Continuing projects

Barger, Nichole, Mike Duniway, Becky Mann, Dave Hoover, and Akasha Faist: University of Colorado – Boulder, USGS, USDA, and New Mexico State University

Project: Restoring Ecosystem Services in Highly Degraded Grazing Lands: Testing Novel Approaches and Evaluating Trade-Offs with Current Livestock Management

Research: The goal of this project is to employ the latest technologies and implementation strategies in soil stabilization and native plant establishment to restore important ecosystem services while maintaining agricultural services provided by rangelands.

Baker, Scott, Alexandra Schuessler and Catherine Gehring: Northern Arizona University

Project: Branch micro-fungi colonization and community structure across an elevation gradient in *Populus fremontii*

Research: This project explores the fungal communities living inside woody tissue of the riparian foundation species *Populus fremontii* from low mid and high elevation populations grown in low, mid, and high elevation common gardens. These fungi can act as a pathogens or mutualists for plants, and while some fungi may be of benefit others may be detrimental. Colonization of fungi is highest in the low elevation trees and lowest in the high elevation trees. In contrast, the diversity of fungi found is lowest in the low elevation garden and highest in the high elevation garden. Source population influences endophyte abundance, but the strongest effect is garden location. These results suggest that *Populus fremontii* can host a diverse array of fungi in its branches, but that the fungi found may be site specific.

Best, Rebecca, Gery Allan, Hillary Cooper, Chris Doughty, Richard Lindroth, and Tom Whitham: Northern Arizona University

Project: Consequences of Phenotypic Plasticity for Gene-to-Ecosystem Linkages

Research: This research will test the hypothesis that understanding the evolution of plasticity in locally adapted genotypes will enhance prediction of the impacts of genetic variation at a broad landscape scale. First, the research will use three existing common gardens to investigate how genotypes of a southwestern tree species express different leaf traits in hot vs. cold conditions. Across all gardens, experimental simulation of herbivore damage (physical hole-punching of leaves) will be used to investigate interactive effects of abiotic and biotic stress on multiple leaf traits. Second, the project will test how variation in traits can be predicted from past variation in the environment at each genotype's home location. Finally, litter transplant experiments and surveys will be used to quantify the impacts of changing leaf traits on whole communities of terrestrial and aquatic insects dependent on these trees. Investigating feedbacks between the evolutionary causes and ecological consequences of phenotypic plasticity across a species' range should greatly improve our ability to predict ecosystem persistence across a rapidly changing landscape. The results will help to identify the types of trees that should be planted to support healthy ecosystems.

Cooper, Hillary: Northern Arizona University

Project: Genetic and environmental effects on Fremont cottonwood traits

Research: The common garden established at Dugout Ranch was replicated in central and southern Arizona in order to understand how important tree traits varied not only among 16 different populations from throughout Arizona, but also when these trees were planted in different environments. This information can help manage and restore riparian forests that are threatened with climate change by informing how far you can move a population and how much important tree traits are able to change before tree performance declines. This research was done as part of my dissertation within the grant, "Landscape genetic connectivity of a foundation riparian species: Implications for dependent communities facing climate change and exotic species invasions".

Duniway, Mike and Tara Bishop: USGS-SBSC Moab

Project: Colorado Plateau Extreme Drought and Grazing in Grasslands

Research: The objectives of this project are to conduct experiments that shed light on how drought and grazing by domestic livestock interact in drylands of the southwest and examines if changes in grazing timing may reduce risk during drought. In this new experiment, we propose looking at how different drought mitigation grazing strategies may influence the structure and function of dryland ecosystems of the Colorado Plateau.

Duniway, Mike, Andreas Ciblis, and Matt Redd: USGS- SBSC Moab, New Mexico State University, The Nature Conservancy

Project: Criollo Cattle Project

Research: Our primary research objective is to examine whether Criollo rangeland use and behavior will lead to more sustainable ranching in Canyon Country rangelands as compared to more traditional cattle breeds. In this pilot study, we will attach collars with GPS trackers to 20 animals (10 Criollos and 10 traditional breeds). This research will be in collaboration with researchers from New Mexico State University and the USDA-ARS Jornada Experimental Range who have expertise in livestock and more specifically the study of Criollo behavior. In addition, the NMSU researchers will collect fecal samples from each collared animal for laboratory analysis of diet. With these data, we will be able to ask questions about differences in forage and habitat preference between breeds and the implications of those differences for sustainable ranching on the Colorado Plateau, now and in the future. The data collected from this study may be used to apply for larger grants in the near future, likely from the Sustainable Agriculture Research and Education Program (https://www.sare.org) or other external funding source.

Duniway, Mike, and Molly McCormick: USGS- SBSC Moab, UT and Flagstaff, AZ

Project: Field Trial Network

Research: We propose to deploy an experiment that investigates how decisions related to restoration treatment and seed mix affect recovery of vegetation. This experiment will be part of a field trial network for dryland restoration led by the USGS Southwest Biological Science Center, in collaboration with Northern Arizona University. Field trial sites have been established near Flagstaff AZ and in the Petrified Forest NM. Treatments to be tested

include Con Mods, wood mulch, planting method (seedlings vs. seeds), and making small depressions in the soil surface. There ¼ of the area will be saved for additional studies.

Duniway, Mike, et al.: USGS- SBSC Moab.

Project: BLM Rangeland Plot Monitoring

Research: Continued monitoring, as funding is available, of a subset of the rangeland plots that Mark Miller (NPS-SEUG) established in 2006-2008 while working for the USGS and Matt Van Scoyoc expanded in 2015. Protocols are similar to the National Park Service's upland monitoring conducted by Northern Colorado Plateau Network's Perkins and Witwicki (reported below in the Recently Completed Projects section). Plots span BLM, State, USFS, and NPS lands

Duniway, Mike, Jayne Belnap and David Houser: USGS- SBSC Moab.

Project: Rainout Shelters Simulating 30% Reduced Precipitation

Research: Within a range of 30 miles from Moab, 40 rainout shelters and control plots were installed in 2010 to evaluate the effect of a press-type drought (30% reduction annually) on Colorado ecosystems. Eleven of the 40 sites occur on CRC lands. Sites span a broad range of soils and plant communities. Data on plant performance, cover, and demographics are collected annually.

Duniway, Mike and David Hoover: USGS- SBSC Moab.

Project: EDGE – Extreme Drought in Grassland Ecosystems

Research: Four-year manipulative experiment testing how extreme seasonal drought impacts grassland communities of the Colorado Plateau. This experiment includes both 66% warm season drought and 66% cold season drought treatments on grassland plots with, and without, shrubs.

Ferrenberg, Scott, Nicole Pietrasiak, and Faist, Akasha: New Mexico State University

Project: Investigating the Role of the Soil Surface Microbiome in Germination, Establishment, and Growth of Rangeland Plants.

Research: Our goal is to quantify the variation within biocrust-soil microbiomes and understand its influence on rangeland plant performance in the presence of drought and grazing. Field methods to test this are through targeting mixed grass and forb species and variable biocrust levels undergoing one of four treatments: 1) Grazing (simulated through clipping biomass), 2) Drought (implementing drought structures), 3) Drought + Grazing, and 4) control plots at five blocks of treatments which equals to 80 plots in total across all treatments. We hypothesize that variation in biocrust photoautotrophs will structure the larger soil microbiome and alter plant-available nutrients and compounds in surface soils with important consequences for plant performance. We will assess plant responses to the combined and individual influences of drought, grazing, and variation in soil microbiomes in field and greenhouse studies that quantify plant germination, growth, survival, and stress levels using a series of multi-omics approaches in both the plant and soil microbiomes. This research is potentially transformative in its ability to predict plant-soil interactions and improve management of forage production in rangeland systems.

Heckman, Chris, Nikolaus Correll, Nichole Barger: University of Colorado Boulder

Project: RestoreBot

Research: Degraded ecosystems, i.e. lands that would generally be capable of supporting vegetation but no longer can (frequently due to anthropogenic factors), make up a significant amount of desert land in the western United States as well as globally. These ecosystems require active intervention, often through artificial seeding, in order to recover from this state and support plant life. Such revegetated lands can become significantly economically active for grazing. We propose the active revegetation of desert landscapes through the deployment of autonomous robotic platforms with mobile manipulators that will learn to identify favorable seeding locations, navigate to these locations, and discern small variations in terrain that might affect later site effectiveness. To do this, we will develop new techniques in robotic navigation, environmental perception, and visual-tactile feedback. The end result of this project will be new ecosystems that can support vegetation and that are re-introduced into productivity through active intervention alongside ecologists.

Jech, Sierra: University of Colorado at Boulder

Project: Assessment of Climate Adapted Biocrust Growth Techniques for Restoration of Ecosystem Function on the Colorado Plateau.

Research: This project tracks the survival and viability of biological soil crusts inoculated at a degraded pasture site that were originally cultivated as part of Sasha Reed and Colin Tucker's 2018 proposal. We will compare biocrust inoculum from both the Mojave Desert and Colorado Plateau that have been grown in field conditions to those that have been grown in a greenhouse. We will monitor the chemical signatures of the biocrust community, the genetic composition of the community, as well as ecosystem functions like prevention of soil erosion and increasing soil moisture over time.

Keith, Art, Tom Whitham, and Gery Allen: **Northern Arizona University**

Project: Cottonwood Arthropod Communities on an Elevational Gradient of Common Gardens

Research: This project examines how the arthropod (insects, spiders, and mites) communities found on Cottonwood trees differ along an elevational gradient. Using multiple identical common gardens like the one at CRC, where tree genetics are accounted and controlled for, we examine differences in the arthropod communities they support. These differences are indicative of what may be expected at the landscape scale across multiple environments as change occurs. The project examines how moving trees to different environments (i.e. to both cooler and warmer) affects the arthropod abundance, richness, and diversity of the communities they support. This research is critical for making predictions about the loss or gain of biodiversity in regards to climate differences and plant assisted migration efforts.

Reed, Sasha, Colin Tucker: USGS-Moab

Project: Climate Adaptive Biocrust Restoration to Restore Ecosystem Function on The Colorado Plateau

Research: To cultivate and restore biological soil crusts (biocrusts) at multiple sites in southeast Utah with the goal of re-establishing ecosystem function and building resilience to a hotter and drier future climate.

Rushing, Dr. Clark and Kim Savides: Utah State University

Project: Utah Black Rosy-Finch Study

Research: At CRC we propose installation of a single conventional bird feeder to asses Black Rosy-finch occupancy. This feeder will be stocked with black oil sunflower seed during the winter and monitored periodically for use by rosy-finch species. If rosy-finches are using the feeder, a simple count of Black Rosy-finches will be conducted when feeding is observed. If Black Rosy-finches are seen in large numbers, we would propose integrating CRC into our state-wide network of radio frequency identification (RFID)-enabled bird feeders.

Scamardo, Julianne: Colorado State University

Project: Understanding geomorphic influences on floodplain function in Southwestern ephemeral streams.

Research: Ephemeral and intermittent streams constitute more than 80% of river networks in the American Southwest, yet ephemeral rivers are understudied compared to their perennial counterparts. Ephemeral river corridors provide important ecosystem services in desert environments – such as nutrient cycling and groundwater recharge – and are important migratory pathways. Ephemeral river floodplains, specifically, host unique habitat, with benefits often disproportionate to their size. Habitat diversity on floodplains is thought to be directly related to geomorphic heterogeneity (i.e. the number and variety of geomorphic units). Here, a geomorphic unit is defined as a region of consistent topography formed by a given process (e.g. mid-channel island). However, drivers of ephemeral floodplain heterogeneity are relatively unknown, in part due to limited research on flood frequency and geomorphology of ephemeral river floodplains. Based on prior research on dryland perennial river floodplains, I hypothesize that ecosystem services related to high heterogeneity in dryland ephemeral river floodplains are closely linked to sediment inputs, floodplain morphology, and disturbance via flash floods.

Schaefer, Elena, Catherine Gehring and Justine Karst: University of Alberta and Northern Arizona University

Project: How does mycorrhizal type influence root exudation of a dual-colonized host species, Freemont Cottonwood.

Research: This project seeks to understand the role of mycorrhizal fungi in carbon flow from tree roots to the soil. The type of mycorrhiza may control the flow of carbon from plant roots to soil, a critical pathway to understanding carbon sequestration in soils. Some tree species, such as the Freemont Cottonwood (Populus fremontii), associate with multiple mycorrhizal types simultaneously, making it an ideal model to investigate the distinct influence of mycorrhizal type on carbon flow without the confounding effect of

species identity. Our study has two main objectives: (1) Confirm differences in EM and AM colonization between select cottonwood populations and environments in the American southwest and (2) Determine whether the flow of C from fine roots to soils differs between EM and AM cottonwoods and how this process interacts with the environment.

Veblen, Kari E., Tal Avgar, Eric Thacker, Juan Villalba, Matt Garcia, Maria Stahl, Mike Duniway, Sasha Reed, Utah State University, USGS-SBSC Moab

Project: Criollo cattle as a strategy to maintain output of ecosystem services under a changing climate.

Research: Climate change threatens the health and sustainability of rangelands worldwide, including the many ecosystem services they provide. In the Colorado Plateau region of the western United States, livestock production is one of the most widespread and culturally important land uses, despite being economically tenuous and severely threatened by future climates. Introduction of heritage breeds, such as Raramuri Criollo cattle, to livestock operations presents a potential opportunity to maintain economically sustainable levels of livestock production under frequent and prolonged drought while also improving rangeland health and outputs of ecosystem services. Raramuri Criollo have been shown to have broader diets and larger home ranges than standard breeds, and to therefore to utilize a wider range of forage on a larger proportion of the landscape. These behaviors stand to effectively increase forage availability during dry times when forage is otherwise limited, and also can result in more diffuse or less intense impacts of cattle activity on the landscape and associated ecosystem services. Our overarching goal is to test whether incorporating Raramuri Criollo, a heritage breed, into Colorado Plateau livestock production systems facilitates adaptation to the more arid conditions that are likely under future climates, and allows for sustained production while maintaining or even increasing ecosystem health and resilience. This goal is directly relevant to the Agroecosystems: Health Functions, Processes and Management Program Area Priority focusing on improvement in ecosystem system health and productivity in managed natural systems that are currently under stress and at risk from increased environmental pressures. Our supporting objectives include: 1) Compare landscape use patterns between Raramuri Criollo and Red Angus, a standard breed for the Colorado Plateau; 2) Assess the impacts of Raramuri Criollo vs. Red Angus on outputs of provisioning services (forage provision), regulating services (erosion prevention), and supporting services (soil formation/stabilization); and 3) contrast the compatibility of Raramuri Criollo vs. Red Angus cattle with Colorado Plateau landscapes in terms of efficiency of beef production (i.e., weaning weights, % weaned calf crop, conception rates, and cow body condition score). We plan to accomplish project goals by analyzing movements of an experimental herd of GPS-collared Criollo and Red Angus cattle, performing field-based measurements of ecosystem services in areas of high, low and non-use for each breed, and analyzing beef production metrics for GPS-collared animals of each breed.