosures were constructed within each treatment within each pasture (15 exclosures/pasture); three 0.25m^2 permanent plots were randomly established in each exclosure. In each plot in June and July, cover (total, by species, bare ground, and litter), vegetation height, and litter depth were measured. Biomass for each species was estimated in July. Soil cores were collected within each exclosure in October to evaluate seed bank. PBG significantly reduced aboveground vegetation cover, height, litter, biomass and increased bare ground for both years, reduced seed bank species richness, abundance and diversity one-year post disturbance. Within each treatment, above- and belowground species composition was strikingly dissimilar after one year (Jaccard's Similarity Index: 18-25%). Aboveground species composition among treatments was, however, 45-60% similar one-year post disturbance. Results indicate WPG may provide similar/greater ecosystem benefits compared to fire. Given the reluctance of regional ranchers to use fire, this study suggests WPG may be a good alternative for preserving habitat, biodiversity, and livestock production.

Propagation of Great Basin Native Annual Forbs for Restoration

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For the past ten years, researchers at the University of Nevada, Reno have been studying the potential for native annual forbs to be used in restoration. These early seral species overlap with cheatgrass in disturbance niche and germination timing, and results indicate that some species can suppress cheatgrass. Current work focuses on collecting and increasing these species to provide foundation seed for larger-scale growouts. Beginning in 2016, UNR and Ely BLM have partnered to incorporate native annual forbs in postfire restoration. UNR provided BLM with G1 foundation seed of *Gilia inconspicua* and *Amsinckia menziesii* that had been wild-collected in western Nevada and increased at the UNR Agricultural Experiment Station. BLM (in partnership with the Eastern Nevada Landscape Coalition) contracted with Benson Seed in Washington to do a large-scale growout. From 400 grams of *Amsinckia menziesii* seed, BFI produced 51 pounds, and from 600 grams of *Gilia inconspicua* seed, BFI produced 7.6 pounds. This seed is currently being used in fire rehabilitation treatments. UNR hopes to continue to work with Ely BLM in developing seed sources for early seral species, and to expand this work to other management units.

Quantifying Restoration Across the Sage Steppe: Mapping Conifer Cover, Removal Efforts, and Fire

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Conifer expansion is one of the primary threats facing sagebrush ecosystems across the intermountain west. Removal of encroaching juniper and pinyon pine has been a critical component of restoring and maintaining sagebrush habitat, particularly to benefit the greater sage-grouse. However, tracking these restoration efforts has proven challenging since they occur across ownerships and may not be recorded with spatial details. Quantifying conifer removal across the sage-grouse range is critical for evaluating the overall distribution of effort, for identifying new management opportunities, and for comparing removal efforts across different conservation considerations. Here we demonstrate a novel approach which enables mapping of conifer cover and removal over large extents and across multiple time periods. By integrating local estimates of cover with temporally-segmented Landsat time series we produce maps of conifer cover across the entire range of the greater sage-grouse for the years 2015-17 with an RMSE of ~11% cover. Change metrics derived from the temporal segmentation were used to map conifer removal efforts and wildfires from 2011-13 to 2015-17 with a commission rate of 19% and an omission rate of 24%. A total of 1,441 km^2 of conifer removal treatments were identified in this time period with 33% occurring in Utah, 58% occurring on BLM land, and 57% occurring in priority areas of conservation for the greater sage-grouse. The conifer cover map and methodology created in this study will serve as a valuable tool for planning future removal efforts. In addition, the mapping of conifer removal efforts since 2011-13 provides stakeholders, planners, and land managers with a much-needed tool to track conifer removal progress both regionally and more locally.

Quantifying Topographic Influences on Cattle Grazing Distribution (Even When it's Not Steep or Rugged)

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Although the effects of topography on cattle grazing distribution in rugged terrain have been well documented, surprisingly few studies have examined topographic controls over grazing distribution in the more gentle undulating terrain that characterizes much of the world's rangelands. We will outline how widely available digital elevation models (DEMs) can be used to create two quantitative indices of topographic variability that may be useful in predictive models of cattle grazing distribution: (1) the topographic wetness index (TWI) and (2) topographic position classes (TPC) derived from topographic position indices. We used global positioning system (GPS) collars to track the grazing locations of cattle within six replicate pastures in shortgrass rangeland of eastern CO, and fit generalized linear mixed models to their locations to quantify the influence of topography on grazing distribution. Additionally, we examine the influence of the presence of saline vegetation communities on cattle utilization of lowlands. The resulting models indicate that TPC more effectively predicts grazing distribution than TWI in our shortgrass landscape, and that the patterns are strongest in the second half of the growing season. Model parsimony was improved with the inclusion of saline vegetation communities, although the magnitude of utilization of these communities by cattle was not consistent across multiple pastures. These models, in combination with local rancher knowledge, can be used to predict and manage livestock distribution even in landscapes with relatively subtle topographic variability.

Quick Carbon: Rapid, Landscape-Scale Soil Carbon Assessment

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Increasing soil carbon content in rangelands could be key to improving the resilience of rangelands in adverse climate conditions. Efforts to promote agricultural practices that sequester carbon have been stymied by difficulties in quantifying changes to soil carbon stocks, such as high analytical costs and analytical tools that require extensive expertise. However, studies have found that visible/near-infrared (VNIR) spectroscopy can be successfully used to estimate soil carbon concentrations instead of more expensive techniques. But standard benchtop spectrometers are still expensive and require expertise to operate. Quick Carbon has recently developed a protocol that makes use of low-cost field spectrometers built on an open-source hardware/software platform to estimate soil carbon content. Using these tools, we hope to create an accessible measurement system that empowers individuals to generate reliable soil carbon data for ecological understanding, decision making, and markets.

Quick Carbon: Tools for Tomorrow, Today

Douglas Goodwin, Noble Research Institute, Ardmore, Oklahoma

A cornerstone of rangeland health is the proper function of the soil resource. Healthy soils are paramount to rangeland resiliency, maintaining ecosystem function, sustaining plant communities, and wildlife habitat. The functionality of ecological processes such as the carbon and water cycles are a key component of ecological health on rangelands. Furthermore, the impacts to ecological indicators such as plant cover, species composition, and biological diversity are commonly governed by land management decisions that affect soil function. Specifically, indices such as soil organic carbon (the main component of soil organic matter) have impacts across the ecological spectrum and are often utilized as quantifiable measures of biologically active and properly functioning ecosystems. The Yale School of Forestry and Environmental Sciences in collaboration with The Noble Research Institute are testing and deploying new technologies to help understand soil carbon distribution and dynamics, reduce the burdensome costs of soil laboratory analysis and better inform producers regarding ecological responses to their management. Quick Carbon is a tool to help demonstrate the effectiveness of a low-cost portable spectrometer for assessing soil carbon at management relevant scales.

Rangeland Analysis Platform: New Technology Revolutionizes Rangeland Monitoring

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The Rangeland Analysis Platform (RAP) is a free, online tool that helps landowners and natural resource managers track vegetation through time and plan actions to improve America's rangelands. Powered by Google Earth Engine, RAP merges machine learning and cloud-based computing with remote sensing and field data to provide the first-ever annual percent cover maps of rangeland vegetation. The RAP can be used to provide strategies to improve productivity of grazing lands, manage weeds, mitigate impacts of wildfire and drought, and benefit wildlife habitats. This new platform allows people to view trends in rangeland resources at an unprecedented blend of space (from the Great Plains to the Pacific Ocean), time (1984 to present), and scale (at the ranch, watershed, or county level). Designed to be combined with local knowledge, the RAP (https://rangelands.app) helps users better understand vegetation change through time to aid in conservation planning, outcome evaluation, and efficiently respond to pressing challenges facing conservation of biodiversity and ecosystem services.

Rangeland Conservation Requires Profitable Ranching Operations

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Rangeland conservation is an important goal of government land management agencies and non-profit organizations. In California, these groups often use livestock grazing to help achieve their conservation goals, but may be unaware of the financial demands ranchers face. In order to sustain a pool of ranching lessees, who can manage for diverse conservation goals, ranching needs to be profitable. Without profitable ranches, there will be no livestock to graze grasslands and manage weeds; reduce risk of wildfire; improve plant and wildlife habitat; and maintain water quality. So what does it take to run a ranch? In order to help answer that question, we developed a cost and return study for a "typical" 300 head, fall-calving cow-calf operation on the Central Coast of California. The vast majority of the rancher's income comes once a year when the calves are sold in late-spring, while costs must be paid throughout the year. Based on a lease rate of $23 per Animal Unit Month (AUM), the lease represents the highest annual cost to the rancher. Hay, mineral supplements, veterinary service, vehicles, and purchasing bulls are also substantial costs to the operation. In our study, revenue above cash costs for the "typical" ranch was $9,701 or $32.34 per head. This is on the margin of profitability with little or no return to risk and management. If society wants to maintain ranching not only for dietary protein, but as a rangeland conservation tool, we should consider how to reduce costs while improving ranch revenue.

Rangeland DRYnamics: Past and Future Ecological Drought in Western U.S. Rangelands

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Climate projections for western North American rangelands indicate rising temperatures and geographically-variable shifts in precipitation throughout the 21st century. Although these long-term climate trajectories are a recognized challenge for resource managers and policy makers, anticipating the impacts of these changes is confounded by two major challenges. First, because rangelands are typically dryland, water-limited ecosystems, the composition and productivity of rangeland plant communities is tightly linked to the spatial and temporal dynamics of soil moisture availability: conditions that are not easily inferred from climate conditions alone. Second, long-term projections of precipitation are less consistent across space and through time than temperature, promoting uncertainty about appropriate expectations for future drought conditions. Here, we defined a suite of ecologically-relevant drought metrics that represent various types of plant stress, including: moisture deficits in particular seasons and soil depth; long-term, chronic, moisture limitation that promotes sustained growth declines; and short-term extreme dry events that can lead to plant mortality. Using an ecosystem water balance model driven by observed and modeled climate for a broad suite of climate models, we quantified these metrics across western rangelands throughout the 20th and 21st centuries. The results identify broad differences among rangeland regions in historical trends and future trajectories of drought, highlighting some areas with clear projections for increasing ecological drought stress, notably the southwest US and the southern Great Plains, and other areas with less severe change, including much of the Great Basin and northern Great Plains. These results also indicate consistent differences in the uncertainty of projected change among drought metrics, with the largest and most consistent increases expected in drought conditions most directly influenced by temperature. Considering future patterns in this diverse suite of ecological drought metrics provides insight into the long-term impacts of climate change on rangeland plant communities and offers a new perspective for mitigating uncertainty in management under climate change projections.

Rangeland Improvement: Evaluating the Productivity of Clover Varieties Across Diverse California Rangelands

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Rangeland livestock producers focus on improving economic returns while sustaining rangeland ecosystems. However, most ranchers are persistently faced with the challenge of low-profit margins. Low profit margins are mainly a function of forage production and quality, cost of supplementary feed, and market prices. Seeding legumes on rangeland is a well-documented rangeland improvement or reinforcement practice that can increase forage production and quality, which will in turn increase animal productivity – rates of weight gain, weaning weight and reproduction. We planted 11 clover varieties on 10 field sites across California coastal, interior valley, foothill and intermountain rangeland areas during the fall season of 2015 and 2016. The 11 clover varieties were seeded in a randomized block design, with four replicates per site. In the past two years, we estimated germination and forage production potential of individual varieties by measuring percent cover of clover per plot. In the long-term, we plan to evaluate persistence and protein content of the different clover varieties. Results to date show high variability in percent cover of clover varieties within and across the different sites. This project will produce a list of clover varieties that can be recommended for rangeland improvement in different rangeland ecosystems across the state of California. Rangeland improvement with clovers will improve forage production and quality, and improve livestock productivity, soil health, and most importantly increase profit margins in the long-term, at lower costs compared to alternatives like protein supplementation or nitrogen fertilization.

Rangelands Assessment and Monitoring System (RAMS) Delivers Data for Decision Support

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Public land managers face challenges every day in meeting analysis needs and making decisions. The Rangeland Allotment Monitoring System is a tool that provides managers, planners, and producers with the latest information and trends on factors affecting the productivity and health of the lands they care for. RAMS leverages freely available data from various drought monitors and other sources, including a collection of rangeland productivity datasets (Rangeland Productivity Monitoring Service; https://www.fs.fed.us/rmrs/projects/development-rangeland-production-monitoring-service-could-improve-rangeland-management), to help assess rangeland conditions and inform actions such as changing stocking rates or duration. While currently in development, the final product is expected to fill essential information gaps for land managers with simple reports and visualizations showing forage projections based on antecedent conditions. This information is useful for understanding the historic range of variability on the landscape. Aside from its strengths as an analytical tool, RAMS is intended to serve as a communication tool providing a reference point for common understanding between permittees and managers. RAMS analyzes key characteristics and projects productivity information throughout the growing season (NowCasting). Trends of key indicators are displayed along with any key thresholds or actions points used in management plans. A web interface with automated graphics, text interpretations and colored alerts will help managers to communicate information in a contemporary format. This novel tool enables more informed decisions to result in improved relationships, better conditions on the ground, and ultimately, more goods and services for local communities.

Rapid Soil and Ecological Site Identification and Vegetation Monitoring Using the LandPKS App and EDIT

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There has been significant progress in standardizing rangeland inventory and monitoring methods in the past 20 years. Improved ecological site descriptions (ESDs) provide access to a wealth of information that can be used to optimize management. The protocols have been adopted by the NRCS and BLM, resulting in large datasets that are increasingly analyzed to improve ESDs. This “big data” could also be used to interpret ranch-level monitoring results. Multiple indicators can be generated from these datasets, addressing a variety of objectives including livestock production, soil and water conservation, and wildlife habitat restoration. The vast majority of landowners and managers, however, are neither applying the standardized protocols nor accessing ESDs because the protocols require too much time, data storage and analysis are too complicated, and it’s too difficult to identify ecological sites. We will provide an overview of a pair of new tools that address these challenges. LandPKS (Land-Potential Knowledge System) is a free mobile app that includes the following functions: (1) guided soil profile description that is used by embedded algorithms to (2) predict the soil and ecological site and (3) link to basic ecological site information in EDIT (Ecological Data Interpretation Tool). EDIT provides (4) the ability to independently identify ecological sites using embedded keys, (5) the information formerly available through ESIS in a much more user-friendly and interactive format, and (6) tools for entering and updating ecological site information. LandPKS also includes a “LandCover” module that allows landowners and managers to (7) collect vegetation cover data compatible with the data collected by NRCS and BLM, and (8) automatically calculates indicators and backs up the data in the cloud. By late 2019 it will also allow users to compare their data with anonymized data from the large NRCS and BLM datasets for land with similar potential.

Recovery of Interior Douglas Fir Forests One Year Post-Wildfire in Areas of Different Burn Severity

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The province of British Columbia, Canada, had an unprecedented fire season in 2017 with over 1.2 million hectares burned. Crown land comprises 94% of the provincial land base and numerous licensees such as forestry companies and ranchers rely on the use of crown land. Post-wildfire recovery is extremely important economically, socially and ecologically to the province. Due to the reduction in forage, ranchers are not able to utilize their grazing tenures allocated by the provincial government in burned areas for an undetermined amount of time. This comes at a high cost to ranchers as they rely on the relatively inexpensive forage supplied by crown land during the growing season. It is important to understand the recovery of the plant communities post-wildfire so that there is enough time for the plant community to recover, but also so that cattle can return to the range as soon as possible to minimize the economic impact on the ranching industry. Plant communities present one year post-wildfire in the IDFxh2 biogeoclimatic ecosystem classification zone were examined at three different locations in the Southern Interior of British Columbia. Two locations were within the Elephant Hill Fire and one was located within the Martin Mountain Fire. At each location six randomly selected sites were sampled, two in each burn severity rating of low, moderate and high, respectively. Data collection included modified Daubenmire transects and bio-mass clippings. Data analysis was conducted using SPSS software. It was determined that the plant communities one year post-wildfire did differ in areas of different burn severity. This information will help support resource managers' decisions on post-wildfire recovery strategies in the future and influence when cattle are able to return to graze on crown lands impacted by fire.

Reducing Kentucky Bluegrass Cover Increases Rangeland Biodiversity Across Multiple Trophic Levels

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Rangeland management sometimes has unintended consequences that impact biodiversity and ecosystem services. Previous management in the Northern Great Plains – particularly fire suppression and rest – coupled with climate change have led to widespread invasion by Kentucky bluegrass (*Poa pratensis*; bluegrass), a cool-season grass. We investigated the efficacy of fire at decreasing bluegrass cover by varying season of burn (early-growing season, late-growing season, dormant season) in the field (bluegrass field experiment) and altering fine fuels in a complementary experimental approach (bluegrass lab experiment). We also explored the relationship between plant and butterfly communities with bluegrass cover in a widespread field study (regional study). We found that bluegrass cover decreased 27% in all burn treatments the first year post-fire, and three years post-fire, late-growing and dormant season burns still had significantly reduced bluegrass cover. In the bluegrass lab experiment, we connected high heat dosages, found in early-growing season burns, with increased native and exotic cool-season grass mortality. Therefore, early-growing season burns meant to reduce bluegrass may also impact native plants dominant in the region. In the regional study, increasing bluegrass cover was correlated with decreasing plant species diversity and butterfly species richness. Obligate grassland butterflies, those that rely on grasslands, decreased in richness and abundance as bluegrass cover increased, including *Speyeria idalia* (regal fritillary). In general, increasing bluegrass cover was associated with the simplification of both plant and butterfly communities, likely reducing the provisioning of ecosystem services. Late-growing season burns may be the best option for decreasing bluegrass and increasing plant diversity longer, but conservation of certain butterfly species will require careful consideration of the spatial and temporal extent of prescribed fires. Ultimately, resource managers should consider restoring fire in rangelands to reduce bluegrass cover and benefit diversity at multiple trophic levels.

Relationship Between Canopy Cover and Forage Nutritive Value in Texas Coastal Prairies

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Huisache (*Acacia farnesiana*) and honey mesquite (*Prosopis glandulosa*) are leguminous trees that have become significant pests in the Gulf Coast Prairies and South Texas Plains eco-regions of Texas, spreading over millions of acres of rangeland. These leguminous species establish and invade quickly due to prolific seed production and their ability to resprout, and have become significant portions of the overstory canopy in many grazing pastures in the regions. However, little research has been conducted regarding the correlation between huisache and mesquite canopy cover and forage nutritive value. We have established an ongoing study at three different ranches in the coastal prairies of Texas, located in portions of Victoria, Refugio, Goliad, San Patricio, and Bee Counties. Total overstory canopy cover (by species) and bulk understory forage nutritive value were measured on ten 300-foot transects across the study area. We used the line intercept method to record canopy cover by species, and evaluated forage nutritive value by taking 10 forage samples at random from each transect line. We sent the forage samples to be analyzed using near infrared reflectance spectroscopy to determine crude protein (CP), digestible crude protein (DCP), total digestible nutrients (TDN), percentage of in-vitro true digestibility (IVTD), relative feed value (RFV), and phosphorus (P). We then used simple linear regression to test the relationship between these response variables and the following independent variables: huisache canopy cover, mesquite canopy cover, huisache + mesquite canopy cover, and total canopy cover. Crude protein (CP; R^2=0.32; p=0.0872) and DCP (R^2=0.31; p=0.0902) increased with total huisache + mesquite canopy cover, but other variables were not affected by any other canopy measure. Although huisache and mesquite are often considered pests in Gulf Coast rangelands, their presence might increase the nutritive value of understory forage.

Remotely Sensed Quantification of Ecosystem Site Potential Community Structure and Deviation in the Great Basin

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Semi-arid rangelands in the Northwest U.S. are impacted by a suite of change agents including fire, grazing, energy development, and climate variability to which native vegetation has low resilience and resistance. Assessing ecosystem condition in relation to these change agents is difficult due to a lack of a consistent and objective Site Potential (SP) community structure framework of the conditions biophysically possible at each site. Our objectives were to assess and quantify patterns in ecosystem condition, based on actual fractional component cover and a SP map and to evaluate drivers of change. We used long-term 90th percentile Landsat NDVI (Normalized Difference Vegetation Index) and biophysical variables to produce a map of SP. Ecosystem condition was assessed using two methods, first we integrated fractional components into an index which was regressed against SP. Regression confidence intervals were used to segment the study area into normal, over-, and under-performing relative to SP. Next, the relationships between SP and fractional component cover produced SP expected component cover, from which we mapped the actual cover deviation. Much of the study area is within the range of conditions expected by the SP model, but degraded conditions are more common than those above SP expectations. We found that shrub cover deviation is more positive at higher elevation, while herbaceous cover deviation has the opposite pattern, supporting the hypothesis that more resistant and resilient sites are less likely to change from the shrub dominated legacy. Another key finding was that regions with significant annual herbaceous invasions tend to have lower than expected bare ground and shrub cover.

Responding to Climate Impacts on Rangeland Systems: a Collaborative Partnership between the USDA Agricultural Research Service, USDA Climate Hubs, and Society for Range Management

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Research conducted by the USDA Agricultural Research Service (ARS) provides value both to the scientific community as well as to rangeland managers. The Society for Range Management (SRM), as one of the beneficiaries of ARS research investments and outcomes, is in an ideal position to synthesize, cultivate, and broaden the impact of ARS science for a broad and diverse rangeland management community. To facilitate this partnership, a pilot project was initiated in 2018 that linked SRM with the USDA Climate Hubs program, which delivers climate-smart, science-based data and information for regional audiences and which is jointly administered by ARS and the U.S. Forest Service. The partnership entailed a series of collaborations between SRM and individual Climate Hubs to synthesize scientific information and communicate it to land managers through materials relevant to region-specific rangeland management challenges under a varying and changing climate. One such collaborative activity, a response to the devastating Southern Plains wildfires of 2016-2018, serves as a useful case study of both the merits of this new ARS-Climate Hubs-SRM partnership as well as a worked example of how the links between science and land management communities can be strengthened.

Re-sprouting Shrub Encroachment in the Tallgrass Prairie: Assessing Various Prescribed Fire and Mechanical Management Strategies

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Shrub encroachment is a global issue. Consequences include decreased biodiversity, hydrological impacts, and reduced livestock productivity. Re-sprouting broadleaf shrub (RBS) species present an added challenge to land managers. This study examines the interactive effects of prescribed fire season, fire intensity, and various mechanical brush treatments on the vigor and survival of *Cornus drummondii* (CD). Key predictions were that CD subject to cutting followed by growing season fire and CD subject to highest intensity fire would exhibit least regrowth and highest mortality. The overarching goal of the study is to develop realistic, evidence-based management prescriptions suitable for immediate application. This study is being conducted at the Konza Prairie Biological Station (KPBS) near Manhattan, Kansas, USA. KPBS is in the Flint Hills of the tallgrass prairie and is subdivided into experimental watersheds, each with a specified fire and grazing regime. Two watersheds, R1A (spring burn) and SuB (summer burn), that are similar in topography, past land use, and community composition were selected for comparison. In each watershed, 40 shrub islands were located and were evenly and randomly assigned one of four mechanical treatments [cut and leave (CL), cut and remove (CR), 1:1 medium fuel addition (A), and control (C)]. Relative fire intensity was determined by proxy, using water evaporation from calorimeters placed within shrub islands. Plant responses were monitored using several response variables: CD and functional group abundance and percent cover within shrub islands, CD stem density, and overall CD biomass. Based on calorimeter data and initial post-fire measurements higher fire intensity has resulted in significantly reduced CD regrowth, cut and left shrubs had significantly higher intensity than other treatments, and spring fire had a significantly higher overall intensity than summer fire.

Restoration Management Influences Functional Composition Change in a Native Bee Community of Restored Tallgrass Prairie

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Ecological restorations that re-establish plant communities are assumed to benefit animal communities, which may re-colonize restored areas from the surrounding landscape. Recent work shows that plant-based restorations are successful at establishing bee diversity and abundance at levels that approach remnant habitats. However, the community assembly process by which bee species from a regional pool are sorted into restored habitats during colonization is not well understood. In existing restorations, understanding the site-level habitat associations of bee species can shed light on the past community assembly process and inform restoration practice. Bee species are expected to occur in sites with characteristics that match up with bee functional traits. In actively managed restorations, site characteristics are often determined by management actions. We used a multi-year dataset of bee specimens collected in a tallgrass prairie restoration to determine how functional traits mediate bee species' occurrence among a chronosequence of restored sites managed with prescribed fire and bison grazing. The functional composition of the native bee community, particularly with respect to nesting substrate, changed with time since a prescribed burn and with the presence/absence of bison. Soil nesting bees responded negatively to time since a burn, while stem nesting bees responded positively. However, the overall bee community abundance and richness responded to landscape context rather than management actions.

Restoration on the Edge, What's Working for Establishing and Managing Wet Prairie Plant Diversity

Dan Shaw, Minnesota Board of Water and Soil Resources, St.Paul, Minnesota

Restoring areas in and around wetlands and other aquatic systems has been a common practice in Minnesota, but success rates vary due to invasive species, extreme weather and a lack of management resources. The Minnesota Board of Water and Soil Resources has been working to document successful strategies through their "What’s Working Website". This presentation will focus on strategies that have been showing promise for managing invasive species and promoting plant diversity over time. Topics that will be covered include reed canary grass and cattail removal, seed mix design, wetland seeding, and long-term management strategies.

Restoration Systems and Costs for Conversion of Bermudagrass to Native Grasses in the Southern Great Plains

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Bermudagrass is an aggressively spreading warm season perennial grass that is a popular forage in the Southern United States due to its high yield potential, ease of management, and persistence. Production and nutritive value of bermudagrass are influenced by nitrogen fertilizer rate and often it is managed as a monoculture providing little wildlife value or species diversity. Managed correctly native grasses require lower inputs of herbicides and fertilizer compared to bermudagrass. Due to the invasive nature of bermudagrass, conversion to native grass is challenging and difficult. The objective of this study was to determine and compare the effectiveness and economics of six conversion systems designed to renovate established bermudagrass pastures to either a native monoculture or a mix of native grass species. Production data are available for six agronomic systems (three cover crop and three chemical fallow systems) from two agronomic experiments conducted in south-central Oklahoma. Enterprise budgeting was used to compute revenues, costs and net returns for each system. Data were analyzed as a randomized complete block design using a mixed ANOVA model. Tillage method (clean-till or no-till), grass type (monoculture or mixed species), and conversion system (n=6) were treated as fixed effects and year was treated as random. Based on a threshold stand establishment of at least 70%, systems that relied on clean-till practices were more (P=0.0019) successful over systems using no-till practices for monocultures and native mixes. The most (P=0.85) economical systems were the mixed grasses and monoculture systems that produced and sold three cover crops prior to clean-till establishing natives with net returns of \$75 and \$72 per acre, respectively.

Restoring Cheatgrass Invaded Areas with Herbicide and Activated Carbon

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Invasive annual grasses have quickly taken over large areas in the western US, reducing plant and animal diversity, increase disturbance, and costing the government millions of dollars in annual firefighting expenses. The only lasting restoration technique is to establish native plants that resist invasion, but restoration efforts have shown little success due to the competitive nature of invading plants. Control of annual grasses is requisite to allow restoration of native plants. Herbicide has proven effective at controlling cheatgrass, but removes the possibility of reseeding to restore native vegetation. Use of activated carbon has been used historically to absorb harmful chemicals, and could potentially be used as a seed coating to provide protection from herbicide effects for desired species. Use of furrows could also limit exposure to herbicide, as the sprayed soil is sideswept away from the planted seeds. We used a full factorial design to test the effects of herbicide, creation of furrow after spraying herbicide, and activated-carbon seed coatings on the establishment of a common perennial bunchgrass *Pseudoroegneria spicata*. Use of Imazapic, carbon seed coating, and a deep furrow (created after spraying of herbicide) allowed us to control invasive cheatgrass, and restore bluebunch wheatgrass. Use of furrows, when treated with herbicide did not increase cheatgrass cover. The integration of microsite improvement with deep furrows and the protective carbon seed coating gives land managers a chance to restore invaded landscapes.

Restoring Sagebrush in the Great Basin: Lessons Learned from the Sage-Success Project

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The once vast sea of sagebrush (*Artemisia* spp.) across the western US has been reduced and fragmented by agriculture, development, invasive species, and wildfire. Some species, as well as many western livelihoods, are dependent upon sagebrush. Thus, restoring this foundational species on public rangelands is a conservation priority. However, sagebrush is not an easy species to sow and grow, and re-establishing sagebrush on disturbed rangelands has proven difficult for resource agencies. To better understand where, when, and why sagebrush seedings and plantings are successful, we initiated the Sage-success Project. Between 2014 and 2017, we sampled 1,459 plots across 284 wildfires in the Great Basin capturing a range of treatment types, times since treatment, and environmental conditions. We found considerable interannual variability in the probability of sagebrush establishment. Preliminary results suggest that big sagebrush occurrence was most strongly associated with relatively cool temperatures and wet soils in the first spring after seeding. In particular, the amount of winter snowpack, but not total precipitation, helped explain the availability of spring soil moisture and restoration success. Variability in sagebrush reestablishment was also explained by soil characteristics, including soil moisture and temperature regimes, providing support for the resistance and resilience paradigm. We also found that the demography of recovering sagebrush populations plays an important role in recovery trajectories. For example, changes in the size structure of post-fire sagebrush populations alone may cause about 50% of the reseeded sagebrush populations to decline over time before (or instead of) reaching a stable population structure. Given the difficulty and uncertainty in sagebrush seeding, adaptive management strategies may include avoiding seeding at the onset of a drought cycle or mitigating effects of environmental variability through repeated seeding.

Rethinking Ecological Monitoring, Boundaries, and Conservation Goals in an Era of Global Change

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In this era of rapid global change, examples of historic ecological systems shifting or shrinking and novel systems appearing are on the rise. As such, it is becoming increasingly clear that assumptions of stationary ecological systems and management for the status quo are insufficient to meet conservation goals. To illustrate this point, we provide examples of continental and local ecological regime shifts (e.g., within North America, the Great Plains, and individual sites) across the past half century. We then discuss emerging methods for using new spatial metrics to identify early warnings of regime shifts, to search for signals outside of preconceived ecological boundaries, and to search for signals across scales. We then discuss options for revising conservation goals that account for the surprise and uncertainty inherent in complex adaptive systems such as rangelands.

Returning Grazing Animals to a Minnesota Prairie System: Politics, Science, and Beyond

Pete Bauman, SDSU Extension

Attendees in this session will hear from a host of individuals involved in the process of returning livestock to the Chippewa Prairie in southwest Minnesota. Chippewa Prairie is highly regarded as one of Minnesota's prairie gems. Historically privately owned, the majority of the Chippewa Prairie complex is owned and managed through a decades-old partnership of The Nature Conservancy and the MN Department of Natural Resources, among other organizations. In addition, many high-quality peripheral tracts remain in private ownership. Presenters will discuss the process, politics, science, implementation, and associated monitoring related to the reintroduction of livestock to this 4,000 acre-plus grassland through a modified patch burn-grazing system. Additionally, we will discuss issues of project goals, sponsor/donor expectations, neighborhood partnerships, public access, local politics, perceptions, infrastructure (fence and water) challenges, legalities, and associated monitoring of the project in relation to vegetation and wildlife.

Riparian Grazing Case Studies - Results from Sixteen Years of Monitoring

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Daniel Macon, University of California, Auburn, California
Rebecca Ozeran, University of California, Fresno, California
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In 2002, riparian sites across California were selected to implement long term monitoring to document changes in riparian habitat resulting from changes in management. On each site a 360 linear foot representative section of the riparian area was selected for monitoring, installing markers to ensure the same area is monitored each return trip. Six transects were placed 72 feet apart perpendicular to the stream. The length of the transects varied from site to site since encompassing part of the upland as well as the riparian area was more important than a standard set length of transects in order to document increasing or decreasing riparian width over time. Transect markers were installed to ensure the same area was examined at each return. A variety of assessments were conducted at each site to document the overall health of the area. USDA Forest Service's Greenline was implemented to document changes in vegetation, both herbaceous and woody. Visual assessments such as USDI Bureau of Land Management's Proper Functioning Condition and University of California Ag and Natural Resources' Riparian Health Assessment for Rangelands were utilized to document overall habitat and ability to transport water and sediments. Channel morphology was documented along the top and bottom transects. Canopy cover was recorded on each transect and habitat parameters were measured throughout the section. The last piece of information gathered was a management survey to document historic and current management of the area. Results from sixteen years of monitoring will be presented.

Riparian Grazing Management versus Serial Engineering

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The best waters in arid rangelands tend be on private property. Hay land and water for livestock enabled people to homestead or purchase land in the 1800s and early 1900s. Large ranches and even smaller parcels are sometimes in degraded condition because of past management when distribution of livestock concentrated near the source of livestock water. Plant health and riparian functions were most impacted by season long use. Some of these lands have been degraded by stream straightening or wetland “reclamation” that drained wetlands in the name of flood control or improved irrigation management. Others were incised and drained when plants were no longer able to resist excessive erosion and/or oxidation of soil organic matter and when flow paths were altered. Riparian plants, especially stabilizing species enable riparian areas to self-heal with more enlightened management that provides periods for recovery. Riparian grazing tools and strategies for better management can restore riparian functions and values. Fish and wildlife habitat, water storage through aquifer recharge, water quality, aesthetics, forage, flood amelioration, and other riparian services respond. However, land that is sold into smaller parcels attracts people living too close to wetlands and on floodplains. The half-life of flood memory allows those people to disremember past floods as they think flood control projects will protect them and build more infrastructure in the way of future floods. With each flood and especially where more property development concentrates flood waters and flood damage, there is more economic incentive to serially engineer rivers and streams. Serial engineering may slide through clearing and snagging, straightening meanders, agricultural levees, channelization, engineered levees, flood control reservoirs, and concrete that begets concrete to fight erosion from accelerated water velocity. This cyclic process destroys riparian functions and values, ecosystems services, and leads to excess cost. People sometimes destroy what they love.

Riparian Valley Bottom Delineation Model: Information for Planning, Monitoring and Assessments

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Riparian ecotones are important natural resources with high biological diversity. These ecosystems have specific settings with unique vegetation and soil characteristics which support irreplaceable values and multiple ecosystem functions. Riparian areas are transitional zones along waterways and wetlands. They function differently depending on the setting. The USDA Forest Service supported the development of a national context for delineating and quantifying riparian areas. The resulting information will support monitoring, planning, management, and policy decisions. Proper land management will provide sustained ecological condition and function of riparian areas. Flooding, nutrient management, land use and land cover change are important factors to consider in riparian areas. The Riparian Area Delineation Model (RBDM) v5.x was developed to define riparian areas across all Forest Service lands. The model uses a variable width valley approach and relies on freely available data. The Riparian Buffer Delineation model recognizes the dynamic and transitional nature of riparian areas by accounting for hydrologic, geomorphic and vegetation data as inputs. The Forest Service will use the information to assess resource conditions, applying a multi-scale approach. The model is being sought by national, state and other partners to support watershed assessments, flood zone identification and much more. Here we present for the first time, a national riparian areas base map in 1:100,000 scale and the associated modeling technique.

Risk Management using Computer Models and Community Based Rangeland Monitoring

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The 2014 National Climate Assessment reports that climate disruptions to livestock production in the US have been rising over recent decades, and that, over the next 25 years, the Northwest is likely to experience water-related challenges due to drought and changing snowmelt. The report identifies the need for “climate resilient technologies and management” to cope with the increased risks to productivity and sustainability faced by ranchers and other rangeland managers associated with these disruptions, including changes in forage availability associated with variable weather patterns. Working with a diverse group of stakeholders in Wallowa County, Oregon, including ranchers, US Forest Service managers, Nez Perce tribal members, and local non-profits, we are creating a rangeland assessment and monitoring system that integrates satellite data with place-based knowledge using computer models and a Community-Based Observing Network (CBON). We are investigating management concerns on US Forest Service grazing allotments and surrounding private rangelands while leveraging the diverse perspectives of our collaborators to improve the models and provide additional information. Our rangeland assessment and monitoring system employs one model to provide near-real time, 30, 60 and 90-day forage forecasts in response to weather and another to identify historical changes to rangeland habitats in responses to changes in weather, climate, and land use. CBON methods are used to enlist local knowledge to assess and improve model predictions and to identify and collect data about further risk factors. We report preliminary results from (1) accuracy assessments of the models’ predictions; (2) the CBON’s efforts to contextualize and collect data related to rangeland management in Wallowa County; and (3) qualitative analysis of barriers to using the system.

Science for Grass-Cast: A New Grassland Productivity Forecast for The Great Plains

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A team of researchers recently developed a new Grassland Productivity Forecast or "Grass-Cast" for ranchers in the Northern Great Plains region (Montana, Wyoming, Colorado, North Dakota, South Dakota, and Nebraska). Using long-term vegetation production data from several sites in the Great Plains, relationships were developed to estimate peak ANPP (aboveground net primary production at the end of July) from cumulative actual evapotranspiration water loss (iAET, from April 1 through July 31). Extending these relationships to counties where direct measurements of ANPP are not available, two steps were completed. First, the correlation between iAET and cumulative Normalized Difference Vegetation Index (iNDVI, from April 1 through July 31, using 17 years of MODIS data) was determined (R^2=0.86). Second, the correction between iNDVI and ANPP was found (R^2=0.65). Observed and simulated weather data are fed into an ecological model, DayCent, to estimate iAET, which is then translated into iNDVI, and then ANPP for each of three different growing-season precipitation scenarios: 1) above-average where the top 1/3 of the 1982-2017 years are used, 2) near-average, using the middle 1/3, and 3) below-average, using the bottom 1/3). Within each scenario, a county's ANPP is estimated multiple times and then compared to the county's 36-year average ANPP to determine a relative percent difference that is mapped for display (see http://grasscast.agsci.colostate.edu/). Grass-Cast maps are available in early May and updated every two weeks. These maps can be used to help inform early grazing season and marketing decisions, with updated maps informing adaptive grazing strategies. Grass-Cast will expand in its second season (2019) to the Southern Great Plains (Kansas, Oklahoma, Texas, and New Mexico).

Seamless In Season Forage Projections: A Component of the Rangeland Productivity Monitoring Service

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Estimating and monitoring annual productivity is a key component of range management throughout the world. It is a critical component of any risk management strategy because producers operate on thin margins and managers are challenged by changing conditions during the growing season. Here we discuss development and delivery of a freely available online service for monitoring rangeland production during the growing season. The projections include both the timing and magnitude of rangeland production with an associated prediction interval. Projections begin March 1 in the growing season and offer updates until the peak has been realized. Projections are developed using near real time remote sensing and climate information and are updated every two weeks for the entire northern Region of the USFS including Montana, northern Idaho, and South and North Dakota while future plans include expansion to all rangelands in the coterminous US. Data for the previous growing season can be downloaded here at https://www.lankstonconsulting.com/data-warehouse. These data are part of the larger Rangeland Production Monitoring Service RPMS (https://www.fs.fed.us/rmrs/projects/development-rangeland-production-monitoring-service-could-improve-rangeland-management) which is a freely available tool offering unprecedented geospatial intelligence for managers and producers alike. The RPMS offers seamless retrospective production data from 1984 to present day for the coterminous US as well as the projections discussed here.

Seeded Plant Community Dynamics in Space and Time after Wildfire in Sagebrush Steppe

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Restoration ecology aims to restore ecosystem resistance and resilience after landscape level disturbances; however, restoration treatments often fail due to multiple factors. Understanding how ecosystem restoration affects plant community composition and structure can shed light on factors determining short- and long-term treatment success. We assessed the effects of wildfire and seeding on plant community characteristics, as well as seedling and adult perennial bunchgrass growth and survival. Sites were located in two historic *Artemisia tridentata* ssp.*wyomingensis* (Wyoming big sagebrush) communities in the Great Basin, USA. Total foliar cover differed by site, year, and functional group; however, only perennial grasses, annual forbs and perennial forbs increased between years. Perennial bunchgrass foliar cover on both sites exceeded the 20% recommendation for reintroduction by the end of the second growing season. Species diversity and richness increased with time on both sites and richness differed by site. Spatial patterns reflected direct competitive interactions among seedlings, as well as between seedlings and adult bunchgrasses. Seedling bunchgrass year-one growth and probability of survival to year-two differed by species and was negatively correlated with increasing neighbor density. Year-two seedling size did not differ by species but was positively correlated with year-one size and was mediated by increasing neighbor density. Our study suggests that post-fire seeding can reestablish desired species and increase species diversity and richness within two years after fire. We observed changes in bunchgrass spatial relationships over time, with seedling only spacing becoming more dispersed and adult bunchgrasses exhibiting dispersive effects on seedlings. Additionally, surrounding neighbor density was the dominant factor limiting bunchgrass seedling growth and survival in the first two years; however, grass species differed in sensitivity to neighbor density. This aspect of density dependence should be accounted for when selecting potential restoration species and monitoring treatments over time.

Selection for Grazing Distribution, Difficulties and Opportunities

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Livestock distribution is a critical part of grazing management. Many concerns with cattle grazing on public lands are the result of undesirable distribution patterns. Practices such as water development, fence construction and herding can help increase uniformity of grazing, but capital expenses and labor costs prevent wide spread application of these tools. Our previous research suggested that selecting cows that preferred to graze steep slopes and areas far horizontally and vertically from water (hill climbers) and culling cows that use gentle terrain near water (bottom dwellers) would improve grazing uniformity across a pasture and reduce concentrated use of riparian areas. However, grazing distribution is a difficult trait to measure and use as a selection criteria. Cattle grazing patterns vary spatially because terrain and vegetation differ among pastures and ranches and temporally because of phenology, precipitation and climate. Culling cows with undesirable grazing patterns has the potential to improve uniformity of grazing and has the benefit of modifying behavior through nature (genetic selection) and nurture (teaching replacement heifers where to graze). However, little genetic progress can be made by culling cows, and the phenotypic information needed for selection requires the expense of GPS tracking collars and the time to process and analyze the data. Tracking data need to be evaluated with geographical information software (GIS) and assessing distribution is complicated because terrain use is multi-dimensional. However our previous study showed that terrain use was related to genetic markers that have the potential to be used to develop genomic breeding values. Potentially, DNA (blood) samples could be obtained by purebred and seedstock operations and used to rank bulls for the potential to sire daughters that are more willing to use rough terrain and areas far from water (hill climbers) at a reasonable cost and without the need to obtain and analyze tracking data.

Shrub Recruitment in Sonoran Grasslands: Grass Utilization is of Little Consequence to Intra-seasonal Precipitation Variation

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Shrub establishment is a critical first-step in the transformation of grasslands to shrublands. Shrub recruitment may vary with the timing, frequency, and amount of precipitation (PPT), with activities of seed/seedling predators, and with levels of grass utilization. Predictions of shrub recruitment therefore require knowledge of the relative strength of these factors and their interactions. Here, we ask, "How do PPT, ant/rodent herbivory, and livestock grazing interact to influence velvet mesquite (*Prosopis velutina*) recruitment in Sonoran Desert grasslands?" An Automated Rainfall Manipulation System (ARMS) was used to manipulate PPT, wherein 10 plots received +65% ambient PPT, 10 received -65% ambient PPT, and 10 received ambient PPT. Half of each plot was clipped to simulate heavy livestock grazing; the remaining half was unclipped. Exclusion treatments (None, Rodents, Ants, Rodents+Ants) were installed within each PPT x Grazing combination. Mesquite seeds were placed within each treatment combination in July 2017 and 2018. Recruitment (mean ± SE) was markedly lower in 2018 (14 ± 1.3%) than 2017 (50 ± 1.4%) even though total monsoonal PPT was comparable in both years (p=0.84), where the maximum number of consecutive days of rainfall in 2017 (16 days; 153 mm) exceeded that in 2018 (9 days; 38 mm). Higher recruitment in 2017 occurred despite both years having an almost equal number of rain days (2018=31; 2017=30). Recruitment and herbivory were lower (p<0.0003) under -65% conditions compared to +65% and ambient conditions in both years. Recruitment was lowest in areas accessible to both rodents and ants; grass clipping had no effect (2017, p=0.39; 2018, p=0.28). Our data demonstrate that shrub recruitment in desert grasslands may be highly sensitive to temporal intra-seasonal rainfall patterns and the abundance of native herbivores, and minimally affected by of levels of grass utilization.

Smart Energy Development: Tools to Inform Planning, Development, and Reclamation

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Smart energy development is a process where science is used to help land managers and policy-makers identify and avoid conflicts when making decisions about various aspects of the energy development life cycle. This process is particularly important when there are conflicting demands on limited natural resources, a need to be cost-effective, and a need for decisions across landscapes. Increased natural resource knowledge and new management tools, risk assessments, and scenario planning can help identify opportunities for energy development that minimize environmental concern while streamlining the planning and permitting process. The U.S. Geological Survey is working with Federal, State, and Industry partners to develop innovations in geospatial assessment and mapping of valued land and wildlife resources, the potential for energy development, and reclamation potential across the United States, with a current focus on western rangelands. Results of these efforts will enable managers and operators to use interactive geospatial analyses to plan for leasing and permitting, inform infrastructure placement, reduce impacts, and increase the likelihood of successful reclamation on cessation of operations. We will highlight how the new Smart Energy Development Tool and associated decision support framework will provide managers and operators with easily accessible information to facilitate planning, development, and reclamation.

Social-Ecological Assessment of Production Interventions for an Agro-pastoral System in Northern Namibia

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Production interventions for pastoralists or agro-pastoralists in Africa typically occur on a piece-meal basis. Projects may focus, for example, on improving livestock production, livestock marketing, rangeland management, or key infrastructure; efforts to build human or social capital can also occur. Rarely, however, are all such factors simultaneously tackled in a project. And rarer still are project outcomes assessed using research to validate project assumptions and reveal lessons learned. The Community Based Rangeland and Livestock Management (CBRLM) project in northern Namibia is such an endeavor. Funded by the Millennium Challenge Account (Namibia), a suite of development interventions were initiated in 2010 with evaluation completed by 2018. Major goals included improvement of household income and well-being, cattle productivity and offtake, and rangeland condition for an agro-pastoral society occurring near the Angolan border. Research approaches were founded on a randomized sampling design for 123 Grazing Areas (GAs), with 52 GAs receiving an intervention package consisting of community training along with selected production and management inputs. Another 71 GAs served as controls. Assessments included use of social surveys, cattle productivity indicators, and standard field assessments for rangeland vegetation and soils. Findings indicated diverse project effects along the social-ecological spectrum. Although the project had positive impacts on the use of collective action for implementing planned grazing schemes, the extent of such behavioral change was limited. For cattle, total sales, herd productivity, and live weights remained unchanged. Slightly worse rangeland outcomes occurred due to treatment, including decreases in cover for herbaceous plants and litter. There were no project effects on household income. Overall, the results indicate that some social aspects of the system are more malleable than most ecological aspects, but the time frame for analysis has indeed been limited. Implications of these findings for development policy and the future design of projects are reviewed.

Soil Carbon Under Different Grazing Practices Across the Northern Great Plains

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Could management of grazing lands be a tool for climate mitigation? Globally, grazing lands make up ~25% of total land area and ~20% of total soil organic carbon stores. Prior research suggests improved grazing management could further increase carbon storage. Yet there is considerable variability in soil carbon responses to management, making it unclear how and where improved management could increase carbon stocks. Here we assess soil carbon under different grazing practices – from intensive rotational grazing to continuous season-long grazing – across a rainfall gradient in the northern Great Plains. We used a space-for-time approach, where we identified nearby site pairs that had used contrasting grazing practices for at least 10 years. In summer 2018, we visited 28 sites across Montana, Wyoming, North Dakota, South Dakota, and Nebraska. Sites ranged in both mean annual temperature and precipitation from 4.4-8.8 °C and 259-609 mm. At each site, we sampled a representative pasture with relatively level topography and loamy soils (e.g., loam, silty loam, clay loam, etc.). We sampled soils for carbon concentration (total carbon % if <7.2 pH, organic carbon % if >7.2 pH), bulk density, texture, and pH and vegetation for percent cover of different plant functional groups and species richness. Finally, we characterized management practices using a survey of participating landowners. Across sites, carbon concentration varied over 20x (0.3%-7.3%). We present results from analyses on the impact of grazing practices on soil carbon content and stocks after accounting for variation in soil texture and climate. By sampling soil carbon under different grazing management practices on working ranches, this work will help identify the potential impact of management change on soil carbon stocks across climates in the northern Great Plains.

Soil Characteristics and Microbial Responses to Different Fire Intensities in a Woody Encroached Arid Savanna

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Southern Great Plains savannas are experiencing a compositional shift to greater dominance by resprouting woody shrubs. Recent experiments have recognized prescribed fire, conducted in extremely hot and dry conditions, as a potentially effective method to control undesirable woody plants. Quantitative changes in soil characteristics, particularly the microbial community, under different fire intensities are lacking in this region. In conjunction with a larger study examining the physiological responses of resprouting shrubs and grasses to varying fire intensities, we are investigating the effects of fire intensity on the soil physical, chemical, and biological properties in an arid savanna in west central Texas. Our experiment included control, low intensity fire, and high intensity fire plots (10 x 10 m). Low intensity plots had a continuous coverage of hay additions (60 kg). High intensity plots had hay additions as well as juniper cutting additions (200 kg). Soil samples (N=36) at a depth of 15 cm were collected before and immediately after the late summer prescribed burns. We measured the moisture content, relative water infiltration rate, aggregate stability, texture, bulk density, pH, total carbon (TC), and total nitrogen (TN). Amplicon sequencing and chloroform fumigation will be used to determine the composition and biomass of the soil microbial community, respectively. To assess the short- and long-term fire effects on the biotic and abiotic soil properties, data collection will continue 2, 8, and 12 months after the fires. We hypothesize that while high fire intensity may improve soil structure, the microbial biomass and diversity could decrease. Results from this study will give rangeland managers a better idea of how prescribed fires alter soil characteristics and microbial communities. These results will provide valuable insights into potential belowground consequences of using savanna restoration strategies promoting extreme, high intensity fires as a means of managing woody encroachment.

Soil Factors Affecting Density of *Agave lechuguilla* in the Northern Chihuahuan Desert, Mexico

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An important native plant from the Chihuahuan desert is lechuguilla (*Agave lechuguilla* Torr.), which is a small succulent composed of a rosette of thick, fibrous leaves. This plant has an important economic value for some inhabitants from the Chihuahuan desert. Despite the importance of this species, there is a lack of information about how this plant is affected by different soil factors. In desert communities, important factors accounting for the abundance of some plant species are the depth of the soil, percentage of bare soil, and the amount of precipitation received in the summer. Precipitation would facilitate plant establishment, deeper soils are associated with deeper available moisture, and bare soil may indicate reduced competition. The aim of this study was to determine the most influential soil factor associated with the density of lechuguilla in the northern Chihuahuan desert in Mexico after accounting for summer precipitation. We tested the hypothesis that the total density of lechuguilla would be higher in deeper soils, and higher in deeper soils with higher percentage of bare soil. To test this hypothesis, we sampled 11 sites among three states in Mexico (Chihuahua, Coahuila, Durango) that cover 80% of lechuguilla distribution in the Chihuahuan desert in Mexico. The relationship between the total density of lechuguilla, depth of the soil, and percentage of bare soil while controlling for summer precipitation, were tested with a drop-in-deviance test using a Negative Binomial Generalized Linear Model. Results indicate that for every 10 cm increase in the average soil depth, the total density of lechuguilla is estimated to increase by 21%. Percentage of bare soil wasn't found to be correlated to the density of lechuguilla under the evaluated conditions. Results present important information for lechuguilla management and soil conservation strategies in the northern Chihuahuan desert.

Soil Health Evaluation in Three Texas Rangelands

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How do different grazing management systems affect soil health? To address this question, the USDA Natural Resources Conservation Service, Sustainable Rangelands Roundtable, and Noble Research Institute evaluated a suite of soil health indicators, and interrelationships with vegetation, under three different grazing management systems in northcentral Texas. Soil samples (0-15cm) were collected in April 2017 from ranches with three different grazing management systems: Ranch 1 (HSHF): high stocking rate and rotation frequency, Ranch 2 (MSMF): medium stocking rate and rotation frequency, and Ranch 3 (LSCG): low stocking rate with continuous grazing. Sampling sites were selected using soil maps and expert knowledge to identify locations with similar soil type, landscape position, and climate. Soil samples were shipped within 48 hours to Cornell Soil Health Lab for the Comprehensive Assessment for Soil Health (CASH), University of Missouri for microbial community composition using phospholipid fatty acid profiling, and, Dr. Haney's lab in Temple, TX for the Soil Health Tool (SHT) Index. Plant community composition, diversity, and production potential were measured along each transect at the same time soil samples were collected. In general, measured soil health differences (SOM, WHC, WEON) were slightly greater in MSMF system compared to LSCG system. Although sampling locations targeted similar soil types, clay content was an important covariate, indicating adjustments for this variable were necessary for proper interpretation of SOM and WHC. SOM and aggregate stability measures were decoupled from each other with the highest SOM ranch having the lowest aggregate stability score. From a soil health perspective, all three ranches exhibited effects of sound grazing management, with only subtle differences in a few soil health indicators; none of the ranches were in a degraded condition. Analyses to explore economic differences and relationships among vegetation data and soil microbial community composition information using molecular tools are pending.

Soil Hydrologic Function Associated with Kentucky Bluegrass Thatch and its Removal

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Kentucky bluegrass (KBG) dominance as a result of idle management results in development of dense thatch, consisting of soil-bound roots and overlaying leaf litter. We suspect that the development of thatch influences the soil hydrologic function, specifically on the soil's ability to capture and store water. We conducted field observations on pastures at the Central Grasslands Research and Extension Center (Streeter, ND) that are subject to management strategies targeting KBG control with fire and grazing. We located sites where fire and grazing have been excluded and KBG and thatch dominate, and sites treated with fire in the spring of 2017 followed by season-long cattle grazing with a moderate stocking rate. At each site, we simulated rainfall events to observe infiltration and surface runoff rates, and we installed soil water content sensors at 5 and 15 cm depths to observe continuous hydrologic dynamics. We observed that hydrology was variable across these conditions, but generally, infiltration rates were higher and runoff rates were lower in sites with KBG dominance and thatch compared to the sites treated with fire and grazing. Thus, more water entered the soil and percolated to deeper depths in the sites dominated by KBG, while the treated sites displayed less capture and shallow storage after a rainfall event. These patterns were supported by the sensor readings, which showed that soils with KBG and thatch experienced larger and deeper fluctuations in water content, with longer and more gradual soil drying after a rain event, compared to the treated sites. These differences imply that KBG and thatch enhance water capture and storage, perhaps providing a positive feedback mechanism supporting KBG growth and dominance. Our observations indicate that thatch is altering the microclimatology of the prairie soil and near-surface, which may in turn affect soil biology, decomposition, and other soil functions.

Soil Nutrient and Microbial Response to Kentucky Bluegrass Invasion and Land Management Techniques

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Kentucky bluegrass (*Poa pratensis* L.) is a non-native perennial grass that has become naturalized throughout the entire United States. This species is an effective competitor and produces abundant litter, which in turn creates a thick thatch layer of living and dead plant material between the soil surface and the plant canopy. In the Northern Great Plains, disturbances such as fire and grazing are being explored as tools to reduce this thatch layer and promote native grass and forb species. The overall objective of this research is to examine below-ground characteristics under accumulated thatch and in response to management with fire and grazing. This project was conducted in the Missouri Coteau mixed-grass prairie region of south-central North Dakota, USA, where Kentucky bluegrass has become the dominant plant species. We hypothesized that the dominance of Kentucky bluegrass and development of thatch strongly influences the soil microclimate and the nature of organic matter inputs, which affects nutrient and microbial dynamics. Soil samples were collected from sites dominated by Kentucky bluegrass with thatch, and from sites one year after management with fire and season-long grazing, where native plant communities had recovered. To understand immediate and in-season effects of fire and grazing on soil properties, we also sampled soil immediately before, and at increasing time steps after spring fires and exposure to grazing aimed to reduce the thatch layer. Soils were analyzed for carbon and nitrogen fractions, microbial abundance and community structure, and decomposition rates. Our observations indicate that the combination of fire and grazing is effective at removing thatch and altering the soil microclimate, though the response of the vegetation community following management is variable. We expect that these results will help us understand consequences of Kentucky bluegrass dominance on fundamental soil processes, and how native prairie management approaches can effectively restore ecosystem function.

Spatial Bibliography of Rangeland Resources using ArcGIS Online

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Information on the science and management of rangeland resources is often made available through published literature that includes journal articles, government documents, agency reports, and books. However, locating all available sources specific to a desired subject using standard web search engines can be challenging. Additionally, the spatial location representing the origin of that information is typically not provided at first glance. The purpose of this project is to develop a comprehensive bibliography specific to rangeland resource subjects that provides source information and the geographic location for each reference. We searched all available published literature for three subjects (quaking aspen, greater sage-grouse, free-roaming horses) and recorded the reference information for individual documents. This included the title, author(s), publication year, publication type, page numbers, its URL location, and the geographic coordinate location for each. Using ESRI ArcGIS Online, we were able to develop a geospatial library that provides a suite of query tools which facilitates the search of target information using key title or subject words, dates, and spatial location (see spatial bibliography at ghal.byu.edu). This resource can be used to improve the efficiency and effectiveness of locating desired information from a wide range of available sources. It can also be used to identify areas that have the highest literature availability across both space and time.

Spatial Interpolation Comparison of Ranch-Scale Rain Gauges to a National Rainfall Network

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National rainfall datasets have limited coverage on rural rangelands in Arizona. This lack of rain gauges adds a major challenge to decision-making for livestock allotments. Drought is often a constant concern for livestock producers because it can significantly affect the rangeland resources producers rely on to continue their operations. Due to precipitation being highly spatially and temporally variable and the large geographical area of livestock allotments, it can be impractical to use the national precipitation dataset estimations on a ranch-scale. The University of Arizona Cooperative Extension rangeland monitoring program, Reading the Range, has placed rain gauges at many of its key areas in an effort to better understand ranch-scale rainfall patterns on allotments that are underserved by the national datasets. Spatial interpolation is a useful tool for estimating rainfall patterns in areas between rain gauges. Through the use of the ArcGIS inverse distance weighted (IDW) interpolation tool, it is possible to calculate a simple gradient of rainfall over a large area which could not be feasibly measured otherwise. The local rain gauge IDW interpolation is compared with the national precipitation estimates to further refine the accuracy. The resulting geostatistical model can help land managers and land users working with Reading the Range to visually understand local climate irregularities so they can make more informed decisions.

Spatial Targeting and Seed Mix Design: Decision Modeling to Support Pollinator Conservation

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There is increasing recognition that conservation and habitat management designed to support bees is needed for both intrinsic and economic values. Intrinsically, the list of bees that are threatened or endangered is growing. Economically, many specialty crops benefit from pollination services of wild bees. Funds for bee management and conservation, however, are limited so there is a need for cost-effective actions while addressing two linked decisions: 1) where is the best place to target for habitat enhancement? 2) what plants should be planted to support bees? We will address these questions through a cost-benefit assessment that combines models that represent our best ecological understanding with decision analysis. Specifically, we use a spatially-explicit model of wild bee habitat with knowledge of habitat preferences and pollinator dependent crops to illustrate where pollinator enhancements would pay off. We then illustrate how to integrate information on plant-pollinator networks with seed costs to design optimal seed mixes for bees. Overall, our framework can be used to provide landscape-specific recommendations and help design seed mixes that account for costs and benefits of wild bees.

Spatially Explicit State and Transition Model Maps for Landscape Scale Management and Restoration

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Disturbance and management decisions on western landscapes occur at a scale far larger than ecological site mapping. Disturbance response groups aggregate ecological sites based upon disturbance ecology, and allow for common state and transition models to be utilized across landscapes. Soil and plant community information was gathered from northern Nevada, where dominant ecological site and related soil differs from minor components in a binary fashion. Loamy and Claypan ecological sites, respectively, vary along an elevation and precipitation gradient through 8”-10”, 10”-12” and 12”-14” precipitation zones. Spatial statistics and water deficit modeling from areas identified during field surveys are utilized to model soil component extent. State and Transition models appropriate to soil component are applied to continuous vegetation mapping derived through remote sensing. Vegetation sampling methods will also be compared to provide a locally accurate relationship between point line intercept, continuous line intercept (for shrub species), Daubenmire and ground based vertical imagery (GBVI) as provided by Open Range Consulting (ORC). ORC has successfully utilized GBVI as training datasets to create land cover maps at a landscape scale. If a relationship is established between traditional plot scale vegetation metrics and GBVI, then existing plot scale vegetation quantification datasets would be able to inform landscape scale cover maps significantly enhancing utility to land managers. This combined with enhanced ecological site maps and appropriate state and transition models as described above could provide a powerful landscape scale management tool. Preliminary data will be presented and methods outlined in greater detail.

Spatiotemporal Patterns of Cheatgrass (*Bromus tectorum*) Die-off in Northern Nevada

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The fast-growing winter annual cheatgrass (*Bromus tectorum*) is invasive and nearly ubiquitous in rangelands across the American Intermountain West. Invaded areas experience dramatically altered fire regimes, reduced biodiversity, and a loss of ecosystem services and function. While cost-effective control of cheatgrass is difficult to achieve, the phenomenon of cheatgrass die-off may provide an unexplored restoration opportunity. In die-offs, patches of cheatgrass fail to emerge despite adequate climatic conditions, with stark boundaries separating areas of remnant litter from dense, healthy cheatgrass. We use remote sensing methods to identify the locations of die-offs in a north-central Nevada study area with approximately 17,500 km^2 of rangeland. Mapped die-off reveals strong spatiotemporal variation in die-off expression. Die-off may be frequent in one valley and rare in the next, or widespread in some years while exceedingly rare in others. We investigate the question of what produces this wide variation by identifying environmental conditions that influence die-off. We use climatic, topographic, and edaphic factors to model die-off frequency from 1984-2018 using boosted regression trees. After removing highly correlated and low-influence variables, we assess the relative influence of retained variables. Climate (maximum, mean, and minimum annual temperature, spring snowmelt, and cumulative climatic water deficit) account for 67.7% of the final model influence, with topography (heatload and slope) and edaphic variables (soil water content) contributing 17.4% and 14.8% relative influence, respectively. The observed patterns imply a complex and largely climatic environmental influence on the die-off mechanism, with a multi-seasonal syndrome of climate conditions interacting with the disease organisms to create die-off. The resulting model provides predictions of areas where die-off is likely to occur in the future based on environmental data. Along with the die-off detection from satellite imagery, these tools can help efficiently target efforts to restore degraded rangeland.

Spectral Behavior and Spectral Indexes of Vegetation of Two Fragments of Natural Pastures

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The objective of this this study was to verify the spectral behavior and application of spectral indexes of vegetation of two fragments of natural pastures located in Taua (CE), during the dry and rainy season of 2018. To obtain the map, the area was delimited through control points, which were identified and georeferenced with a Garmin etrex-10 navigation GPS. The images of the sentinel-2 satellite were used through the bands B2 (Blue), B3 (green), B4 (red), and B8 (near infrared) of the MSI multispectral sensor, with images representing the rainy season (May) and dry period (September) of 2018. Atmospheric correction of the images was performed from the SCP routine (Semi-Automatic Classification Plugin) of the QGIS free software (version 2.18). The bands 4 (red) and 8 (near infrared) were used to calculate the indexes' means using the following equations: NDVI = (B8-B4)/(B8+B4) and SAVI = (1+L)*(B8-B4)/(B8+B4+L), where L is the soil adjustment factor (0.5). The conserved pasture presented a spectral response of the band B2 of 6.7% (dry) and 4.5% (rainy), while for the B4 band it presented a reflectance of 13.1% (dry) and 7.9% (rainy), and the preserved pasture presented higher values for NDVI and SAVI (0.50 and 0.38, respectively) in comparison to the thinned pasture (0.43 and 0.35), in the evaluation performed during the rainy season. The lower values of SAVI in the rainy season can be explained by the presence of the soil adjustment factor (L), which, considering soil exposure, generates a lower final value when compared to NDVI. This happens because the vegetation is rich in photosynthetic pigments, which are mainly found in photosynthetically active leaves and these are the ones that absorb the energy, reducing the reflectance.

Standardized Landscape Scale Vegetation Monitoring Using Multi-Spectral Imaging: A New Approach to Adaptive Management

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Quivira National Wildlife Refuge KS, USA partnered with Fort Hays State University to begin a collaborative research project that investigated a long-term monitoring protocol guided by the comprehensive conservation plan for the refuge. The plan identified specific avian taxa underrepresented in management impact assessments on the property, and surveys were established to monitor interactions between grassland breeding bird and vegetation communities. Sixteen point count surveys were conducted 18 May to 13 July 2017 for 122 observation points across four transects, and 17 vegetation variables were measured at each observation point in June 2017. Multi-spectral imagery was obtained during that same time period from GeoEye-1 satellite operated by Satellite Imaging Corporation to compare the 17 vegetation variables with remotely sensed vegetation data. Reflectance signatures of five unique vegetation classes were used to generate five cover types by using supervised Maximum Likelihood Classification in ArcGIS. Single-season occupancy modeling using traditional and remote-sensed vegetation variables/cover types as covariates was performed for five species of grassland birds amenable to advanced occupancy analysis. Covariates derived from multi-spectral imagery consistently performed equal to or better than comparable on-the-ground assessment covariates for four of the five species. The classification technique was then applied to multi-spectral imagery of proposed wilderness area at Crescent Lake National Wildlife Refuge in NE, USA captured June 2018 to assess translatability of the methods. Five habitat classes sensitive to vegetative productivity and exposed bare ground were identified that could be reassessed on an annual basis to determine vegetation changes across the 9,915-hectare proposed wilderness area. These annual assessments promote an adaptive management approach to plant community dynamics and how they may influence the avian fauna on federal properties.

Statewide Monitoring of Bee Communities across North Dakota

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Native pollinator services are essential to global food security and the stability of native prairie ecosystems. Yet, increasing pressures from human activities have led to a global decline in bee populations that threaten their contributions to both agricultural and natural systems. Monitoring studies have allowed researchers to detect rapidly declining populations by comparing historical to present data. However, the status of pollinator populations is still relatively unknown in many regions due to a lack of baseline data. The Northern Great Plains is among such regions that would undoubtedly benefit from increased native pollinator monitoring as the diversity and distribution of pollinator species across the region is relatively undetermined. Moreover, several species considered for federal listing also have distributions that may intersect the region giving further demand for spatially robust information regarding the status of pollinator species. We initiated a four-year survey of North Dakota pollinators to address the lack of current data on bee species across the state. We surveyed bee communities and their floral resources in each North Dakota county (53 total counties) at three separate grassland-dominated locations, twice per year, totaling 636 surveys annually. We incorporate both active netting surveys and passive sampling through bee bowls to sample communities more representatively. In 2017, we collected 10,330 bee specimens representing 187 species and are currently processing specimens captured in 2018. Our spatially extensive survey will represent bee communities from the diverse assemblage of rangelands within the region and will provide baseline information on the distribution of bee species required for future conservation planning.

Status of Range Grasses and Seasonal Availability from the Thal Desert, Punjab, Pakistan

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This study was carried out to evaluate the status of range grasses, palatability and availability in the Thal desert rangeland located in the Punjab, Pakistan. This is a hot and semiarid tract characterized by high temperature and scanty rainfall. This rangeland feeds four domesticated species (camel, cow, goat, and sheep). In all, 62 range grasses and sedges were recognized as the livestock feed of the area. Some of the highly palatable grasses and sedges such as *Cenchrus ciliaris*, *C. setigerus*, *Cyperus rotundus*, *Dactyloctenium aegyptium*, *D. aristatus*, *Lasiurus sindicus*, *Ochthochloa compressa*, *Setaria pumila* and *Tragus roxburghii* were found 1st rank grasses which were seasonally available to feed the livestock. This paper will highlight seasonal availability, palatability and animal preference of range grasses of this desert rangeland.

Stocking Density Effect on Aboveground Plant Production and Soil Properties on Nebraska Sandhills Meadow

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Ultrahigh stocking density (a.k.a., mob grazing) has been proposed as a management tool that will result in greater aboveground plant production and increased soil organic carbon content. However, much of the information about mob grazing is anecdotal. Even grazing distribution and complete trampling of aboveground plant mass are reported to increase nutrient cycling and increase plant production. The study objective was to determine grazing treatment, haying, or defoliation exclusion effects on aboveground plant production and soil properties. In 2010, 25 ha of Sandhills meadow dominated by perennial, cool-season grasses were divided into two replications of three grazing treatments and the hay and control treatments in a randomized complete block design. Grazing treatments were a 120-pasture rotation with one grazing cycle (mob), a 4-pasture rotation with one cycle (4PR1), and a 4-pasture rotation with two cycles (4PR2) and at stocking densities of 225,000 $kg \cdot ha^{-1}$, 7,000 $kg \cdot ha^{-1}$, and 5,000 $kg \cdot ha^{-1}$, respectively. The treatment pastures were stocked by yearling steers (365 kg) at 7.4 $AUM \cdot ha^{-1}$ from May to August in 2010 to 2017. Hay fields were harvested annually in mid-July but clipping data was only collected in 2010, 2011, 2017, and 2018. The control plots were not defoliated over the eight years of the study. Aboveground plant biomass was clipped at ground level in annually established cages within each experimental unit in mid-August of each year. Soil cores were taken at 0-10 cm and 10-20 cm depths in each experimental unit. Aboveground plant production did not differ among grazing and hay treatments but was greater for the grazed treatments than control in four years (2013-2015 and 2018). Soil carbon and carbon:nitrogen did not differ among treatments over the course of the study. We concluded that stocking density was not a major driver of plant production and soil carbon on Sandhills meadows.

Summary of Prescribed Burning/Grazing Impacts on Kentucky Bluegrass in Kansas

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Prescribed burning has been studied intensively for many years in the tallgrass prairie of Kansas. The Kansas Agricultural Experiment Station began a series of studies in 1918 to compare the impacts of spring burning on soil temperature, forage yield, and plant composition. Kentucky bluegrass (*Poa pratensis*) increased dramatically on the unburned plots. A long-term study was initiated in 1928 to compare the effect of time of burning. The dates compared were winter (December 1), early spring (March 20), mid-spring (April 10), late-spring (May 1), and unburned. Kentucky bluegrass was reduced by all dates of burning in this study making up less than 1% of the composition with about 14% on unburned plots. More recent studies on the Konza Prairie Biological Station have indicated less than 0.4% Kentucky bluegrass cover on ungrazed watersheds burned in November, February, and April. Summer burns have also decreased Kentucky bluegrass cover with plant frequency reduced more on uplands than on lowland sites. A 17-year study near Manhattan, KS compared vegetation response on unburned pastures with those burned on March 20, April 10, and May 1. All pastures were grazed season-long at 5 acres/animal unit. All burning dates reduced Kentucky bluegrass basal cover. The average composition of Kentucky bluegrass on season-long grazed burned and unburned pasture was 3 and 28%, respectively, after 28 years of treatment. Intensive-early stocking decreases Kentucky bluegrass composition when compared to season-long grazing. More complete burning with intensive-early stocking results in greater Kentucky bluegrass mortality. Increasing stocking rates with intensive-early stocking to three times the season-long rate or grazing cows at higher stock densities will also allow Kentucky bluegrass to increase. This is likely due to reduced fire intensity associated with lower fuel loads.

Switchgrass Grazing Management in an Integrated Crop Livestock System

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In eastern Nebraska, corn (*Zea mays* L.) followed by soybean (*Glycine ma*x) is the most common cropping system. Marginally-productive land formerly in pasture has been converted to corn and soybean production due to high commodity prices over the past decade. However, producers are now looking for opportunities to improve revenue because of current low commodity prices. Integrating livestock and perennial pasture into grain cropping systems could help increase revenue while increasing long-term economic and environmental sustainability. Our objective was to develop a model integrated crop-livestock production system for eastern Nebraska. In 2014, on marginally productive land, a 20-ha demonstration site was established, including 4-ha of 'Newell' smooth bromegrass (*Bromus inermis* Leyss.), 4-ha of 'Shawnee' switchgrass (*Panicum virgatum* L.), 4-ha of 'Liberty' switchgrass, and 8-ha of corn near Mead, NE. All perennial grasses were harvested for hay in 2016. Pastures were grazed by 18 cross-bred yearling steers. In 2017, the grazing rotation was smooth bromegrass (May 18-June 8), Liberty switchgrass (June 13-June 20), Shawnee switchgrass (June 20-Sept. 1), and smooth bromegrass (Sept. 7-Oct. 6). Triticale (x*Triticosecale*) was planted after corn harvest for grazing as a forage double crop in early spring, but failed due to late planting, poor autumn precipitation and spring growing conditions. In 2018, grazing began with smooth bromegrass (May 2-June 1), then the herd was split to graze the Shawnee (9 steers) and Liberty (9 steers) switchgrass (June 11-August 29), then the herd was combined and returned to the smooth bromegrass (Sept.5-Sept. 18). Cornstalks were also grazed in 2018 beginning Sept.26 for approximately 30 days. Field-scale hay yields, livestock gains, crop yields, and greenhouse gas measurements will be reported. Of specific interest is differences in livestock gain and forage quality between the two switchgrass varieties. The system demonstrates a climate resilient crop-livestock-bioenergy production system for eastern Nebraska.

Synchronizing Conservation to Seasonal Wetland Hydrology and Waterbird Migration in Semi-Arid Landscapes

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In semi-arid ecosystems timing and availability of water is a key uncertainty associated with conservation of wetland-dependent wildlife. Wetlands compose only 1-3% of these landscapes; however, large populations of migratory waterbirds rely on wetlands to support energetically demanding life-history events such as breeding and migration. Migration is considered a crucial period for birds associated with individual survival and reproductive success, yet our understanding of migration ecology remains limited. To quantify synchrony of wetland availability and waterbird migration, we reconstructed bi-monthly surface water patterns from 1984-2015 across North America's semi-arid Great Basin and linked results to seasonal waterfowl migration. Seasonal patterns were used in landscape planning simulations to assess conservation efficiency that aligned temporally sensitive wetland flooding and species migration. Wetland data were combined with ownership to evaluate periodicity in waterfowl reliance on public and private lands. We found migration chronologies misaligned with wetland flooding. In spring half (43-59%) to three-quarters (68-74%) of wetlands were flooded and available to early- and late-migrating species while seasonal drying restricted flooding to 13-20% of sites during fall migration. Simulations showed wetland conservation inconsiderate of temporal availability were only 67-75% efficient in meeting habitat goals on private lands that made up ~70% of wetland availability in spring. Private-public wetland availability was equivalent during fall migration. Accounting for temporal uncertainty linked to seasonal wetland availability and waterfowl migration can assure conservation outcomes translate to population benefits. Timing of public-private wetland availability, demonstrated by our models, provides landscape context that emphasized a joint role in supporting waterfowl habitat. Integrated management scenarios may capitalize on public lands flexibility for fall flooding to offset private lands drying while targeted incentive based conservation assures private wetland availability in spring. Such scenarios illustrate a departure from traditional public-private wetlands management, but represent a forward-looking alternative to forecasts of increasing water scarcity.

Targeted Fungicide Seed Coatings Improve Seedling Recruitment

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Seeding is a prevalent management tool used in the restoration of dryland systems; however, these environments characteristically experience low seedling establishment. Seed treatments commonly used in the agricultural industry to protect against pathogenic fungi may have the potential to improve seeding success in dryland restoration. We evaluated the efficacy of our targeted fungicide formulation to maintain seed viability and increase spring seedling emergence of fall-sown seed. We selected *Pseudoroegneria spicata* (bluebunch wheatgrass) as our model species, a drought-tolerant bunchgrass commonly used in North American dryland restoration seeding projects. We applied a fungicide mix to *P. spicata*, formulated to control for six seed-borne pathogenic fungi associated with this native bunchgrass and other common soil-borne fungal pathogens. Seeds were sown at five degraded big sagebrush ecological sites across the Great Basin, U.S.A. At all Great Basin sites, seed treated with fungicide maintained viability longer and increased germination by 1.4-fold over untreated seed. Emergence of fungicide-treated seed outperformed untreated seed by a factor of 1.5-3.2 at four of the five study sites; conversely, untreated seed at one site had 2.5 times greater seedling emergence than treated seed. Fungicide seed treatments appear to have the potential to overcome the barriers to successful restoration caused by fungal pathogen attacks; however, variations in microbe communities, soil properties, and site microclimate may impact the effectiveness of fungicide seed treatments. Our research needs to be repeated over a broader range of environmental conditions to fully understand the utility and limitations of a fungicide seed treatment.

Targeted Grazing of Kentucky Bluegrass as a Restoration Practice

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Kentucky bluegrass (*Poa pratensis* L.) has increased rapidly on North Dakota grasslands in a relatively short time period. Kentucky bluegrass starts growth earlier in the spring than many native cool-season grasses in the region potentially providing a time frame to apply targeted grazing. A five-year study (2008-2013) was initiated in Mandan, North Dakota to evaluate whether early spring grazing could reduce Kentucky bluegrass. Ten cow-calf pairs or pregnant cows grazed 3-ha paddocks in early spring (EARLY) when adequate forage was available for at least one week of grazing and continued until 30% of the native species were grazed. After June 1st, five cow-calf pairs grazed 3-ha paddocks (LATE) for twice as long as the EARLY treatment. Biomass was collected using cages and 100 10-point frames were taken annually to determine percent native grass, Kentucky bluegrass, *Bromus inermis* Leyss. (smooth bromegrass), native forbs and introduced forbs composition. After five years, native grass abundance in the EARLY paddocks was 26% greater than in the LATE paddocks. Kentucky bluegrass abundance only differed in 2010 when the EARLY paddocks had 32% less Kentucky bluegrass than the LATE paddocks. Total biomass was greater in the EARLY paddocks than LATE paddocks in 2010 (886 ± 74 $g \cdot m^{-2}$ vs. 608 ± 28 $g \cdot m^{-2}$ for EARLY and LATE, respectively). Targeted grazing by cattle in early spring can increase native grass abundance and may decrease abundance of Kentucky bluegrass. Early spring targeted grazing could be used as a tool in adaptive management programs focusing on Kentucky bluegrass reduction.

Tebuthiuron as a Tool to Restore Ecohydrologic Function in a Shrub-Encroached Semi-Arid Grassland

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The herbicide tebuthiuron has been utilized extensively to combat shrub encroachment in degraded rangelands in the southwestern U.S. We examined the medium-term (5 yr post-treatment) ecohydrologic effects of a tebuthiuron application in a semi-arid shrub-encroached grassland in southern Arizona. To investigate rainsplash and sheetflow erosion processes, small plot (0.5 m^2) rainfall simulations (n=41) were completed in a tebuthiuron-treated, grassland ecological state and an adjacent untreated, shrub-dominated ecological state. Infiltration, runoff, and sediment yield were measured during successive 45-minute rainfall simulations at 64, 102, and 120 mm/hr rainfall intensities. Our research found significant differences in foliar cover between the treatment and the control. Grass foliar cover was more than 5-fold that of the control. Shrub foliar cover was <1% in the treatment and 47% in the control. Preliminary rainfall simulation results show a divergent runoff response most prominently at the 102 mm/hr rainfall intensity. 65% of the treated plots had runoff at 102 mm/hr as compared to 100% of the untreated plots. Interspaces within the shrub state were the most likely to runoff at the lowest rainfall intensity (40% of plots). Infilling of these interspaces with a mixture of both non-native and native perennial grasses appears to promote infiltration and decrease runoff. The significant increase in grass cover and the corresponding decrease in shrub cover suggests tebuthiuron can facilitate a transition to a grass state from a degraded shrub state. This conversion appears to result in a shift from abiotic-driven hydrologic processes back to resource-conserving and vegetation-regulated hydrologic processes at the plot-scale.

Tending the Tallgrass Prairie: An Adaptive Management Case Study

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Adaptive management (AM) is widely recommended as an approach for learning to improve resource management, but natural resource managers unfamiliar with the process often remain skeptical. Therefore, documented examples of AM being applied on the ground are scarce. We used AM to make management recommendations for native tallgrass prairie plant communities in western Minnesota and eastern North and South Dakota, USA. Much of the native prairie managed by conservation organizations in the region is extensively invaded by undesirable plants; particularly problematic are cool-season introduced grasses (e.g., smooth brome *Bromus inermis*, Kentucky bluegrass *Poa pratensis*) and woody plants. Our collaborative, multi-agency AM effort is intended to provide reliable, robust information on the effects of grassland management tools and frequency of management on prairie composition, particularly how to reduce invasive species without harming the native floristic diversity. Our approach to AM employs Bayesian updating to generate management recommendations. This has allowed annual updates to model weights, providing the earliest possible information to managers; a classical statistical approach, in contrast, would have required waiting to accumulate robust data before providing recommendations to managers. In addition to 10 years of monitoring and learning, we now have a data set that can be used to supplement what we have learned through AM. We used logistic regression to evaluate the actions which lead to attaining management goals. We report on whether the condition of our prairies is improving with management and which management actions and frequency of management actions are allowing improvement. After 10 years of monitoring, we still have low sample sizes in some 'states' and we recommend continued learning through AM to ensure that our management continues to be effective, efficient, and is adapting to changing conditions.

Teosinte: A Novel Weed for Animal Feeding and Producing High Yielding Resistant Maize Varieties

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Teosinte (*Euchlaena mexicana*) the progenitor of maize, is believed to be originated in Mexico over 10,000 years ago. Agronomically it has several useful characteristics, including its capacity to produce high biomass, withstand multi cutting, produce more tillers than maize, and has a good capacity to resist biotic and abiotic stresses. It can be grown at various elevations and stays green for a longer period of time, ensuring an extended supply of green herbage for livestock during periods of fodder scarcity. Besides, teosinte could also be domesticated for forage purposes and it can be a continuous source of forage during the scare hot periods. As a forage crop, it is now widely cultivated in some Asian and African countries along with USA, Egypt and Brazil. However, it has become a noxious weed in maize fields of Mexico, Spain and France. Teosinte has been suggested as a possible source for maize development. *Euchlaena mexicana*, belongs to the genus *Zea* and sub species *mexicana*. One form, *Z. mays* ssp. *parviglumis*, shares a particularly close genetic relationship with maize and available evidence indicates that it is the direct ancestor of maize. Some cryptogenic studies of maize and teosinte determine that they belong to the same biological species, although transformation exists. Further, DNA marker based and Isozyme related studies have shown that *Zea mays* ssp. *parviglumis* is very similar at the molecular level while at the morphological level *Z. mays* ssp. *mexicana* has a more maize like appearance than *Zea mays* ssp. *parviglumis*. Further, because of its resistant and hardy nature, teosinte can be domesticated as a potential forage crop along with supplying noble genes to produce high yielding maize varieties.

terradactyl: R Package for Rangeland Core Methods Data Extraction and Calculation

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The rangeland core methods described in the Monitoring Manual for Grassland, Shrubland, and Savanna Ecosystems are widely adopted by federal land management agencies, such as the Bureau of Land Management (BLM) and Natural Resources Conservation Service (NRCS), research institutions, and other land management organizations. Within the BLM and NRCS these data are stored in large databases and are generally shared with collaborators and partners via file geodatabase or text file. While a limited suite of indicator calculations is available with these raw data, custom calculations can be complicated given the differences in data structure. Here we present an R package, called terradactyl, which handles data formats from the BLM TerrAdat database, the NRCS Natural Resources Inventory, and the Database for Inventory Monitoring and Assessment. This package provides several groups of functions. The first are a set of tidying functions, which gather data from BLM and NRCS data files into a common long data format to improve calculation efficiency. The second set of functions provide a grammar of rangeland indicator descriptions within which specific classes of indicators (e.g., cover) can be flexibly calculated based on user's categorical inputs. The third set of functions provide outputs specifically formatted for the inputs into modelling applications such as AERO, RHEM, and APEX or specified data archiving formats, such as the BLM's Terrestrial Indicators table. This R package is used by both the BLM and the NRCS to compute calculations from core methods data and is a powerful tool for integrating core methods data from different datasets.

Texas Wintergrass Growth and Seed Production Responses to Grazing

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Resource managers have mixed attitudes toward Texas wintergrass (*Nassella leucotricha* (Trin. & Rupr.) Pohl; TXWG), a native, cool-season perennial bunchgrass. In the Rolling Plains and other land resource areas of Texas, the preferred habitat of TXWG is beneath honey mesquite (*Prosopis glandulosa* Torr.) canopies. An abundance of TXWG and other cool-season forages typically corresponds with a shortage of warm-season forage species, leading producers to try to shift the balance toward warm-season grasses. This study, established near Vernon, TX, USA, evaluated effects of a single, short-duration targeted grazing event (~ 33,000 lbs/ac) (G1) versus repeated short-duration targeted grazing events (Gx) on TXWG growth and reproductive vigor. We selected individual TXWG plants in one of two positions relative to mesquite trees; out of the canopy (OC) plants were located ~ 2 m from mesquite trunks, while under the canopy (UC) plants were located ~ 0.3 m from mesquite trunks. In May 2018, individual TXWG plants were clipped at the ground surface. TXWG plants located under the canopy had longer leaves and larger basal areas, but lower live weight:basal area ratios than OC TXWG plants. As TXWG live tissue weight increased, so did the number of reproductive stalks and cleistogamous seeds produced. Rate of development of reproductive stalks was not related to live tissue weight or canopy position. Leaf lengths were shortest in Gx plants, intermediate in G1 plants, and longest in ungrazed controls. Grazing treatment had no effect on the number of reproductive stalks produced. Both canopy positions produced similar numbers of reproductive stalks as well. Reproductive stalk development tended to occur more quickly in ungrazed individuals than grazed individuals. Neither treatment nor canopy position affected the number of cleistogamous seeds produced. Results from the first year of study suggest targeted grazing may be able to slow aerial seed development in TXWG.

The Changing Relation Between Precipitation and Rangeland Grazing Capacity in a Warmer Southwest

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The rule of thumb of 'one cow per section per inch of rainfall' is often used by ranchers in New Mexico (NM) to estimate grazing capacity of cattle ranches. This notion, apparently rooted in 1920s government documents, articulates an empirical precipitation/beef production relationship that has not been validated. We determined actual AU equivalents (1,000 lb. cow) per square mile per inch of mean annual precipitation (MAP) for the grazeable rangeland area of the state (111,628 sq. miles) over a 98-year period (1920-2017). Inventory data for beef cows, weaned calves, sheep, and horses were retrieved from USDA-NASS databases. MAP and mean air temperature (MAT) data were retrieved from the Western Regional Climate Center. AU calculations considered the increase in average weight of the US beef cow herd and sheep flock over the past 100y. A factor of 1.25 was used to convert horse numbers to AU. Mean long term grazing capacity of NM rangeland was 0.52 ± 0.02 AU*sq. mile^{-1}*in. MAP^{-1}. Grazing capacity reached or exceeded the 1 AU*sq. mile^{-1}*in. MAP^{-1} only three times over the 98y period. Each of these events occurred before 1960 during drought years when MAP dropped below 75% of the long term average. Despite no trends in MAP, we observed a long term decline in grazing capacity from 0.69 AU*sq. mile^{-1}*in. MAP^{-1} in the 1920s to 0.34 AU*sq. mile^{-1}*in. MAP^{-1} in the 2010s. This trend became more pronounced after the mid-1970s when NM MAT began to surge. Calf crops, a measure of system secondary productivity, surged briefly in the late 1970s but dropped below the long term 50% average shortly thereafter. Our analysis suggests that similar amounts of MAP are able to support significantly less beef cows in today's hotter NM and that historical water-food relationships are changing possibly in response to a warming climate.

The Conflict of Privately-Owned Stockwater on Federally Administered Lands

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Recent court decisions have brought the conflict between rancher-owned vested and certificated stockwater and federal management decisions to cut or eliminate permitted livestock into sharp focus. Dave Duquette and Ramona Morrison will review the historical basis for this conflict, the scope of the problem, and the potential for water removal from federally administered lands as a direct result of land policy decisions. Speakers will summarize history of laws originating from settlement of the West to the laws establishing modern federal land management agencies; fast forwarding to today, speakers will review recent court decisions providing for the removal of vested waters off federally administered lands when permits to access and use the water in situ are denied; speakers will discuss policy implications on the ecology and wildlife of west as well as a wide variety of circumstances wherein court decisions may also have an impact on municipal water rights and other use rights.

The Ecological Benefits of Grazing Prairie

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This presentation unifies relevant ecological theory into a coherent framework to illuminate multiple benefits for using grazing animals to enhance, restore and maintain healthy prairie ecosystems. The resulting narrative questions the legitimacy of grassland management that excludes grazing and suggests grasslands that aren't grazed eventually suffer significant declines in ecological integrity. The presentation begins by describing the coevolution between grazing animals and prairie vegetation, during which time the vegetation transitions from forest to grasslands and becomes increasingly more edible. Eventually biomass harvest by herbivores becomes the primary intermediate disturbance regime that maintains healthy diverse grasslands, and the herbivore and vegetation become codependent upon one another. Humans show up recently and employ fire to maximize herbivory, and by the end of the Pleistocene, the grassland-savanna-grazing community becomes the dominant, most functional, productive and provisional terrestrial ecosystem ever! The presentation then examines ecological theories used to illuminate the benefits of grazing and include: 1) casting grazers as keystone species, 2) concepts of disturbance and feedbacks between grazing, diversity and function, 3) introducing grasslands as obligate to grazing, 4) modeling the importance of grazing over nutrient regulation, 5) modeling the importance of game trails for landscape connectivity, 6) linking dung piles to foodwebs, 7) modeling the importance of grazing on structure and organization, and 8) introducing a successional model where grazing is removed to see how the vegetation devolves from grassland to woodland, nutrient regulation is lost, and trophic cascades facilitate declines in ecological integrity. The presentation then shifts from theoretical to practical and introduces a grazing plan focused on conservation objectives that differs from MIRG, by explicitly capturing aforementioned ecological attributes. The presentation ends by describing the emergence of markets that support this type of restorative agriculture, including agriculture programs and partnerships that would help facilitate this type of grazing.

The Effects of Flash Grazing on Water Quality in a Riparian Stream

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Riparian ecosystems maintain numerous services towards watershed health, as well as provide forage and water opportunities for ranching operations. Unmanaged livestock use can negatively affect water quality through pathogen introduction as well as degrade ecological structure. Flash grazing is a strategy used to increase livestock density, control animal distribution, and achieve uniform forage utilization, while potentially mitigating the negative effects of grazing on water quality. Flash grazing was conducted for a two week period in May 2017 along a freshwater stream in south central Nebraska. An upstream-downstream design was used to compare microbial and physicochemical quality of monthly water samples collected before, during, and after grazing. Feces samples were collected during grazing. The most probable number (MPN) of total *Escherichia coli* before cattle were moved onto the grazing site were 3.1 MPN/100 ml of water, and increased to >2,419.6 MPN/100 ml of water after one week. Total suspended solids (TSS) increased from 9 to 190 mg/L of downstream water after one week of grazing, and returned to pregrazed levels seven weeks after the cattle were removed. In general, both *E. coli* and TSS decreased after the two week grazing period, but high *E. coli* levels in downstream water were further associated with rainfall events >12.7 mm and the presence of a flock of about 200 mallard ducks that were attracted to the open waters of the stream in January-February. The pathogen *E. coli* O157:H7 was detected in 10% of fecal pats collected during cattle grazing, and in 100% of downstream water samples collected after one week of grazing. Thereafter, the pathogen was detected sporadically for three months after grazing. These results are summarized from the first year of an ongoing multi-year study, but suggest that flash grazing can limit the negative impacts of cattle grazing on water quality of riparian streams.

The Effects of Prescribed Fire on Forb Cover in the Pacific Northwest Bunchgrass Prairie

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Grasslands are declining globally due to agricultural conversion and exotic plant invasion. Furthermore, grassland management can have large impacts on species diversity and overall ecosystem health. Forbs account for most of the plant species diversity in grasslands and their decline is concerning for conservation of pollinators. Although fire dynamics are well documented across North American grasslands, little is known about fire in Pacific Northwest Bunchgrass Prairie (PNBP). Our objective in this study was to examine the relationship between prescribed fire and forb cover in PNBP. We sampled forb foliar cover in 2008, 2010, 2016, and 2018 in long-term monitoring plots at The Nature Conservancy's Zumwalt Prairie Preserve to examine effects of prescribed fires that occurred in fall of 2006 and 2016. Overall forb cover was low across all plots and all years (mean 1.8 ± 0.1%). There was no statistically significant difference in forb cover between burned and unburned plots when data were averaged over the four sampling years. Forb cover decreased over time in both burned and unburned sites from 2008 to 2016. In 2018, forb cover increased slightly in unburned sites but remained the same as previous years in unburned sites. Cover of two common species differed significantly between burned and unburned plots. Old man's whiskers (*Geum triflorum*) had higher cover in burned plots, while hoary balsamroot (*Balsamorhiza incana*) had higher cover in unburned plots. Our findings suggest that while repeated prescribed fires in the fall may lead to declining overall forb cover, certain species may increase with burning. This study did not examine differences in responses of native vs. exotic species and, given the low cover values associated with these changes, it is uncertain if the statistical differences observed will also have biological implications for pollinators or other management considerations. More research should be done to understand the forb response to help manage and conserve diversity in PNBP.

The Effects of Time Since Fire on Cattle Use and Foraging Behavior in a Subtropical Grassland

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Fire to improve forage, control woody vegetation, and enhance wildlife habitat is a common management tool used on subtropical humid grazing lands, but the potential to manipulate cattle behavior via patch-burning (PB) in subtropical grasslands is not well understood. Our objective was to understand how PB affects cattle use of improved and semi-native pastures in subtropical grasslands. We expected that cattle use would be equally distributed across full burn pastures while cattle use would be clustered in recently burned patches within PB treatments. We also expected that within PB pastures cattle use would be higher in recently burned patches compared to unburned. These patterns were expected to weaken as time since fire (TSF) increased. An experiment was established in 2017, with 16 pastures (16 ha each) in two different pasture-types (improved (IM) vs. semi-native (SN)) at Archbold Biological Station's Buck Island Ranch in FL, USA. In 2017, eight pastures were completely burned ("full-burned": FB). The remaining eight pastures followed a fire regime of one-third burned yearly with the first third in 2017. Eight herds of cattle with four GPS collars each were rotated between four pairs of FB and PB pastures within each pasture-type. In both pasture-types, there was a significant interaction of burn and TSF. In improved pastures the percent of fixes (use by cattle during grazing periods) was higher in burned patches vs. unburned patches the first three weeks post-fire and then equalized. In semi-native pastures, percent of fixes was higher for at least seven weeks post-fire. Future analyses will use speed to categorize cattle behavior to inactive, grazing and walking, increasing our confidence of how cattle use PB and FB. We will also assess changes in spatial patterns of fixes in PB vs. FB treatments and expect more aggregated non-random grazing patterns forming as TSF increases.

The Future of Pinyon-Juniper Woodlands in the Great Basin: Expansion, Decline, or Structural Transformation?

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Land management of pinyon-juniper woodlands, which occupy over 30 million hectares throughout the western US, has emphasized large-scale tree removals. Goals are to increase the area of suitable habitat for sagebrush-dependent species and to restore landscapes that are believed to have experienced an increase in tree cover over the past century. Yet extensive areas of pinyon-juniper woodlands have more recently experienced pronounced diebacks that are associated with hot droughts. By integrating information from a Landsat remote sensing analysis (1984-2016) of the Nevada Great Basin with a resampling study (2005-2015) of 98 field plots across 11 mountain ranges, we report on multi-decadal trends in woodland dynamics. The Landsat study, encompassing a 34,000 km^2 area, found that recent drought-related die-off, wildfire and management treatments have balanced previous expansion, resulting in little net change in tree cover. Areas experiencing canopy cover loss were more common at lower elevations, on south-facing slopes, and on sites with greater climatic water deficits. The field study found tree mortality to be an order of magnitude greater than background levels, with canopy dieback more likely in denser stands and hotter, drier sites. Thus, the trajectory of change highlights the potential for large-scale woodland decline, should regional drought trends associated with anthropogenic climate change continue. Unfortunately, we also observed that the understories of woodlands showing decline were more prone to cheatgrass invasion, and that native shrubs, the larger-statured bunchgrasses, and most native perennial forbs did not establish abundantly in the small canopy gaps created by overstory mortality. We suggest that the dominant management paradigm – one of "landscape restoration from woodland expansion" - needs to be broadened to achieve resilience of the overall landscape mosaic, including woodland communities, to climate change, fire regime shifts, and other stressors.

The Great American Bison Diet Survey: A Continental-Scale Analysis

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The North American Plains Bison (*Bison bison*) are an integral component of the Great Plains ecosystems, Native American cultures, and regional economies. Ensuring that bison thrive and are sustainable culturally, economically, and ecologically requires quantifying patterns of dietary quality and dietary composition of bison across the U.S. Developing baseline data on regional dietary quality and composition can aid managers in recognizing when to supplement (and what to supplement), as well as help create strategies to improve access to plant functional groups associated with higher diet quality to improve overall herd performance. Here, we quantify bison dietary quality and dietary composition across the U.S. from >48 private, public, and tribal herds in June and September of 2018 using Near Infrared Reflectance Spectroscopy and DNA metabarcoding analysis of fecal material. Similar to cattle, bison herds located in colder, wetter regions had higher diet quality, whereas herds located in warmer, drier regions were more prone to nutritional stress due to low crude protein (CP) values. In June, on average, 60% of bison protein intake comes from eudicots, with legumes contributing 32% of their protein. The remaining 40% of protein was derived from warm and cool season grasses. Northern herds tended to have higher proportions of cool-season grasses and woody plants in their diet versus southern herds. In all, bison rely on diverse grasslands and are subject to regional nutritional stress, requiring more work to promote grassland diversity to help reduce nutritional stress.

The Impact of Wildfire on the Rangeland Soil Seedbank on the Central Coast of California

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Seedbanks in rangeland soils in California are maintained by the regular input and output of annual and perennial grass and shrub species. These seedbanks vary seasonally, between years, and by species. During wildfire, the pattern and severity of burning is highly uneven across these landscapes and largely depends upon temperature, humidity, wind direction, slope/aspect, soil texture, fuel type/moisture, and grazing history. Accordingly, impacts from fire to the already-complex soil seedbank are highly spatially and temporally variable and species-dependent. We collected soil core samples in grassland and shrubland areas at different burn severities (no burn, low, high) from five sites that burned during the Thomas Fire (Ventura County, California, December 2017) in order to understand potential impacts to soil seed supply and grassland forage productivity. Samples were watered in a greenhouse and germinating seedlings were counted and identified by functional group (grass, forb). In grassland soil samples, high fire severity had significantly fewer grasses compared to no burn or low burn. Forbs also were significantly lower after fire but made up most of the plants in the high severity grassland vegetation. Seeds in shrubland areas showed the same trend with burn severity but differences were not significant due to variation, low seedling density, and small sample size. Burn severity in grassland areas largely depended upon previous grazing history. Areas that had been grazed by domestic livestock previous to the fire burned at a lower severity, while areas with higher biomass due to lower levels of grazing burned more severely. This research has important implications for land managers looking to supplement the soil seedbank with seeding after wildfire. Our results suggest that effective seeding only needs to target areas that experienced high severity burning.

The Impacts of Grazing Removal on the Kelso Creek Monkeyflower

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The Kelso Creek monkeyflower (*Mimulus shevockii*) is a small annual herbaceous plant located only in arid regions of Kern County, California. One of the known population locations is in Cyrus Canyon on land owned by the Bureau of Land Management (BLM). Historically, Cyrus Canyon was privately owned and grazed rotationally as part of a local ranching operation. Cyrus Canyon was acquired by the Audubon society and then the BLM. In 2014, the Bakersfield BLM office finalized and implemented their Resource Management Plan, which included removing grazing from Cyrus Canyon. In 2014, UC Cooperative Extension and the Rancho Santa Ana Botanic Gardens initiated a project aimed at tracking monkeyflower population dynamics in Cyrus Canyon. The sampling area for this study was limited as the area where the monkeyflower grows in Cyrus Canyon and is limited to about 40 square meters. Two $20m^2$ plots were established, one that contained a significant population of the monkeyflower and a vegetatively similar plot that would be expected to contain the monkeyflower, but where no monkeyflower was found. Using a modified Whitaker design sampling method, three $1m^2$ subplots were established within the $20m^2$ target plot with varying levels of monkeyflower present in each. In the $20m^2$ control plot three $1m^2$ subplots were established at the north and south ends of the plot and in the center of the plot. Data were collected in 2015, 2016, and 2018 due to variable rainfall and the associated effects on the annual plant population. Monkeyflower plants were only found and counted in 2015 and 2016. Preliminary results indicate greater species richness in the target plot versus the control plot. Insight into vegetation community dynamics, the impact of disturbance regimes and the timing of rainfall on the monkeyflower will be presented along with preliminary findings.

The Landscape of North American Rangeland Social Science: A Systematic Map

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Rangeland science aims to create knowledge to sustain rangelands over the long-term. Range scientists have made substantial progress on understanding ecological dynamics of these lands, but the social factors have received less attention in North America. Recently, a body of range social science research has emerged, but the findings have not been systematically reviewed to assess the state of rangeland social science and potential research gaps. We developed a systematic map to characterize this literature by 1) who is studied, 2) where research is conducted, 3) how theories, methodologies, and methods are applied, 4) and how these characteristics have changed from 1970 to 2017. In the 296 papers that met our criteria, we found that most (81%) rangeland social science has studied ranchers or range livestock producers, farmers, and/or landowners, with limited consideration of other stakeholders. While educational level (40%) and age (43%) are often included in analyses, other components of identity such as gender (28%) and race or ethnicity (18%) are less frequently considered. The most frequently used research method is surveys (52%) and much rangeland social science has not been framed by explicit methodological or theoretical approaches. The limited application of theories and explicit methodologies and reliance on surveys to the exclusion of more diverse methods, has potentially constrained who and what has been studied. The lack of consideration of gender and race in rangeland social science is echoed in the near absence of studies that address the effects of simultaneous and intersecting social identities and relationships of power among people who depend upon rangelands. This review highlights the need for more theoretically informed research on a broader range of stakeholders, using a wider array of methods that account for the effects of simultaneous and intersecting social identities on people’s connection to and management of rangelands.

The Most Important Endangered Range Plant Species and Change in Ground Cover in North Kordofan State, Sudan

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This study was conducted in North Kordofan State with the objectives of identifying changes in ground cover, other range attributes and the endangered plant species. The primary source of data was mainly previous studies, while secondary data were obtained from field work using a loop and transect method, in addition to personal interviews, a rapid rural appraisal technique and direct observation. SPSS software was used in statistical analysis. The results indicated that there were notable changes in range composition in the period 2003-2008. Live plants decreased by 17.5%, while litter and rock increased by 17.9% and 0.30% respectively. Some species still exist, with high percentages such as *Eragrositis termula* (Banu), *Aristida* spp. (Gaw) and *Cenchrus ciliaris* (Haskaneet). Other species were found in very low percentages, (endangered), e.g., *Chrozophora brocchiana* (Argassy), *Aristida seibrana* (Bayad), *Echinochloa colona* (Difra), and *Indigofera spinosa* (Singid). Low rainfall savannah zone has higher percentage in live plants and lower percentage in bare soil compared to semi desert zone. In semi desert zone the five most dominant species include: *Aristida mutablis* (Gaw), *Eragrositis termula* (Banu), *Cenchrus biflorus* (Haskaneet Khishin), and *Fimbristylis dichtoma* (Um fisysat). They represented 70.9% of the species composition. In low rainfall savannah zone, the five most dominant species include: *Zornia glochidiata* (Shilini), *Eragrositis termula* (Banu), *Aristida mutablis* (Gaw), *Fimbristylis dichtoma* (Um fisysat), and *Cenchrus biflorus* (Haskaneet Khishin). They represented 69% of the species composition. The important palatable endangered range species included grasses such as *Blepharis linariifolia* (Bugheil), *Monosomia spp.* (Garin), *Oldenlandia senegalensis* (Garajob), *Vigna sun-hum* (Tagtaga), and *Chloris gayana* (kloris). Changes in range attributes were clearly noticed and some important plants are being endangered. Therefore, the study recommends a strategy for rangeland rehabilitation to be adopted in relation to composition of important, palatable and endangered plant species.

The National Vegetation Classification (NVC) Has Some Communication Opportunities for Ecological Site Work

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The National Vegetation Classification (NVC) was publicly released in 2016 though it has been in the works for over 25 years. Currently, federal land managers are required by OMB Circular 16A to translate (crosswalk) local classifications to the NVC. The Federal Geographic Data Committee (FGDC) established the Vegetation Subcommittee to create this Standard. A database for vegetation plots (VegBank) contains over 100,000 plot records and a peer review system that allows for evidence-based changes to the NVC. Though logical as a hierarchy, the 'kinds and amounts' of vegetation are measured differently than those used for ESD. The NVC uses canopy and structure to differentiate while ESD uses weight per vegetative species per unit area per annum and ecological functions. ESD uses land as the hierarchy while the NVC uses climatic biomes and regional disturbances. The differences do not make one better than the other. But knowing the differences will aid communication of on-the-ground local needs, for understanding desired conditions, and describing vegetation for inventory purposes.

The Promise and Challenges of Agent-Based Modeling of Livestock Foraging Behavior

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Agent-based models (ABMs) are “bottom-up” computational simulation tools that focus on the behavior of individual “agents” as they interact with one another and the environment. They are particularly useful in modeling complex systems, where the results of interactions between various systems elements are difficult to predict. ABMs are thus well-suited to improving our understanding of groups of herbivores foraging amid heterogeneity, especially within the context of social-ecological systems. In this presentation, we will describe results from two applications of ABMs to livestock foraging behavior, one examining an applied challenge and one a more theoretical question. The first explores relationships among stocking density, herd cohesion, cattle, and larkspur-induced alkaloid toxicosis, aiming to understand potential management strategies to mitigate the risk of death in larkspur (*Delphinium* spp.) habitat. The second uses neutral landscape models to test relationships among plant patchiness, herd cohesion, and toxicosis within the context of ecological theory on the evolution and utility of herd behavior. Taken together, both examples highlight the tremendous potential of ABMs to improve our understanding of livestock foraging behavior and the consequences thereof. However, the limitations of these studies point toward important gaps in livestock grazing management research, with gaps especially evident at certain scales of behavior. Filling these gaps requires a combination of old and new methods, informed by feedback from models. Ultimately, we envision a future in which affordable GPS tags, remote sensing data, virtual herding technology, producer knowledge, and ABMs are seamlessly integrated to improve the effectiveness of our research and management.

The Purple Plague: Effects of Two Years of Grazing Post Fire on Purple Threeawn

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Matthew Bain, The Nature Conservancy, Oakley, Kansas
Mitchell Greer, Fort Hays State University, Hays, Kansas

Purple threeawn (*Aristida purpurea*) is a native warm-season bunchgrass quickly gaining attention in western Kansas on The Nature Conservancy's Smoky Valley Ranch. Upon reaching maturity, grazing/clipping pressure decreases for this bunchgrass due to poor forage quality and extreme unpalatability for cattle (*Bos taurus*) and black-tailed prairie dogs (*Cynomys ludovicianus*). This decrease in grazing/clipping has led to near monocultures which cause negative impacts to the prairie ecosystem including decreases in the amount of palatable forage produced and suitable habitat for prairie dogs; a keystone species. These impacts directly affect many species on the ranch that rely on prairie dogs for habitat and/or food including the black-footed ferret (*Mustela nigripes*), North America's most endangered mammal. This study aims to determine a large-scale management strategy using natural processes such as fire and grazing to decrease purple threeawn. We are investigating the effects of high intensity grazing by cattle, at season long (6 months) and short duration (3 months) as well as the additional effects of clipping by prairie dogs, post burn. Through two grazing seasons, purple threeawn cover and reproductive tiller count has decreased in both short and long duration grazing treatments with the greatest decrease seen in the short duration treatments. With this decrease in purple threeawn, prairie dog densities have increased within both short and long duration treatments with the greatest increase in the short duration treatment. With an appropriate management plan, action can be taken against purple threeawn to increase economic benefits while creating better quality habitat for prairie dogs and all organisms that rely on them.

The Restore New Mexico Collaborative Monitoring Program: The Action and the Science

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Restoration treatments to reduce shrub cover and increase grass cover have a long history in the Chihuahuan Desert region of southwest New Mexico. Brush management treatments on Bureau of Land Management (BLM) land became common in the 1980s, but with very little monitoring to evaluate restoration outcomes. The Restore New Mexico program was initiated in 2005 to accelerate brush management and other restoration applications through a partnership of the BLM, Natural Resources Conservation Service, Soil and Water Conservation Districts, and wildlife-oriented non-governmental organizations. There was also increased interest in monitoring to: 1) estimate the effects of brush management treatments on vegetation; 2) identify environmental factors explaining variations in treatment outcomes; and 3) determine which brush management treatments are not performing as expected and identify strategies to maximize future benefits (adaptive management). BLM staff reached out to the USDA-ARS Jornada Experimental Range in 2006 for assistance with tools to design restoration treatments based on existing knowledge (ecological site descriptions and mapping) and to embed monitoring experiments featuring paired treated and untreated plots within treatment areas. From 5-10 years of monitoring data have been analyzed in 39 areas spanning millions of acres. Analyses and interpretations were initially developed with BLM and presented and refined with a broader coordination group. Care was taken to allow explanations for trends to emerge from the group setting, rather than to present them outright. The data provided a complicated “report card” on restoration practices – confirming some hypotheses, finding little support for others, and raising new questions. We will discuss how these scientific interpretations will be used in the management of past restoration investments and the development of future restoration efforts.

The Reverie Alone Won't Do: Response of Bee Communities to Grazing and Burning in Prairies

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Julia Leone, University of Minnesota, St. Paul, Minnesota
Diane Larson, U.S. Geological Survey, St. Paul, Minnesota
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Minnesota's native tallgrass prairie has greatly decreased in area since European settlement in the mid-19th century. Of the 18 million acres of native prairie that once covered the state, less than 1% remains. What persists is highly fragmented. In order to prevent remaining areas of tallgrass prairie from undergoing succession into woodlands, land managers must provide disturbance on a fragment by fragment basis. Two common techniques used to supply this disturbance are prescribed fire and cattle grazing. While the differing effects of these techniques on prairie plant communities is well documented, their effects on wild bee communities that pollinate many tallgrass-prairie plants has not been as well investigated. To that end, in the summers of 2016 and 2017 we surveyed 20 native tallgrass-prairie remnants for bees. We were interested in how bee abundance, provided by standardized passive traps, and species richness, supplemented from traps data by directed netting efforts, differed between burned and grazed prairies. We also investigated how bee nesting behavior responds to management and environmental traits of study sites.

The Role of Agricultural Land Cover in Shaping Bee Communities in Restored Prairies

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One of the primary challenges with restoring prairie habitat is fragmentation. Fragmentation is the process by which natural habitats are relegated to small and isolated patches. In the prairie region of the Midwest these natural habitats are often relegated to small islands amid a larger landscape of row crop agriculture. Highly simplified agricultural landscapes have been shown to have negative effects on biodiversity, however other studies have shown that restored prairies are still highly diverse. One community of increasing concern in prairie habitats are native bees. Native bees are important pollinators of many prairie forb species, but have only recently become a community of conservation concern. While much research has shown that bee communities in restored prairies can be as diverse as in natural habitats, these studies have not addressed the issue of how the agricultural landscape shapes it. To answer the question of how the agricultural land cover that surrounds a restoration impacts native bee communities, we sampled 16 prairie restorations that varied in the amount of agriculture surrounding the site. We then analyzed bee communities in these sites to see if agricultural land cover could explain patterns of diversity and composition. In addition, we also sampled remnant prairies paired with a subset of restored sites to test if agricultural land cover effects the similarity of native bee communities inhabiting remnant and restored prairies. Preliminary results will be discussed as well as potential implications.

The Role of State-and-Transition Models in Prioritizing Conservation and Restoration Actions

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The magnitude of ecosystem disturbances in rangelands of the western US often necessitates prioritizing conservation and restoration actions where they will provide the maximum return on investment. Recent research in sagebrush rangelands provides the basis for characterizing ecosystems according to their ecological resilience to disturbance and resistance to invasive annual grasses. This has enabled development of a strategic, multi-scale approach that links information on resilience and resistance with knowledge of critical habitat for at-risk species and ecosystem threats to prioritize areas for conservation and restoration actions. At landscape scales, soil temperature regimes and soil moisture regime subclasses are used as an indicator of relative resilience and resistance. Generalized ecological types and State and Transition models (STMs) are characterized according to their resilience to disturbance and resistance to invasive annual grasses based on soil temperature and moisture regimes and other biophysical characteristics. Restoration strategies in the STMs are based on relative resilience and resistance of the type to invasive annual grasses. A resilience and resistance/habitat matrix is used to help determine the priority for restoration and conservation actions based on the relative resilience and resistance of the assessment area and the capacity of the current state(s) to support critical habitat or other resource values. The generalized STMs and restoration strategies can be linked directly to the cells in the matrix to determine the most appropriate management actions. Information and tools are available to help managers step down to the ecological site/project area scale.

The Timing of Livestock Producers' Drought Management Decisions during the 2016 Northern Great Plains Drought

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Livestock producers make operational, tactical and strategic decisions before and during drought that have significant consequences in terms of farm/ranch finances, productivity, and ecological health. They make these decisions in the context of multiple sources of uncertainty, ranging from farm policy, market prices, and resource constraints, to the uncertainties associated with the onset, severity, and length of the drought event. For example, in 2016, a quickly-developing drought event occurred across the northern U.S. High Plains in 2016, leading to forest and grassland fires, reductions in grain yields, reduced forage production, water quality and quantity problems, and economic losses. Drought impacts were compounded by a late May freeze event that degraded range and forage productivity. The decisions producers made during this drought, and specifically the timing of those decisions, had consequences for the outcomes that they experienced. We conducted a survey and focus groups of livestock producers affected by the 2016 drought to better understand producers' drought management decisions, the information they used to inform their decisions, and the outcomes of their decisions. This talk will summarize research findings and highlight opportunities for linking producer decision-making with scientific information and tools related to precipitation and forage production.

The Utility of Patch Burn Grazing to Manage Large Tallgrass Prairie Reconstruction in Northwest Minnesota

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Patch burn grazing (PBG) is a management system used in grassland habitats to manage habitat diversity in both structure and species composition. Its intended biological goal is to mimic the historic disturbance of bison, deer and other grassland foragers with the vegetative regeneration that occurs after a prairie fire. This management system can be adaptable, allowing managers to apply disturbance on small patches in a larger unit without the restrictions of interior infrastructure. To test the utility of a PBG program, we designed and piloted a study in northwestern Minnesota from 2010-2015 at Glacial Ridge National Wildlife Refuge (NWR). The goal of the study is to determine whether this management system is beneficial to the habitat and wildlife of Glacial Ridge NWR. We selected an 810 hectare reconstruction unit of varying type and quality of habitat as our study area. Management infrastructure was installed around the perimeter and 12 burn patches were created and divided into a four year burn rotation. We took a comprehensive approach to monitoring in which vegetation, cow movement, forage utilization, and calf weight were monitored annually. Results from this study can provide land managers and producers information to make informed decisions about the utility of this management system on their land.

Threat-Based State and Transition Models for Managing Rangeland in Dysfunctional Ecosystems

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Persistent and complex ecosystem threats such as altered wildfire regimes and the continued spread of exotic annual grasses are prevalent throughout the sagebrush biome. These alterations have had a cascade of ecological consequences that have culminated in declines of sagebrush dependent wildlife species including greater sage-grouse. State-and-transition models (STM) are ideally suited to adaptively managing complex problems because they allow managers to determine current conditions, desired conditions, and management actions for bridging the two. We worked with a diverse group of stakeholders in Oregon to design three simple threat-based STMs (TBSTM) for use in managing sage-grouse habitat on private and state lands threatened by exotic annual grasses, expanding conifer, or both. States in these models represent generalized vegetation conditions that can be managed for at large spatial scales. We then rated states with respect to ecological resilience and their potential to provide seasonal or year-around habitat for sage-grouse. We used remotely sensed data to map states at large spatial scales. These maps allow practitioners to simultaneously evaluate the diversity of ecological status as well as potential sage-grouse habitat availability across large landscapes. Subsequent evaluation has shown that states within TBSTMs compare favorably to traditional resource selection functions for predicting sage-grouse habitat occupancy. TBSTMs are now being used for management planning and stakeholder communication by the Bureau of Land Management, and they form the basis of the State of Oregon sage-grouse habitat mitigation plan. At present, these models impact management of approximately six million acres of public and private rangeland in eastern Oregon. While TBSTMs have proven useful to a variety of practitioners, they are biotic assessments that should be paired with landscape scale abiotic information (e.g., the Resistance and Resilience Framework) for large scale management planning, and site specific abiotic information (i.e., Ecological Site Descriptions) for developing management prescriptions.

Tick Species Observed in Burned versus Unburned Rangeland Sites in the Edwards Plateau of Texas

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Among the many documented uses of fire by Native Americans was the reduction of insect and acarid pests which both killed pests and altered supportive vegetation habitats. Prescribed fire is a common resource management practice on the Texas Edwards Plateau. While there are no documented reports of prescribed fire tick suppression in this region, it has been demonstrated to be effective in integrated tick management in other U.S. regions. Ticks are serious pests to livestock production on rangelands and can impact wildlife species as well. Our objective was to assess the effect of a winter prescribed fire on indigenous tick species with which to inform ungulate herbivore management. In May of 2018 at the Sonora Research Station, we collected ticks by trapping in ~3ha paddocks of native rangeland that had been either unburned for ~20 years or burned repeatedly (6-12 year intervals) in winter, most recently in January of 2018. CO_2 traps (n=48) were set in the morning within live oak (*Quercus virginiana*) canopy, grass (*Bouteloua curtipendula*) canopy, or in interspaces. Traps were removed approximately four hours after placement and all ticks captured were placed on ice and transported to the Tick Research Laboratory at Texas A&M University in College Station. Ticks were identified by sex, stage, and species. Differences in tick abundance by treatment and location within treatment were determined by analysis of variance procedures. Mean and standard error were 0.081 ± 0.4 (*Amblyomma americanum*) in burned and 2.278 ± 1.1 (*Amblyomma americanum*) in unburned sites, respectively (P>0.1). All ticks were more abundant (P<0.06) under live oak than grass canopy and in interspaces. The complex tick-habitat-host interactions effecting short and long-term efficacy of prescribed fire treatments indicate fire may be used to manage ticks in the Edwards Plateau.

To Review, or Not to Review, an Ethical Question (Among Others)

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My topic is the ethics of peer review. To begin with, it is important to consider when you should do it at all! Ethically, when should you say no? And, what is our responsibility when it comes to peer review? If you do accept a review, there are certainly things you should do, but there are also things that do not belong in journal reviews. I will recount a case of politics entering review, even though the journal was trying to do the right thing. How do we avoid implicit or explicit bias? I will briefly discuss civility in peer review and why it is important. I will also discuss the increasing demand for speed, obsession with impact factors, and how this has contributed to the proliferation of journals that some might consider unethical for various reasons.

Topoedaphic Effects on *Ventenata dubia* Production in the Pacific Northwest Bunchgrass Prairie

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Invasive annual grasses, such as cheatgrass (*Bromus tectorum*) and medusahead (*Taeniatherum caput-medusae*) are a widespread and growing management issues across the western United States. Ventenata (*Ventenata dubia*) is a relatively recent invasive annual grass raising concerns in a variety of habitats such as timothy grass hay pastures, grassland and shrubland rangelands, and openings within forests. Unfortunately, published research on the factors influencing its distribution, ecology, and spread is still quite limited, especially in the Pacific Northwest Bunchgrass Prairie. Our study examines the effect of soil texture, depth, slope and aspect on the standing crop of ventenata at the Zumwalt Prairie Preserve in northeastern Oregon. We contrast the standing crop of ventenata and all other vegetation across a range of topoedaphic conditions, including six Edaphic Habitat Types (EHTs included moderately deep silty, moderately deep rocky, shallow silty, shallow rocky, clay, and very shallow rocky), soil depth, slope, and aspect. We clipped current year's growth of ventenata and all vegetation from 18 plots within eight 640 m^2 paddocks (N=144). Ventenata standing crop was a relatively small proportion of the total standing crop. Ventenata standing crop was lower in moderately deep silty soils, but similar across all other EHTs. In contrast, all other vegetation had lower standing crop in shallow and very shallow rocky soils. Standing crop did not differ for any of the vegetation based on slope. Standing crop for all other vegetation was higher for northern and eastern aspects, whereas ventenata production was higher on western, southern, and flat aspects. This study supports observations that ventenata is rapidly dominating shallow rocky scablands, and drier and warmer site conditions within the region.

Toxic Beauty: Viper's Bugloss (*Echium vulgare*)

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Viper's bugloss (*Echium vulgare*) is considered a beautiful plant. It is sold as a garden ornamental and is highly rated by beekeepers as a great nectar plant. However, this deceptively attractive plant contains pyrrolizidine alkaloids that can cause liver failure in humans, horses, cattle, and swine when ingested over time. Even honey made from the nectar of this plant is toxic to the liver when consumed continuously. Since Viper's bugloss is toxic and can easily take over pastures, rangelands, and riparian areas, it is listed as a noxious weed in Washington, Montana and other western states. However, in Oregon, this plant is only listed as a noxious weed on the Confederated Tribes of the Umatilla Indian Reservation, and in Umatilla County. Our objective is to aid in the identification of this plant and raise awareness about the potential threats it poses as an invasive species on private, tribal, state, and federal lands in our region.

Tracking Monarch Butterflies with Radio Telemetry: Insight for Conservation Planning

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Habitat loss is a key factor in monarch butterfly (*Danaus plexippus*) population decline. Monarch habitat restoration efforts are focused on increasing milkweed (*Asclepias* spp.) for oviposition and larval development and other native prairie plants for adult forage. To implement habitat restoration in locations that are biologically relevant for monarch butterflies, we must first understand how monarchs are currently navigating and utilizing the landscape on a large scale. Radio telemetry techniques are being employed with monarch butterflies to track flight patterns, perception distance, and step-length. In 2016, hand-held radio telemetry methods were adapted for simultaneous bearing collection and subsequent triangulation to estimate female monarch flight paths. Thirteen radio-tagged, field-collected monarchs were tracked individually for up to 87 minutes. In 2017 and 2018, an automated radio telemetry system, adapted from Kays et al. (2011), was implemented to reduce error and increase the frequency of data collection. To test the system and explore monarch perception distance, 200 radio-tagged monarchs were released known distances downwind of a single ‘patch’ of potted milkweed and nectar plants placed in a 16 ha sod field. Direct flight was observed from 3-125 meters downwind of the resources, suggesting that monarch butterflies have a perception distance of at least 125 meters. Monarchs took flight steps ranging from 1- 1,100 meters. Future telemetry studies will assess female flight patterns and habitat utilization while foraging/ovipositing in 42 ha landscapes comprised of crop fields, restored prairie, pastures, and roadsides. Results from these studies will inform conservation planning by assessing how different spatial arrangements of habitat patches in the landscape can optimize efficient resource utilization by monarch butterflies.

Treatment Longevity and Changes in Surface Fuel Loads after Pinyon-Juniper Mastication

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In the Intermountain West, land managers masticate pinyon pine (*Pinus* spp.) and juniper (*Juniperus* spp.) trees that have encroached sagebrush steppe communities to reduce canopy fuels, alter fire behavior, and promote growth of understory grasses and shrubs. At three study sites in Utah, 45 total sampling plots spanning a range of tree cover from 5-50% were masticated. We measured surface fuel load components several times over a 10-year period. We also measured tree cover, density, and height as indicators of treatment longevity. Changes in these variables were analyzed across the range of pre-treatment tree cover using linear mixed effects modeling. We observed decreases in 1-hr downed woody debris by 5-6 years post-treatment. Duff + tree litter decreased by one year post-treatment where pre-treatment tree cover was at least 15%. Herbaceous fuels (all standing live and dead biomass) increased by two years post-treatment. At 10 years post-treatment, tree cover ranged 0-2.6%, and the majority of trees were less than 1 m in height. Given that 1-hr fuels were the only class of downed woody debris that decreased, it may be beneficial to masticate woody fuels to the finest size possible. Decreases in 1-hr downed woody debris and duff + litter fuels over time may have important implications for fire behavior and effects, but should be analyzed in the context of increases in herbaceous fuels. At 10 years post-treatment, there was not any risk of canopy fire, and understory grasses and shrubs were not being outcompeted by trees.

Trials and Tribulations of Quantifying Hotspots of Cattle Use in Large Desert Pastures

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Overuse of particular locations by cattle in arid environments is associated with perennial grass loss, lateral soil redistribution, dust emissions, and suboptimal forage utilization. We sought to identify the abundance and distribution of hotspots (i.e., locations with multiple visits of long duration) for two types of cattle (Raramuri Criollo, Angus x Hereford) alternating use of a large desert pasture during four phenologically-defined seasons in 2008. We used Gridded Time-Use Maps in the Time Local Convex Hulls (T-LoCoH) package in R to quantify the distribution of both types during the four seasons. This entailed creating a map for each of 32 cows (4 collared cows x 8 trials), and then creating eight maps – one per trial – illustrating, per cell, the average number of visits and average duration of those visits. Most hotspots were adjacent to watering points, and they were least abundant during the season with the greatest pasture-level forage production. These results were expected in a general sense, but there were several decision points during the analysis, and had we decided differently, different counts and locations of hotspots would have been identified. For instance, we used expert knowledge to a) select the size of the cells (150 x 150 m), b) define a “visit” (at least one occurrence in a cell separated by at least 12 hours from the previous occurrence in that cell), and c) designate cells as hotspots (cells visited on average >4 times for >2 hours). Most analytical methods entail some decision-making, and we found T-LoCoH to be highly useful for our research questions. We seek to discuss the utility of T-LoCoH, and our choices for it, with the SRM livestock tracking community to identify whether there might be guiding principles for all when using the tool to quantify cattle use hotspots.

Understanding the Hydrology of Kentucky Bluegrass Dominated Rangelands in the Northern Great Plains

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According to the USDA-NRCS National Resource Inventory, Kentucky bluegrass is now present in over 85% of the areas sampled in the northern Great Plains. This invasive, perennial, cool season grass can serve to stabilize soils and increase site stability; however, it also alters nutrient flows, soil structure, and plant community composition ultimately degrading biotic integrity. To clarify the effect of Kentucky bluegrass on hydrological characteristics of invaded sites, rainfall simulation experiments and hydrophobicity measurements with water drop infiltration time and molarity of ethanol droplet tests were conducted at three locations all within the same ecological site in the northern Great Plains. Our results indicate that on dry soil strata, water drop penetration time increased by 20 seconds on litter and 3 seconds on thatch for every percentage point increase in Kentucky blue grass in the vegetation, confirming the close association between this grass species and the development of soil hydrophobicity. Rainfall simulation on dry soils (less than 20% volumetric water content) also revealed that the time needed to initiate runoff was shortened by 5 minutes and the runoff ratio increased by 0.004 for every percentage point increase of Kentucky blue grass in the vegetation. In contrast to the rainfall simulations on dry soils, wet runs (volumetric water content ≥ 20%) showed a beneficial effect of Kentucky bluegrass on hydrologic response with delayed runoff and reduced runoff ratios.

Understory Vegetation and Soil Moisture Response to Thinning Piñón-Juniper Woodlands

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Portions of the western United States, extending from west Texas up through southern parts of Oregon, are found to be densely populated with piñon-juniper woodlands. Managing the quantity of trees could have positive ecological implications for rangelands watersheds and wildlife habitat. The objective of our study was to determine the understory biomass and soil moisture response to tree removal in small watershed areas. This research reports comparative data collected in relation to the understory response as well as soil moisture levels from six watersheds situated within Santa Fe Ranch. In 2009, six paired watersheds (1.00-1.35 ha) in Santa Fe, were selected, three of the watersheds were treated by thinning juniper trees (treatment watersheds) while the juniper trees at the remaining three areas were left untreated (control watersheds). We hypothesized that by reducing the density of the trees, the understory biomass production, as well as soil moisture, would increase. In 2013-2014, we measured understory biomass and soil moisture. This study found that understory biomass significantly increased by thinning the trees in both years 2013-2014. The understory biomass was higher in treated watersheds (double) more than untreated watersheds, and sideoats grama (*Bouteloua curtipendula*) relative cover was significantly increased in thinned watersheds comparison to other species relative cover. However, the results showed that there were no significant differences in soil moisture between the controlled and thinned watersheds. This study should provide land managers with critical information for actual effects of tree clearing in small watershed areas.

Update on a Program to Strategically Reduce Fine Fuels Using Targeted Livestock Grazing

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Wildfires are increasing in size and frequency in the Great Basin fires due in large part to invasive annual grasses (e.g., cheatgrass (*Bromus tectorum*)) which increase fuel continuity and promote longer fire seasons. The Bureau of Land Management is working with partners, scientists and stakeholders to investigate using livestock to strategically manage fine fuels as part of their Integrated Rangeland Fire Management Strategy. Targeted grazing objectives are to reduce fine fuels prior to the start of the fire season to enhance fire suppression effectiveness. Accomplishments include: 1) Establishment of two large targeted grazing demonstration projects in northern Nevada and southwestern Idaho with another one starting in 2019 in central Oregon. The USDA Agricultural Research Service is implementing a multi-faceted study to quantify the effects of cattle grazing on fuels, vegetation and soils at each demonstration area. 2) Developing and maintaining a web-based "Resource Center" to capture and continually update the targeted grazing research and to share the lessons learned by the implementers. This website will serve both the strategic targeted grazing and dormant season grazing approaches to manage invasive annual grasses. 3) Distributing findings and facilitating information sharing through workshops, webinars and technical assistance. If successful, this program will provide another option to reduce fine fuels and wildfire impacts on Great Basin rangelands.

Use of Genetic Markers to Study and Potentially Improve Grazing Distribution of Beef Cattle

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Distribution is an important aspect of grazing management. Approximately one third of the rangelands in the western United States are ungrazed by beef cattle due to rugged terrain; thus, more forage may be harvested if cattle disperse across these types of rangeland. Modifying pasture attributes is effective in improving grazing patterns; however, these practices are laborious and costly. Previous research suggested that the traits used in indices to describe grazing distribution are genetically influenced. These traits were quantitative (i.e., distance from water, slope, and elevation) and very polygenic. Specifically, genotypes in five candidate genes (ACN9, FAM48A, GRM5, MAML3, and RUSC2) were associated with grazing distribution, GPS-derived grazing distribution phenotypes in a study published in 2015 involving 80 cows from seven ranches in the western United States. Additional data has been collected and is being analyzed in a study funded by Western Sustainable Research and Education Program (SW15-015). Those recent results involving 251 mostly Angus-influenced cows with high density genotypes (n=777,962 single nucleotide polymorphisms; SNP) again revealed that quantitative grazing distribution traits are very polygenic; however, the chromosomal loci of importance observed in these expanded data did not parallel the results of the study of only 80 cows. These observations were not discouraging as the ranches, pastures, and cows added to the study were diverse; therefore, we learned that grouping the pastures into terrain categories, such as mountainous, rolling, or rolling and mountainous, is important to properly statistically model genotype to phenotype association analyses. From these types of analyses, we will eventually be able to develop a genome-enhanced expected progeny difference (GE-EPD) which is the product summed from the estimated effect of each SNP and spares phenotypic information. This EPD will allow producers to rank sires with desirable versus undesirable breeding values for grazing distribution traits.

Using AIM Data to Inform Wild Horse & Burro Management Decisions

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AIM data collection for BLM offices has been a major project for several years now. Northeastern California was one of the pilot areas that implemented AIM monitoring early on. Northeastern California also has one of the nation's largest wild horse and burro herd management areas. AIM data can be used to document environmental conditions and possibly to detect change over time. This paper examines possible uses of AIM data and key concepts within the suite of indicators that may be used to inform wild horse and burro management decisions. Even with all the data collected, it was apparent that AIM data needed to be paired with local knowledge of conditions to answer management questions.

Using AIM Data to Tailor ESDs for IIRH on Sage-Grouse Habitat in Southern Idaho

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The Ecological Site Concept classifies land based on the ability of recurring soil, physiographic, geological, and climatic variables to produce distinctive vegetation communities and to have a similar pattern of response to disturbance and management actions. Ecological Site Descriptions (ESDs) are interagency-developed documents that describe vegetation potential and the natural range of variation in these variables within an Ecological Site. Two components of ESDs frequently used by the Bureau of Land Management (BLM) are the state-and-transition model (STM) and the Interpreting Indicators of Rangeland Health (IIRH) reference sheet. STMs are conceptual schematics of plant community dynamics in response to disturbances, land uses, and biological processes. IIRH is an ecological assessment protocol that evaluates soil/site stability, hydrologic function, and biotic integrity of an evaluation area by rating observed departures of a suite of seventeen qualitative indicators from conditions documented in a reference sheet and reflective of the natural range of variability for an ecological site. The Idaho BLM is reviewing priority ESDs to better understand site potential and management responses for seven ecological sites, representing the majority of designated greater sage-grouse (*Centrocercus urophasianus*) habitat in Idaho. Empirically developed STMs and reference sheets are critical for assessing ecological responses to land management, particularly in habitat for species of concern such as *C. urophasianus*. Achieving this goal requires extensive landscape-scale soil and vegetation data. Assessment, Inventory, and Monitoring (AIM) is a BLM monitoring protocol implemented throughout the agency's jurisdiction that provides vegetation and soil data to guide management decisions across spatial scales, ranging from local field offices to all BLM lands nationwide. Here, we will demonstrate how AIM data can inform the development and update of STMs and reference sheets, and better tailor these components of ESDs to the implementation of IIRH.

Using Assessment, Inventory and Monitoring Data for Adaptive Management of Northern New Mexico Rangelands

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As the relevance of public renewable resources becomes more apparent, the need to accurately document changes in these resources is growing. In particular, it is important to understand how restoration actions may affect different landscapes. Due to a lack of standardized monitoring, the Bureau of Land Management (BLM) developed the Assessment, Inventory and Monitoring (AIM) strategy. The AIM approach is based on five key elements: 1) a standardized set of core and contingent indicators, 2) an appropriate sampling design, 3) a structured implementation process, 4) electronic data capture, and 5) integration with remote sensing. This strategy can help to more efficiently meet national, regional and local resource information needs. The Taos Field Office (TFO) has used the AIM protocol for four successive years to monitor vegetation treatment effectiveness and inventory wildlife habitat. Here we discuss the implementation of AIM protocols and use AIM data to describe five piñon pine (*Pinus edulis*) and juniper (*Juniperus monosperma*) thinning areas as well as six sagebrush (*Artemisia tridentata*) removal treatments in Taos, New Mexico. Indicators relevant to wildlife habitat such as vegetation composition, soil stability and tree density were compiled from these treatment areas and compared to non-treated areas within the same Ecological Sites. Data from non-treated areas were used as a ‘reference’ to evaluate each vegetation treatment with respect to their management objectives. Reference data was grouped using three nested methods based on: species composition from desired plant community phases described in state and transition models, ecological sites derived from soil and landscape characteristics and, and groups of similar ecological sites. Evaluations using this reference data showed improved desirable species cover following chemical application compared to mechanical treatments. Summarizing AIM data in this way is an effective means of leveraging available data and creates an accessible tool for adaptive management.

Using Biodiverse Seed Mixes to Buffer against Plant Establishment Failures During Ecological Restoration

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Plants seeded during ecological restoration sometimes persist but more often fail to establish. Biodiversity has been shown to stabilize ecological processes, suggesting more biodiverse seed mixes may provide more consistently successful plant establishment. Particularly, it may be possible to design seed mixes to increase chances at least some species/biotypes will survive whatever environmental conditions arise after seeding. To explore this possibility, we conducted 30 field experiments (15 sites × 2 seeding years) in a big sagebrush (*Artemisia tridentata* Nutt.) ecosystem in Idaho, Nevada and Oregon. In each experiment, three native grasses were sown (600 seeds·m^{-2}) in separate plots, and we estimated the probability each species germinated and survived through two growing seasons. Applying an optimization algorithm to the survival probabilities allowed us to assign species identities to 600 seeds·m^{-2} in a manner maximizing the number of experimental conditions yielding ≥5 plants·m^{-2}, a common plant density goal in rangeland restoration. Allocating 353 (216, 555) [point estimate (95% CI)] seeds to *Poa secunda* J. Presl and 247 (11, 378) seeds to *Pseudoroegneria spicata* (Pursh) Á. Löve maximized our native plant density goal (goal achieved in 12 (10, 14) of 30 experiments), and the allocation to >1 species supports the hypothesis biodiverse seed mixes could be designed to reduce establishment failures. Averaged over experiments, *P. spicata* survival was roughly half of *P. secunda* survival, but *P. spicata* nevertheless contributed to the density goal by compensating for low *P. secunda* survival in certain experiments. These encouraging preliminary results led us to begin a longer-term study involving much larger numbers of species/biotypes, and we will present results from the first two of five years of this study. Strategically combining species/biotypes with different seed/seedling traits may increase chances of achieving adequate plant establishment during ecological restoration.

Using COMET-Farm and COMET-Planner to Assess Potential Greenhouse Gas Reductions in Livestock Management

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The USDA-NRCS COMET-Farm© and COMET-Planner© tools give producers and natural resource professionals the capacity to assess how conservation activities reduce the net greenhouse gas emissions from agricultural operations. Trace Gases from livestock production are a significant source of greenhouse gas emissions, accounting for one-third of direct greenhouse gas emissions from the U.S. agricultural sector, or ~3% of total annual U.S. emissions from 1990-2015 and ~18% of total worldwide emissions. Major emissions sources are enteric methane from ruminants as well as methane and nitrous oxide from livestock manure. Without emissions reductions in the agricultural sector, the proportion of emissions from the livestock sector is likely to rise, as renewable energy and emissions reductions technologies infuse the energy and transportation sectors. Livestock emissions sources represent an important conservation opportunity for the agricultural sector. In the COMET© tools, users may describe their current livestock operation and superimpose conservation scenarios on their current operations by adjusting feed rations, grazing intensity, grazing timing, and/or modifying manure management methods to gauge the potential greenhouse gas reduction benefits of management changes.

Using Ecological Site Descriptions and State and Transition Models to Inform Native Plant Restoration Strategies

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The 2008 Tejon Ranch Conservation and Land Use Agreement required an adaptive management plan for over 200,000 acres of conserved lands, including vast expanses of rangelands on which the landowner retained the right to graze cattle. Ecological Site Descriptions (ESDs) and State and Transition Models (STMs) were developed for over 100,000 acres of grasslands using a field-based, data-driven approach. In the southern San Joaquin Valley side of the ranch, we identified ecological sites that support states dominated by native plant communities with high native forb species diversity and abundance. These forb-dominated communities have naturally lower fall biomass, as measured by Residual Dry Matter (RDM), than nonnative annual grass-dominated communities, and support several vertebrate species of conservation concern (e.g., San Joaquin kit fox and blunt-nosed leopard lizard) that are hypothesized to prefer low plant biomass conditions. By linking STMs with field data about temporally dynamic environmental conditions, we identified the interactions between annual Mediterranean weather patterns and ecological sites as drivers of native and nonnative plant-dominated community phases and states, which in turn influence conditions for other conservation targets. Our adaptive management plan used ESDs paired with STMs to identify the spatial distribution of grassland types and focal species, understand drivers of the temporal transitions of specific grassland types and the feasibility of achieving desired conditions, and hypothesize grazing strategies to promote conservation values. For instance, a recommended practice to achieve conservation objectives in the Holocene Alluvial Flats Ecological Site is to maintain RDM <500 lbs/acre, particularly in years with high levels of rain early in the growing season that encourages nonnative annual grass growth and high RDM conditions. To help facilitate this practice, the Conservancy and the ranchers cooperated to install new fences and waters in pastures supporting Holocene Alluvial Flats Ecological Sites.

Using Ecophysiology to Draw Inference into Grassland Ecosystems Management

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Grassland ecosystems are comprised of diverse assemblages of grasses, forbs, and woody plant species. These species often have unique physiological and morphological mechanisms that facilitate persistence and require tradeoffs that balance competitive efficiency for resources, and an ability to tolerate (or avoid) frequent periods of resource limitation. In addition, alterations in bottom-up or top-down drivers (or their interactions) have the potential to modify coexistence dynamics among diverse species assemblages. Here, I will present a conceptual overview linking the physiological and morphological characteristics among C4 grasses, C3 forbs and C3 woody plants using long-term data from the Konza Prairie LTER, and Kruger Park, South Africa. These data include long-term observations of grassland change based on legacies of fire management, as well as short-term experimental manipulations of drought and woody-plant removal. Fundamental ecophysiological differences among these plant types are manifest as distinct traits when competition for water is high compared to coexistence when water is plentiful. Ultimately, these hydraulic traits and ecohydrological strategies among key species influence landscape patterns, ecosystem processes, and susceptibility to drought in many grasslands and savannas. Identifying these unique plant traits may prove useful for successful ecosystem management by utilizing management strategies that increase stress among undesirable species and maximize the likelihood of mortality during prescribed fires.

Using GPS Collars and Daily NDVI Images to Assess Grazing Spatial Dynamics

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Tanglehead (*Heteropogon contortus*) is a grass native to south Texas that has begun to behave like an invasive, forming monotypic stands that contain course stems often unpalatable for cattle. With the development of daily satellite imagery, remote sensing provides new capabilities to monitor landscape changes at greater spatial and temporal resolutions. This research aims to evaluate the effectiveness of using daily satellite imagery and GPS collars to monitor cattle utilization of tanglehead. The study site is a 96 ha (236 ac) pasture heavily invaded by tanglehead, located in Jim Hogg County, Texas. This site is being used to test patch burning and continuous cattle grazing treatments to increase plant species richness and forage palatability. GPS tracking collars were placed, three months before burning, on eight of the 10 cows that grazed the pasture, each collar recording a location every 10 minutes for a period of 15 months after burning. One satellite image was downloaded from each month of the study using the Planet© archives. Each image was classified in ERDAS into four classes: woody, tanglehead, non-tanglehead herbaceous, and bare cover. GPS locations during prime grazing hours were used to look at NDVI and cover class in a 5-day span from the image acquisition. Cattle utilization of tanglehead decreased from 34% before burning to 16% after burning, while non-tanglehead herbaceous utilization increased from 34% before burning to 65% after. Burned areas were classified as non-tanglehead herbaceous because there was no difference in NDVI between burned areas and non-tanglehead herbaceous cover. The decrease in tanglehead utilization and the increase in non-tanglehead herbaceous utilization is associated with the re-emergence of tanglehead from burned areas which is more palatable than mature tanglehead forage. This demonstrates that classification of aerial imagery in conjunction with GPS tracking collars can be effective at determining cattle utilization of cover-types.

Using Livestock to Regenerate Soils at Stony Creek Farm

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Dawn Breitkreutz, Rancher, Rewood Falls, Minnesota
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Grant and Dawn Breitkreutz have operated Stony Creek Farm in Southwest Minnesota since 1996, which consists of beef cattle and row crops. When they started farming, pastures were continuously over-grazed. The animals grazed for 3-3.5 months and were on feed the remainder of the year. The cropland consisted mainly of corn, soybeans, hay, and a small amount of wheat. Management of the cropland relied on tillage, herbicides, and synthetic fertilizers. Looking for ways to improve sustainability and profit, Grant and Dawn began to make management changes in the late 1990s that involved using livestock to regenerate soils. They implemented management intensive rotational grazing systems on their pastures, which involves moving animals to new pasture every 1-3 days followed by long rest periods of 6-8+ weeks while also leaving higher amounts of plant residue behind. Due to these management changes, grazing periods AND stocking rates have dramatically increased. In 1998, Grant and Dawn began making changes to their cropland management. They started no-tilling soybeans and slowly started no-tilling other crops. As of 2012, they have been complete no-till on all crops. The cropping rotation has changed to include equal shares of corn, soybeans, and small grains. The Breitkreutz's have also increased the diversity in the cropping rotation by adding cover crops. Cover crops are inter-seeded into standing corn and planted after the soybeans and small grain are harvested. Livestock have also been integrated into their cropland management to graze crop residues and cover crops by following similar grazing management protocols that they implement on their pastures. Incorporating no-till, cover crops, and livestock onto the cropland has allowed the Breitkreutz's to reduce the amount of fertilizer and herbicide use on cropland as well as extend the grazing season for the cow herd, which has improved the sustainability and profit on the farm.

Using Raster Soil Maps to Inform Oil and Gas Reclamation

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Soil is a core resource in determining ecological potential via water storage, nutrient availability, and soil chemistry constraints on organisms. Understanding the basic soil properties that control these higher-level functions, such as soil texture, salinity, pH, depth to bedrock, among others, can streamline planning reclamation actions, including following oil and gas development. Although conventional soil maps, like the soil survey geographic (SSURGO) database, provide estimates of these parameters, they are not derived with a validated statistical method, and are generally mapped at a scale not suitable for providing well pad estimates of soil properties. Fortunately, there have been large advances in predictive mapping capacities in the soil science community in the last few decades, and mapping these properties on a 30 m or finer raster grid scale is becoming feasible. New predictive soil maps provide a consistent basis for reclamation planning, as well as broad scale monitoring of oil and gas reclamation outcomes. Raster soil maps along with new maps of ecological site groups in concert with remote sensing can help industry and agency specialists prioritize work and broadly plan strategies for reclamation (e.g., custom seed mixes, mechanical site preparation, amendments). In this presentation we explore the most current soil maps available, and give examples of how they can be used for assessing and planning reclamation efforts.

Using Remote Sensing to Model Recovery of Sagebrush Following Oil and Gas Extraction

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Energy production is a common and increasing land use in sagebrush-dominated (*Artemisia* spp.) ecosystems such as in Wyoming. While much of our understanding of how sagebrush recovers is informed by numerous localized studies, there is a paucity of research quantifying the spatial and temporal factors influencing recovery across landscapes in the context of different disturbance types. Using remotely-sensed estimates of vegetation collected from southwestern Wyoming (1985-2015), we developed a framework for modeling changes in sagebrush cover over time from 375 inactive well pads that no longer produce oil and gas. We found that trends in sagebrush cover are dynamic and vary with seasonal and annual weather as well as with site-level conditions such as soils, elevation, and well pad size. The rate of change in sagebrush cover was lowest during years with cool and dry weather and increased with greater moisture and temperatures. The rate of change in sagebrush cover also increased and decreased with greater percent sand and well pad size, respectively. Many of these results conform to previous studies at fine scales, but here we use estimates from our models to predict and map time to recovery across the landscape. These maps can help land managers by informing future restoration efforts or identifying appropriate sites for mitigation with respect to disturbances from oil and gas production. We also can apply these methods to a variety of disturbances (e.g., treatments and fires) across sagebrush-dominated landscapes and estimate recovery rates based on the type of change, providing spatially-explicit maps to inform management of sagebrush ecosystems.

Using Step-selection Functions to Understand Free-roaming Horse Selection for Dynamic Resources

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Aridland systems typically exhibit unpredictable variation in both quality and quantity of resources across space and time. Species that evolved within these systems should be able to adjust their movements in response to such dynamism. However, introduced animals, such as free-roaming horses (*Equus ferus*) and cattle (*Bos taurus*), may not respond accordingly. Quantifying the ability of introduced animals to track resources changes is not necessarily straightforward given commonly used spatial analysis tools. For example, resource selection functions (RSF) are useful for quantifying broad-scale habitat selection, but offer limited insight into how animals select for dynamic resources as they move across the landscape. Conversely, by modeling selection across movement steps and incorporating temporal changes in resources, step-selection functions (SSF) allow for such understanding. To understand if introduced free-roaming horses track aridland resource dynamics, we initiated a GPS-tracking project on wild horses in the Red Desert of Wyoming. In 2017, we fit 37 adult mares with GPS collars in the Adobe Town Herd Management Area (HMA) of southcentral Wyoming. This is an ideal study site as it is a large (~1,940 km^2) and relatively unfenced area allowing for unrestricted movement; and is restricted by precipitation with annual 30-year normal precipitation ranging from 146-207 mm. Vegetation is dominated by sagebrush (*Artemisia* spp.) and saltbush (*Atriplex* spp.) communities with sparse herbaceous cover. Here we discuss the theory of SSF modeling and present preliminary results to illustrate how SSFs can enhance understanding of wild horse response to changes in forage quality, biomass, and distance to water.

Using STMs to Inform and Assess the Restoration of Ecological Processes on Rangelands Affected by Energy Development

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Restorations on interim oilfield sites to a historical reference state do not always follow the trajectories depicted in State and Transition Models (STM). Biotic as well as abiotic conditions (e.g., plant invasions, loss of soils surface) have most often changed and the potential to grow specific types and amounts of vegetation may no longer be what is expected based on a historical reference. Furthermore, the management interventions necessary to transition from one ecological state to an acceptable restored state are sometimes not applicable in a restoration context. We evaluate the utility of STMs to inform and assess restorations using an experiment in which a seven-species perennial grass mix with different combinations of cover crops were planted in oil pad reclamations. Measures of plant establishment and Interpreting Indicators of Rangeland Health (IIRH) were used to assess reclamation and restoration success. We found that cover crop treatment and grass mix treatments were not significant determinants of perennial grass establishment, while soil nutrients appeared to drive early revegetation establishment. IIRH results trended towards improvements in soil and site stability, hydrologic function and biological integrity when a cover crop was planted. We discuss results in a state and transition model context and identify benefits and drawbacks of taking a species establishment versus an ecosystem process approach to determining restoration success.

Using Telemetry as a Landscape Analysis Tool to Assess Wild Turkey Habitat in South Texas

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Radiotelemetry is a common tool used to locate and track many different forms of wildlife. However, triangulation errors occur as a result of location error, mapping error, signal bounce, proximity of surrounding vegetation, electromagnetic effects, animal movements, distance effects, and observer error. Confidence ellipses have been used to combat inaccuracies in triangulations, yet there is little research on the effects of the size and shape of these ellipses on error estimates. We used error ellipsoids derived from telemetry triangulations conducted in 2004 and 2005 to obtain estimated Rio Grande wild turkey locations. Telemetry locations were calculated using LOAS to generate error ellipse areas drawn from triangulated coordinates. There were approximately 1,400 initial error ellipses derived from locations taken on 90 turkeys during breeding and wintering seasons over a two-year span. We calculated the major and minor axis for each ellipsoid, which will be used for filtering the data based on the ratio between the minor and major axis. We classified 40 digital aerial images from the Texas Natural Resources Information System into three classes: woody, herbaceous, and bare ground. We will use the classified imagery to assess landscape structure within selected ellipsoids. The metrics we will use to assess landscape structure are percent woody cover (P-LAND, %), largest patch index (LPI, m^2), mean patch area (MPA, ha), aggregation index (AI), edge density (ED, m/ha), patch density (PD, patches/100 ha), and Euclidean nearest neighbor distance distribution (ENN_MN). Landscape metrics used in this study link vegetation spatial patterns and provide information on the spatial structure for wild turkey habitat. This is the first step in building spatial models to quantify and assess breeding and wintering habitat for wild turkeys in South Texas.

Using Trigger Points to Manage Livestock Grazing on Rangeland During Drought In the Northern Plains

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The early detection and rapid response to drought is needed to minimize degradation of grassland resources and lost livestock performance. Drought, a normal part of the climate for virtually all regions of the U.S., is of particular concern in the West, where an interruption of the region's already limited water supplies for extended periods of time can produce detrimental impacts to the herbage production for livestock feed. Timing of moisture is critical when determining direct impact on vegetative production. Analysis of 14 data sets collected across 11 years in eastern Montana revealed that on average, 35, 69 and 91 percent of perennial grass production is completed in eastern Montana by May 1, June 1 and July 1, respectively. The 91 percent completion by July 1 was consistent across years in eastern Montana. From this, the opportunity to grow substantial amounts of forage after July 1 is limited. In western and central North Dakota, 75 percent of perennial grass production is completed by July 1 and more than 85 percent is completed by Aug. 1. Thus, proactive stocking rate adjustments can be made with considerable confidence for the Northern Plains, including North and South Dakota, eastern Montana and western Minnesota, thereby reducing ecological and economic risks that arise from late-season forage demand/availability imbalances. Moisture later in the season, such as August and September, also can influence forage production, specifically cool-season grasses. Cool-season grasses have fall regrowth potential, allowing producers to harvest forage that would be available and palatable. It should be noted, this growth is relatively small in terms of total biomass produced since plants have already matured, and late-season biomass rarely exceeds 20 percent of total growth. Grassland managers and ranchers deal with drought before, during and after its onset. The most effective management for drought occurs before the drought happens by practicing good rangeland management and having a financial plan that includes drought contingency options. Proper implementation and timely reaction to drought should reduce short- and long-term effects. Monitoring precipitation early will help determine if the drought response triggers have been met.

Using Geospatial Technologies to Optimize Brush Management on a South Texas Rangeland

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Brush encroachment is a limiting factor for ranching operations in the Southern United States. Increased brush cover reduces the amount of available forage, decreasing overall carrying capacity, with decreased profits, especially on long-term lease properties. Geospatial technologies have been used to evaluate the spatial and temporal dynamics of brush cover on rangelands. These technologies can also be used to optimize brush management and brush removal by integrating ecological site description spatial data into brush cover data. The specific objectives of this project were to (1) quantify the increase of brush cover between 2006 and 2018 on a south Texas rangeland (3,887 ha) and (2) to evaluate the potential benefit of integrating spatial soil data with brush cover to optimize a brush management program. We acquired National Agriculture Imagery Program (NAIP; 1-m resolution) for 2006 and 2016 and satellite imagery from Planet Labs Inc. (3-m resolution) for 2018 on a south Texas ranch property. Imagery was classified into woody and non-woody using an unsupervised classification. Overall accuracy of image classification was 83 percent. Spatial soil data was acquired from the NRCS web soil survey and forage potential was determined for each soil type based on three precipitation conditions: favorable, average or unfavorable. Soil data was integrated with brush cover and soils were selected based on their potential forage productivity. A comparison between current potential forage production and post brush-removal potential forage production was conducted. Woody cover increased from 449 ha in 2006 to 1,772 ha in 2018. An average of three percent of grazeable area is lost each year. If brush removal on most productive soils is conducted, then ranchers can implement brush management practices on soils with the greatest economic return. This information can help ranchers develop strategies to increase forage production, carrying capacity and profitability on rangelands.

Utilization and Beef Cattle Production on Pastures of Fertilized Smooth Bromegrass and Smooth Bromgrass/Legume Mixtures

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Smooth bromegrass (*Bromus inermis*), an invasive, cool-season grass in the central and northern Great Plains, is a valuable pasture grass used in both intensively and extensively managed beef production systems. Smooth bromegrass responds to moderate levels of nitrogen fertilizer with a 30% increase in aboveground production. Interseeding legumes into smooth bromegrass monocultures can increase aboveground production without the financial and environmental expenses of nitrogen fertilizer. The objectives of this study were to compare forage and animal production between fertilized smooth bromegrass and smooth bromegrass-legume pastures and monitor the persistence of interseeded legumes. The study site, a smooth bromegrass pasture, was divided into six paddocks of equal size (1.2 ha). Three of the paddocks were randomly selected and interseeded with a mixture of alfalfa (*Medicago sativa*), red clover (*Trifolium pratense*), and birdsfoot trefoil (*Lotus corniculatus*). In each paddock, four yearling steers stocked at 11.5 AUM/ha were rotated through six fenced strips with 4-6 day grazing periods and four grazing cycles in April-September 2013 and 2014. Put-and-take steers were used to maintain similar grazing pressure among paddocks. The cattle were weighed at the beginning and end of each grazing cycle. Five exclosures (1 m^2) were placed in each paddock prior to the initiation of grazing. The vegetation in exclosures was clipped at ground level in mid-June and late September to estimate forage production each year. Total forage production did not differ between the two treatments and exceeded 10 Mg/ha each year. Average daily gain of the grazing steers (0.79-0.92 kg/head) did not differ between treatments; however, steer days of grazing were greater for the bromegrass-legume than the fertilized bromegrass pastures (571 v 487, respectively). Legume production (2 Mg/ha) did not change over the life of the project. Interseeding legumes into bromegrass pasture extended the grazing season and/or capacity.

Variable Restoration Success: Analyzing Trends to Inform Active Management in Drylands

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Severe land degradation is estimated to affect up to 20% of global dryland systems, and millions of hectares continue to be degraded each year. Over the past 20 years research targeting the restoration of these systems has expanded across the globe. Tools such as State-and-Transition Models advise when and how to actively intervene for reversing degradation. When active intervention is required, restoring biodiversity and function often can be achieved through species reintroductions. A first step in effectively restoring species is to pinpoint broad drivers of seed success in drylands. The developing Global Arid Zone Project (GAZP) aims to bring together data from studies around the globe to track overall trends in seed-based dryland restoration. Here, we present initial results of the first data collection effort, including an overview of seed success as it relates to site-level climate conditions, seeding strategies, and landscape disturbance. We provide a description of GAZP and its emerging network, which aims to connect restoration researchers and practitioners through sharing of the publicly available data-sets, communication and authorship. Though the cornerstone of dryland restoration often rests on seeding foundational species in degraded systems, the practical result of seeding is often limited germination, recruitment, and survival of the seeded species. Projects like GAZP explore limitations to our current restoration strategies and can inform more effective future strategies to achieve active intervention goals.

Variables Influencing the Management of Cattle Ranches of Eastern Paraguay and Eastern Uruguay

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The long-term success of cattle ranching operations lies, in great part, on proper management for soil and water health. While ranchers may attempt to prioritize the state of these resources, there are physical, historical and political variables that call for tailoring approaches to management. I compared ranch management in Paraguay and Uruguay, which are part of the Grassland Alliance of the Southern Cone of South America. The context wherein these countries work towards sustainable cattle ranching differs significantly. This is particularly true for the technology and infrastructure used for management in Uruguayan ranches as these are typically funded by federal projects. On the other hand, the few conservation practices found in Paraguayan ranches are typically self-funded as federal funds are unavailable for these purposes. The Grassland Alliance continues to prioritize results instead of management regimes, which are highly influenced by each country's contextual reality. This presentation will explore management approaches by Uruguayan and Paraguayan ranchers who are part of the Grassland Alliance and face variability in hydrological, ecological, geological, political, and historical contexts. This comparison will provide an array of case studies, from both countries, as evidence of how important it is to allocate federal and local support to management approaches that fit ranchers' needs.

Variation of Seed Banks among Ecological States in the Chihuahuan Desert: Implications for Restoration

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State transitions involving the encroachment of shrubs and loss of herbaceous species are known to be highly persistent in the Chihuahuan Desert, even when disturbances are reduced and shrubs are removed. The existing seedbank in these soils is poorly documented and seed bank limitation might constrain the recovery of historical herbaceous communities. From 2015 to 2017 we conducted a germinable seed bank study by collecting a total of 258 soil samples (each measuring 796 cm^3) from randomly selected sites on 190,000 acres of the Jornada Experimental Range in Southern New Mexico. Sites were stratified by ecological states within each of the 10 ecological sites found on the range. Over a two-year period, these samples were provided ample water and monitored in greenhouse conditions. The soil yielded 12,777 seedlings from 159 species of vascular plants. Variance partitioning and redundancy analysis showed that ecological site and state explains significantly more variability in germinable seeds by species than spatial structure alone (15.17% and 5.94%, respectively; p=0.001); however, a considerable amount of unexplained variability exists. Seed banks in degraded states within ecological sites were generally limited with respect to desirable (native perennial) species with the exception of mesa dropseed grass (*Sporobolus flexuosus*) which occurred in 61.24% of the sites and 39.54% of the seedlings identified. Additionally, mesa dropseed is more widely dispersed than other desirable grass species within ecological sites. Our results suggest that seed bank limitation may contribute to the persistent absence of key herbaceous species. The prevalence of mesa dropseed in the seed bank – even where it is not abundant aboveground – suggests that establishment limitations including soil surface degradation and herbivory need to be overcome to trigger mesa dropseed increase, but that seeding may not be necessary.

Vegetation GIS Data System (VGS) Tutorial Video Series

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Vegetation GIS Data System (VGS) is a free software application designed for recording and managing ecosystem sampling data. The application provides a data repository for organizing and managing data, photos, documents, positional coordinates and other information associated with an unlimited number of study sites and electronic tools for recording data in the field. It also provides reports and tools for summary and presentation of results in the field and in the office. Data forms are available for a variety of vegetation sampling methods and can be designed for specific protocols and needs. Dr. Del Despain created the program at the University of Arizona with the first version released in 2007. Since then VGS has become widely used across the nation. Rangeland management professionals with the Forest Service, Bureau of Land Management, Natural Resource Conservation Service, University of Arizona, University of Idaho, Utah State University, Colorado State University, Texas A&M, private ranches, consulting firms and foundations are currently using the program. Due to the program's widespread use, video tutorials were created to provide around-the-clock service and support users as they work through basic issues. The tutorial videos are divided into brief sections that cover specific help topics and are a maximum of 10 minutes.

Water Induced Soil Erosion Problems and Management in Jicarilla Apache Range Lands

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Lambert Chee, US Department of Interior, Dulce, New Mexico
Kurt Sandoval, US Department of Interior, Dulce, New Mexico
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Severity of water erosion in Jicarilla Apache Range lands is so great that huge gullies can be seen everywhere on the reservation. This could be attributed to extensive road network development on highly erodible soils to service oil and gas developments. To date, no study has been conducted to document how much sediments have been transported through sheet and rill erosion and road development disturbances toward these gullies. The primary objective is to report innovative soil and water conservation work of Mr. Kurt Sandoval and determine the mass of total soil sediments conserved. Mr. Sandoval is the permittee of Range Unit 52 (winter and summer), who has built five earthen dams against runoff flow path at various interval lengths along the dry creek in 2014. This created runoff collection ponds for drinking water to his 115 cattle and wildlife. These ponds were named as Pond 1, 2, 3, 4, and 5. The areas of these ponds were 0.35, 0.21, 0.14, 0.12, and 0.57 hectare and depths of these ponds were 2.5, 4.0, 2.5, 2.5, and 1.2 meter, respectively. By 2017, these ponds were all filled up with soil sediments. Surface soil bulk density of these deposited soil sediments was 1400 $kg \cdot m^{-3}$. Estimated mass of total dry soil sediments deposited in five ponds were 11,881, 11,449, 4697, 4006, and 9671 tons, respectively. We conclude that constructing several sediment catchments upstream might extend the life of the pond and can serve as an excellent example of a best management practice for soil, water, and nutrient conservation, where ranchers can also have plenty of drinking water for livestock and wildlife for many years to come. Minor design modification of the earthen dam construction is recommended by including overflow mechanism, addition of clayey materials, and installing several upstream sediment catchment structures such as vegetative filter strips.

What Is the Basis for Grazing Distribution: Nature Vs. Nurture?

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Concerns with cattle grazing in the western U.S. are usually not a consequence of too many cows, but rather, are due to cattle selectively concentrating use in certain areas while avoiding others. Land managers can improve uniformity of grazing by using water, salt, supplement, fencing, and herding to encourage cattle to graze underutilized areas. Although these traditional range management practices are effective, they can be expensive, require regular maintenance, and may not be practical. Disparate terrain use observed among individual animals is apparently affected by both nature and nurture. Nearly 30 years ago, Howery and associates demonstrated that natural mothers (as well as foster mothers) influenced the distribution patterns that their calves (and foster calves) exhibited later in life, which provided evidence that learning was an important nurturing factor that managers might be able to use to their advantage. For example, selecting or culling cows with favorable or unfavorable distribution patterns over several years could collectively, albeit slowly, improve distribution of a cattle herd through both nature and nurture mechanisms. However, this approach works only if movements of individual cows can be intensively monitored to identify superior and inferior phenotypes. Recently, Bailey and colleagues demonstrated a relatively strong association between cattle terrain use and multiple genetic markers near candidate genes, suggesting that cattle distribution is a heritable trait that is also influenced by nature. This new discovery raises the prospect of selecting bulls and cows with favorable “distribution” genotypes to provide ranchers and land managers with a powerful, time efficient, and relatively inexpensive tool to much more rapidly improve distribution patterns of entire herds without the need to intensively track and monitor grazing distribution patterns of individual cows. These new “broad brush” DNA tools have the potential to significantly improve both economic and ecological sustainability of working ranches on public lands by expanding the forage base for cattle while simultaneously attenuating overuse of riparian areas and other critical habitats.

What Role Do Plant Communities Have in Shaping Our Responses to Cool-Season Invasive Grasses?

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Kentucky bluegrass (*Poa pratensis* L.) and smooth bromegrass (*Bromus inermis* Leyss.) are two invasive cool-season grasses that have increased in abundance on native cool-season dominated grasslands in the Northern Great Plains. Many restoration efforts have focused on the invasive grasses and their responses to control treatments. This presentation will review several studies, based in North Dakota, which provide information on how communities can shape species' responses to treatment. The first study evaluated the responses of Kentucky bluegrass, smooth bromegrass and native grasses in five different community types ranging from invasive grass dominated to native grass dominated. Response to treatment varied depending both on which invasive species was being targeted and the community which those species occurred. Warm-season native dominated communities responded well to a burn plus herbicide treatment while the same treatment decreased native grasses in the Kentucky bluegrass dominated communities. In a study based on sandhill rangelands in eastern North Dakota, different burning and herbicide treatments were tested on three communities with different levels of Kentucky bluegrass invasion. The largest positive response in relative species composition for the high and moderate level of Kentucky bluegrass invasion occurred with a fall burn followed by a spring application of glyphosate. However, in areas with low levels of Kentucky bluegrass all treatments were similar by the end of the study. Therefore, land managers should incorporate community considerations into their restoration strategies.

What's In Store? Can Plant Traits Explain Changing Rangelands, and Do Seedbanks Suggest Alternative Futures?

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Environmental uncertainty poses a challenge to vegetation management – no two parcels are the same, and it can be difficult to anticipate potential changes in response to climate. Plant traits (root, leaf, and seed attributes) are increasingly being used to understand how particular species and whole communities respond to environmental change. However, while most efforts use only what plants are present aboveground generate predictions, responses over time also rely on which plants can recruit from the seedbank. The seedbank could store a wider range of plant functional diversity, which may boost vegetation resilience, or contain only a subset of the aboveground vegetation, which may constrain potential responses. In this study, we ask (1) whether traits are a good indicator of plant abundances across a soil gradient and (2) whether the composition and trait diversity of seedbanks differs from the aboveground vegetation. We sampled plant and seedbank composition across 12 xeric tallgrass prairie sites on grazed public lands in Boulder, CO. The sites span a soil age gradient, where soil properties result in different soil moisture dynamics under similar rainfall patterns. Species composition and richness differ substantially over the gradient and relate to plant traits associated with soil water use and tolerance. The match between seedbank diversity and vegetation diversity also varied across the soil gradient, suggesting some areas where seedbanks may limit and other areas where seedbanks may expand responses of the vegetation to changing conditions. We show how exploring ties between plant functional traits in the vegetation as well as the seedbank over space (e.g., across a soil moisture gradient) could provide insight into which communities will be better able to track changing environmental conditions and where management interventions may boost rangeland resilience.

When Patience Pays, and When It Does Not, in Prairie Reconstruction

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Most practitioners of prairie reconstruction realize that the first few years of a new reconstruction are fraught with anxiety-producing vegetative manifestations. The towering giant ragweed we are fairly certain will be outcompeted in short order, but what about the species that are known to be troublesome in the long-term? When is it reasonable to trust in the power of the species we are nurturing to fend for themselves, and when should we initiate an intervention? What is a reasonable time to wait for seeded species to express themselves in the vegetation? To answer these questions, there is no substitute for long-term studies of reconstructions with known planting methods, land use history, and management. Two ways to gather these kinds of data are 1) to initiate a large, long-term experiment designed to address them; and 2) to retrospectively observe the outcome of reconstructions planted over time. Results of nine experimental reconstructions initiated in 2005 on US Fish and Wildlife Service land in Minnesota and Iowa have suggested that patience pays with respect to most invasive forbs (e.g., *Cirsium arvense*, *Carduus acanthoides*, *Sonchus arvensis*, *Daucus carota*), but the same cannot be said for cool-season invasive grasses (e.g., *Bromus inermis*, *Poa pratensis*) which were still increasing 10 years after reconstruction. Species richness, on the other hand, requires extreme patience. The experimental studies as well as retrospective studies at two US Fish and Wildlife Service refuges indicate increasing species richness and often increasing coefficients of conservatism 10-12 years after reconstruction. Knowing when to expect various benchmarks of progress can help managers and practitioners better judge when to intervene, and when to have patience.

Wild Horse Walkabout: A Journey of Collaborative Discovery

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In early fall 2018, BLM Wild Horse and Burro Specialist for Northern California BLM hosted a three day, two night camping excursion in a herd management area and invited wild horse advocates. Sequential curriculum and experiential learning helped participants gain a basic understanding of soils, plants, herbivore physiology and morphology, carrying capacity, stocking rate, ecological sites, ecosystem resilience and resistance, and ecosystem monitoring. Pre- and post-tests showed substantial increase in participant knowledge and evaluations showed a high level of satisfaction. Success of the event was attributed to units of curriculum built upon one another and field activities designed to enhance the learning environment.

Wild Horse, Livestock and Wildlife Use of Lentic Meadows: Influence on Sage-grouse Conservation in Nevada

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Jacob Burdick, Univeristy of Nevada, Reno, Reno, Nevada
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In Nevada, many lentic meadows are non-functional or functionally at risk, threatening the long-term stability and short-term quality of critical late-brood rearing habitat for greater sage-grouse (*Centrocercus urophasianus*), a focal species of conservation efforts in much of the Great Basin and the Arid West. What puts these riparian areas at risk, however, is often debated where cattle (*Bos taurus*), federally protected wild horses (*Equus ferus caballus*), and wild ungulates are all present on public lands. In 2016, 2017 and 2018 we used time-lapse trail cameras to establish the timing, duration and number of grazers using 12 meadows across Nevada. All meadows were within designated core sage-grouse habitat where both cattle and wild horses grazed. We investigated how grazing patterns influenced the quantity and quality of sage-grouse preferred forb species such as dandelions (*Taraxacum officinale*), and how grazing patterns affected the abundance and structure of stabilizer species such as Nebraska sedge (*Carex nebrascensis*), which are important for the long-term stability of meadow morphology, hydrology, and vegetation. We measured forage quality for sage-grouse chicks based on the abundance, phenology, and succulence of their preferred forb species throughout the meadows and adjacent upland transition zones. In addition, we measured the short-term effects of grazers on stabilizing vegetation along the central flow path through the meadows, specifically stubble height, hoof-alterations and stabilizing species cover and composition. This research will help improve our understanding of how wild horse and cattle grazing management is supporting or detracting from current management goals identified by federal land management agencies, and how grazing management strategies might be improved moving forward.

Will Prescribed Fire Exacerbate or Constrain *Ventenata dubia* in the Pacific Northwest Bunchgrass Prairie?

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Ventenata (*Ventenata dubia*) is a relatively new exotic annual grass that is rapidly spreading across much of the Palouse and the Pacific Northwest Bunchgrass Prairies (PNBP) of the Pacific Northwest in the United States. Reports about its basic ecology and invasion dynamics are just beginning to emerge, but it is quickly raising concerns about impacts on agricultural production, wildlife habitat, plant community composition, fire spread, and watershed services. There is currently little research looking into prescribed fire management and potential control of ventenata outside Conservation Reserve Program seeded pastures, and many questions about the role of fire remain, especially in the PNBP. The objective of our study was to evaluate how ventenata abundance responded to single and multiple prescribed fires in the last 12 years in the PNBP. We collected data at the Zumwalt Prairie Preserve (ZPP, managed by The Nature Conservancy), the largest remaining remnant of this grassland type. We resurveyed monitoring plots from an established study that was burned in the fall of 2006 and 2016 and recorded ventenata abundance (foliar cover, frequency, and density). Preliminary findings suggest that burning did not increase ventenata abundance as compared to unburned plots. Rather ventenata abundance has been increasing in at the study site regardless of the number of fire treatments. Our results indicate that it is unlikely that fall prescribed burns will constrain ventenata populations in the PNBP.

Will Selection for Grazing Distribution Cause Problems with Rangeland Livestock Production?

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Historically, cattle traits relating to nutrition, reproduction, calf performance, and genetics have driven cattle selection for ranchers. Expected progeny differences (EPD), genetic tests that provide evaluations on an animal's worth as a parent, provide beef cattle producers with reasonable expectations of animal performance. However, these tests do not allow for the vast environmental differences where beef cattle are raised. In order to select animals that are better suited for their home environment, researchers and ranchers have begun looking at grazing behavior data to identify animals that are thought to interact with the landscape better by improving grazing distribution, distances they are willing to travel from water/supplement, and utilize more challenging terrains, like steeper slopes and higher elevations. Researchers have investigated correlations with grazing behavior and pulmonary arterial pressure (PAP), associated with high altitude disease, breed, sire selection, pregnancy, residual feed intake, and environment, among other characteristics. Will selecting for grazing behavior traits interfere with rangeland livestock production? Authors will explore topics of past and current research to help answer this question, and provide insight on emerging trends as tracking sensors such as pedometers, GPS, accelerometers, and RFID (radio frequency identification) become more prevalent in the researchers' and ranchers' arsenal of tools to help improve livestock production and rangeland sustainability.