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Working to protect and restore Western Watersheds and Wildlife

September 2, 2020

Attn: Emma Williams
Coronado National Forest
300 W Congress St
Tucson, AZ 85701

Attn: George Garcia, District Ranger
Coronado National Forest
Safford Ranger District
711 14th Avenue, Suite D
Safford, AZ 85546

Submitted this date via: https://cara.ecosystem-management.org/Public//CommentInput?Project=56958

RE: Pinaleño FireScape Project

The following comments on the Pinaleño FireScape project are being submitted on behalf of the staff and members of Western Watersheds Project (WWP) who are concerned with the management of our public lands. WWP is a nonprofit organization dedicated to protecting and restoring western watersheds and wildlife through education, public policy initiatives, and legal advocacy. With over 15,000 members and supporters throughout the United States, including Arizona, WWP actively works to protect and improve upland and riparian areas, water quality, fisheries, wildlife, and other natural resources and ecological values. WWP's staff and members are concerned with the management of public lands throughout Arizona, including the lands managed by the Forest Service in the Coronado National Forest and specifically in the Safford Ranger District and the Pinaleño Mountains.

WWP appreciates the Forest Service acknowledging that the land known as Mount Graham is the traditional homeland of the Apache people. The Forest Service also has an obligation to accurately discuss the long history of livestock grazing in Arizona and within the project area, identifying how many livestock were historically grazed, how many livestock have been grazed in the past two decades, and disclose the impacts of that livestock grazing, including a thorough description of how livestock grazing has contributed to and continues to exacerbate altered fire regimes, invasive species,

loss of species diversity, and degraded watersheds – all problems the Forest Service seeks to remedy with this project.

This project covers more than 198,000 acres of federal public lands in the Pinaleño Ecosystem Management Area and includes the Mount Graham Biological Research Area, Goudy Canyon Research Natural Area (RNA), Wet Canyon Talussnail Zoological Area, Mount Graham Wilderness Study Area (WSA), a wide variety of vegetation types from Montane and subalpine meadows to semi-desert grasslands, and eligible Scenic and Recreational river segments. The area is rich with cultural resources and is formally recognized as a Traditional Cultural Property of the western Apache people. These facts, combined with the proposal to use mechanized and motorized equipment and the long-term use of herbicides throughout the project area, require the development of an Environmental Impact Statement (EIS) and preclude a Finding of No Significant Impact (FONSI).

The stated purpose and need for this project is to:

- Reduce fuel accumulations and treat vegetation composition and structure in the Pinaleño EMA created by the absence of naturally occurring fires.
    - The Forest Service notes here that the exclusion of fire has contributed to the potential risk of large, uncharacteristic wildfire and the associated negative effects of habitat loss, soil erosion, and flooding.
- Create fire management opportunities within the project area to provide for public and firefighter safety and ability to manage natural ignitions to achieve desired Forest Plan objectives.
- Create conditions that enable naturally occurring fires to play their historic role within the EMA.
- Provide protection to values at risk within the project area, including, but not limited to, cultural heritage sites, threatened and endangered wildlife habitat, wetlands and other natural water sources, wildland-urban interface (WUI) communities, and Forest Service infrastructure.
- Restore, sustain, and promote ecological processes to retain and enhance the overall health and resiliency of watersheds and desired native plant and animal species and communities.
- Improve habitat quality, quantity, and connectivity of threatened, endangered, and sensitive wildlife species and forage for range and wildlife.

Design features for this project include:

- Resting burned areas from grazing for specific periods after treatment.
- Protecting riparian areas to prevent or minimize impacts to watersheds and the riparian habitat and species that occur there.

- Provide long-term benefits to aquatic and riparian resources by reducing threats associated with dewatering and surface disturbance or by improving the condition of the watershed and enhancing watershed function.

WWP is deeply concerned with the proposed use of herbicide application and mechanical thinning, including grubbing and mastication. However, we strongly support the Forest Service's wise decision to forego the use of "biological treatments" which would include the use of livestock to remove vegetation. The Forest Service acknowledges that livestock grazing is a historic cause of unnatural fire regimes in the project area as a result of a reduction in fine fuels. Scoping letter at 2. WWP therefore strongly recommends the Forest Service consider an alternative for this project that provides for livestock permit retirement as a long-term solution to the ongoing problem of unnatural fire regimes. Eliminating livestock grazing would help initiate restoration of desired conditions and processes in fire excluded areas, help maintain desired conditions where they exist, and promote recovery of areas burned uncharacteristically - all goals the Forest Service hopes to accomplish with the very expensive FireScape program, but eliminating livestock grazing could be accomplished at no cost to the Forest Service, and therefore the taxpayer.

WWP recognizes the Forest Service changed the name of the Mount Graham Biological Area to identify this important biological refugia to include the Astrophysical area. However WWP also notes that the Biological Research Area was designated for a very different, and perhaps contrary, purpose than the Astrophysical area. WWP asks the Forest Service to recognize these important differences when completing the environmental analysis for this project.

Citing the Forest Plan, the Forest Service tries to justify the need for this project:

> The Forest Plan objectives for the Pinaleño EMA state "every 10 years treat the vegetation using wildland fire (planned and unplanned ignitions), prescribed cutting, and mastication on at least 25 percent of the Pinaleño Ecosystem Management Area to create resiliency to disturbances…The Forest Plan objective for WUI is: 'treat 5,000 to 10,000 acres in the wildland-urban interface using wildland fire (planned and unplanned ignitions), prescribed cutting, and mastication every year to reduce fire hazard and risk to communities and the forest.' (Forest Plan, p. 23).

Scoping letter at 2. While there are cabins and other private property located within the project area, this can hardly be considered an "urban" area. Additionally, the Forest Service must take into account how natural or human caused fires have usurped the need for the agency to use mastication and herbicides for vegetation treatments. If wildfires have done the work the Forest Plan calls for, the agency should avoid duplicating that work, especially when mastication and herbicide uses have significant negative impacts. As the Forest Service is aware, weather is a key part of this proposed project. Weather factors, limited operating periods, and recent fire events dictate the amount and type of activities that might be applied in any given year. WWP strongly recommends that natural fire events be utilized to accomplish the goals of fire resiliency as much as possible.

I. The Forest Service Must Use the Best Available Science

In general, researchers have found that "[r]educing fuel loads" in forests "has little, if any, benefit for protecting structures and communities from wildfires." Bracmort 2013. Fuels treatments "can leave slash on the ground, [and] increase[e] fire hazards at least in the short-run." *Id*. In one study, "rate of spread and flame length" in forest fires "were positively correlated with the proportion of area logged in the sample watersheds." Gedalof *et al*. 2005. The Forest Service should explain why it believes this project will be successful in light of the 2003 McClaren report indicating that "burroweed cycles appear to be more closely related to winter precipitation patterns and maximum plant longevity than land management activities. McClaran *et al*. 2003. Mesquite density seems unchanged as a result of fire regimes as well and is spread via livestock grazing. *Ibid.* And, "[s]imilar to burroweed, the eruption of cholla and recent increases of prickly pear appear to be largely independent of livestock grazing and fire manipulations." *Id*. at 26. Fire produced only a short-lived decline of cactus density and within 10 to 13 years after fire the cactus density exceeded that which existed prior to the fires. *Ibid*.

Livestock grazing promotes the spread and colonization of alien plants, which can increase fire frequencies. Billings 1990, Billings 1994, Rosentreter 1994, Belsky and Gelbard 2000, Kimball and Schiffman 2003. Disturbance is a reliable indicator of alien dominance in vegetation composition, and livestock grazing is a significant disturbance. Brooks and Berry 2006. Further, weed invasions are strongly associated with livestock watering sites. Brooks et al 2006. Disturbed soils with fewer intact soil crusts favor invasive annual plants like cheatgrass and medusahead over native perennial grasses and forbs. Reisner *et al*. (2013) found "strong evidence" that livestock grazing indirectly increases cheatgrass dominance by: increasing native bunchgrass abundance, shifting bunchgrass composition, increasing gaps between perennial plants, and damaging biological crusts. Cheatgrass invasion has in turn been found to increase fire frequency and severity. Therefore, the Forest Service should carefully analyze the cause and effect relationship of livestock grazing with the woody vegetation and altered fire regime, and make a determination regarding the effects of eliminating livestock grazing from the project area. *See*, e.g. Bahre and Shelton 1993.

The effects of fire as reported in McClaran *et al*. 2003 indicate that native grass abundance decreases following fire, and the recovery is dependent on subsequent growing conditions while seed germination of the non-native lovegrass increases after fire. *Id*. at 30.

II. General Questions and Recommendations

The Forest Service must include analysis of the impacts of this project on butterflies and bees.

What model was used to determine the potential fire behavior for the existing condition?

How did the Forest Service make a fire history determination?

What percent of large diameter trees, snags, and shrubs will remain following fuel treatments in the project area? Are large paniculate agaves present and if so, how many (by percent) will remain on the landscape post-treatments?

How will implementation of this project affect ecological condition?

What is the likelihood the Forest Service will be able to repeat/retreat the area to ensure fuel reduction is effective?

Who is paying for this project/what is the source of the funds?

Will converting portions of the project area from a shrub and woody species dominated area to a grassland affect soil storage of CO2?

Please include an alternative that excludes livestock grazing for the entire area.

III. Compliance with NEPA

As a preliminary matter related to NEPA, we note that the NEPA regulations are currently undergoing a revision and the new NEPA regulations are set to take effect September 14, 2020. As the Forest Service has initiated the NEPA process for this project prior to that date, the Forest Service should proceed with this project under 42 U.S.C. § 4331 *et seq*., as agencies that begin projects prior to September 14, 2020, are not obliged to employ the new regulations. The Forest Service is likely aware that the new regulations are facially invalid and facing legal challenge. Regardless, the Forest Service must explicitly indicate which regulations are utilized for this project.

"NEPA is a procedural statute intended to ensure environmentally informed decision-making by federal agencies." *Tillamook Cnty. v. U.S. Army Corps of Eng'rs*, 288 F.3d 1140, 1143 (9th Cir. 2002). It requires federal agencies to take a "hard look" at a proposed project's environmental impacts, but it does not mandate particular results. *Id*. Under NEPA, federal agencies must prepare an EIS before "taking 'major Federal actions significantly affecting the quality' of the environment." *Kern v. U.S. Bureau of Land Mgmt*., 284 F.3d 1062, 1067 (9th Cir. 2002) (quoting 42 U.S.C. § 4332(2)(C)). The Council on Environmental Quality regulations require an EIS to state the purpose and need of the project and to consider a reasonable range of alternatives. 40 C.F.R. §§ 1502.13, 1502.14.

An agency may prepare an environmental assessment to determine whether an EIS is needed. 40 C.F.R. § 1501.4(b). If the environmental assessment shows that the agency action may significantly affect the environment, then the agency must prepare an EIS. *Nat'l Parks & Conservation Ass'n v. Babbitt*, 241 F.3d 722, 730 (9th Cir. 2001), abrogated on other grounds by *Monsanto Co. v. Geerston Seed Farms*, 130 S. Ct. 2743, 2756-57 (2010). If an agency concludes in its environmental assessment that the proposed action will not have a significant environmental impact, then it may issue a finding of no significant impact and proceed without further study. *See Te-Moak Tribe of W. Shoshone of Nev. v. U.S. Dep't of Interior*, 608 F.3d 592, 599 (9th Cir. 2010).

NEPA's requirement that agencies "study, develop, and describe appropriate alternatives . . . applies whether an agency is preparing an [EIS] or an [EA]." *N. Idaho Cmty. Action Network v. U.S. Dep't of Transp*., 545 F.3d 1147, 1153 (9th Cir. 2008) (*per curiam*) (citations omitted). Although an agency must still "give full and meaningful consideration to all reasonable alternatives" in an environmental assessment, the agency's obligation to discuss alternatives is less than in an EIS. *Id*.

"The existence of a viable but unexamined alternative renders an [EA] inadequate." *Westlands Water Dist*., 376 F.3d at 868 (quoting *Morongo*, 161 F.3d at 575).

In *Idaho Sporting Congress v. Thomas*, 137 F.3d 1146, at 1149 (9th Cir. 1998), the court recognized that under 42 U.S.C. § 4332(2) an EIS "must be prepared if substantial questions are raised as to whether a project may cause significant degradation of some human environmental factor." "The plaintiff need not show that significant effects will in fact occur, but if the plaintiff raises substantial questions whether a project may have a significant effect, an EIS must be prepared." *Id*. at 1150. This is a low standard.

A. This Project Requires the Development of an EIS

Unfortunately, the Forest Service plans to utilize an Environmental Assessment (EA) to comply with National Environmental Policy Act (NEPA) requirements. The use of an EA for this project is clearly inappropriate and will fail to comply with NEPA requirements for multiple reasons. The proximity to and overlap with specially designated areas require a higher level of analysis in light of the intensity and context of this specific project. Similarly, the presence of federally listed species and their habitat covering vast swaths of the project area raise the level of analysis necessary to ensure compliance with federal regulations. *See* 40 C.F.R. §§ 1508.27(a) (context), b (intensity)).

In assessing "context," agencies must look at different geographic scales and the short- and long-term impacts of the proposed action within those different geographic scales (40 C.F.R. § 1508.27(a)). In assessing "intensity," agencies must look at the severity of the impact based on several factors:

1. The fact that impacts "may be both beneficial and adverse" and that "[a] significant effect may exist even if the Federal agency believes that on balance the effect will be beneficial." 40 C.F.R § 1508.27b(1).

2. "The degree to which the proposed action affects public health and safety." 40 C.F.R § 1508.27b (2).

3. "Unique characteristics of the geographic area such as proximity to historic or cultural resources, park lands, prime farmlands, wetlands, wild and scenic rivers, or ecologically critical areas." 40 C.F.R § 1508.27b (3).

4. "The degree to which the effects on the quality of the human environment are likely to be highly controversial." 40 C.F.R § 1508.27b (4).

5. "The degree to which the possible effects on the human environment are highly uncertain or involve unique or unknown risks." 40 C.F.R § 1508.27b (5).

6. "The degree to which the action may establish a precedent for future actions with significant effects or represents a decision in principle about a future consideration." 40 C.F.R § 1508.27b (6).

> 7. "Whether the action is related to other actions with individually insignificant but cumulatively significant impacts. Significance exists if it is reasonable to anticipate a cumulatively significant impact on the environment. Significance cannot be avoided by terming an action temporary or by breaking it down into small component parts." 40 C.F.R § 1508.27b (7).
>
> 8. "The degree to which the action may adversely affect districts, sites, highways, structures, or objects listed in or eligible for listing in the National Register of Historic Places or may cause loss or destruction of significant scientific, cultural, or historical resources." 40 C.F.R § 1508.27b (8).
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> 9. "The degree to which the action may adversely affect an endangered or threatened species or its habitat that has been determined to be critical under the Endangered Species Act of 1973." 40 C.F.R § 1508.27b (9).
>
> 10. "Whether the action threatens a violation of Federal, State, or local law or requirements imposed for the protection of the environment." 40 C.F.R § 1508.27b (10).

Here, the Forest Service can anticipate significant beneficial and adverse effects, a significant risk to public health via the use of fire and herbicides, the project is taking place in a culturally and ecologically unique area that has several special designations, the use of herbicides is highly controversial scientifically and socially, the use of herbicides and managed fire involve unknown and uncontrollable risks, there are significant cumulative effects from related actions from long-term grazing authorizations as well as the expired permit for the astrophysical observatory and related structures, there are significant risks to culturally and ecologically important resources including the Traditional Cultural Property of the western Apache, the red squirrel refugium, and botanical areas, and the action has the potential to significantly impact large areas of habitat for the Mexican spotted owl, a federally listed species. Clearly, the Forest Service can and should acknowledge the significance factors call for the preparation of and EIS and in the interest of saving time and public resources, the Forest Service would be well advised to notify the public of the intent to prepare an EIS immediately.

> The most incontestable conclusion from this century of vegetation change is that future changes cannot be perceived and understood if there are no records of previous conditions. An equally important conclusion is that the response of vegetation to management practices will be contingent on past and future precipitation patterns, elevation and soils at the location, and the current mix and vigor of plant species.

McClaran 2003, at 31. With this in mind, it is imperative that the Forest Service act cautiously and responsibly and acknowledge that livestock grazing played a large role in the current conditions of this project area and it is likely that continued livestock grazing will undo the restoration the Forest Service has planned for this area. In this light, the Forest Service must include a range of alternatives sufficient to satisfy NEPA requirements. The Forest Service should consider: 1) an alternative that prohibits use of mechanized and motorized equipment in WSAs; and 2) an alternative that eliminates livestock grazing throughout the project area as a low-cost alternative that will reduce fire susceptibility, especially the continued proliferation of non-native invasive plants. The single most

effective thing the Forest Service could do to stop the spread of non-native invasive plants and reduce fire risk is to eliminate livestock grazing throughout the forest.

B. Wilderness Study Areas

In addition to the scientific and political controversy surrounding fuel reduction/treatment projects, this area is home to threatened and endangered species, there is also a Wilderness Study Area, which should be managed as a Wilderness area and which prohibits the use of motorized and mechanized equipment, which is planned for this project.

In 1964, Congress passed the Wilderness Act "to secure for the American people of present and future generations the benefits of an enduring resource of wilderness." The law provided statutory protections for wilderness areas and established the National Wilderness Preservation System. The Act, among other things, mandated that wilderness areas be administered in a manner that will leave them "unimpaired for future use and enjoyment as wilderness" and that will provide for "the protection of these areas" and "the preservation of their wilderness character." The Wilderness Act defines "wilderness" in part: "A wilderness, in contrast with those areas where man and his works dominate the landscape, is hereby recognized as an area where the earth and its community of life are *untrammeled by man*, where man himself is a visitor who does not remain." Wilderness is "land retaining its *primeval character and influence*, without permanent improvements or human habitation, which is protected and managed so as to *preserve its natural conditions*…"[1] In addition, wilderness should be "*affected primarily by the forces of nature, with the imprint of man's work substantially unnoticeable*."

The forthcoming analysis should analyze the impacts to WSA individually and cumulatively and the Forest Service must include an alternative that fully protects the WSA by prohibiting this use of mechanized and motorized tools. The use of herbicides within a WSA also requires special consideration by the Forest Service and an alternative that prohibits the use of herbicides within WSAs must be considered.

C. Climate change and drought

NEPA expressly calls on agencies to provide for intergenerational equity, stating that it is intended to "fulfill the responsibilities of each generation as trustee of the environment for succeeding generations." 42 U.S.C. 4331(b)(1). This is particularly relevant with respect to climate change, given its long-lasting impacts. As the Forest Service is aware, a severe drought has gripped the American Southwest since 2000. New research indicates this drought is as bad as or worse than long-lasting droughts in the region over the past 1,200 years, and climate change is a likely contributor. While the term megadrought has no strict definition, it is generally considered to be a severe dry period persisting for several decades or longer. Many climate researchers and hydrologists have long thought that a southwestern megadrought was highly likely. A 2016 study put the probability of one occurring this century at 70 percent or higher. Ault *et al*., 2016.

A recent study reconstructed drought conditions in the Southwest for every year back to 800 A.D., using tree growth as a proxy for soil moisture content. Examining nearly 1,600 tree-ring records,

they found four periods of more than two decades each during which soil moisture content was far below the baseline for the entire 1,200 years, indicating severe drought conditions of lack of precipitation and increased dryness. Williams *et al*., 2020. One of these megadroughts, in the 13th century, lasted more than 90 years. The recent analysis shows that, as measured by soil moisture content, the current drought is more severe than three of the ancient ones. Only one in the late 1500s was worse, and only slightly so. Using 31 computer climate models, the researchers estimated that climate change contributed nearly half to the severity of the current drought. Put another way, without global warming the current drought would be only of moderate severity rather than one of the worst.

IV. Livestock grazing and fire

To reiterate our concerns stated above, the Forest Service should closely examine the relationship between livestock grazing and fire. "Grassland-to-shrubland state transitions in drylands are the result of changes in disturbance regimes amplified or mitigated by abiotic factors related to climate and soil (Archer and others 2017). For example, livestock grazing coupled with drought reduces fine fuel mass and continuity, thus reducing the probability of fire—a disturbance that historically kept woody plants in check (Higgins and others 2007). In the absence of fire, shrubs can establish and progress to more advanced life-history stages (Higgins and others 2000). At the same time, rates of erosion typically increase with declines in grass cover in arid grasslands, depleting soil resources and concentrating them below developing shrub canopies, as well as increasing disturbance to grasses by burial and abrasion, which constitutes a positive abiotic feedback that impedes future grass recovery while promoting shrub survival (Schlesinger and others 1996; Okin and others 2009)." Pierce *et al*., 2019.

New scientific studies more definitively link the presence of livestock grazing with cheatgrass. Time-series data and results in Williamson *et al*. (2019) indicate that grazing corresponds with increased cheatgrass occurrence and prevalence regardless of variation in climate, topography, or community composition, and provide no support for the notion that contemporary grazing regimes or grazing in conjunction with fire can suppress cheatgrass. This concept is applicable to the project area and invasive species of grasses that are spread by livestock use, and the Forest Service must analyze these impacts with a critical eye towards protecting natural resources. The continued spread of invasive species of plants that are likely to alter the fire regime on project area present a clear risk to native plants and wildlife.

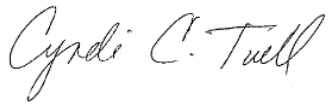
V. Conclusion

Finally, WWP notes the legal notice published in the Eastern Arizona Courier includes an incorrect URL for submitting comments and the address for comment submission in the legal notice differs from the address in the scoping letter. We have addressed our comments to both George Garcia, District Ranger for the Safford Ranger District, and NEPA Planner Emma Williams, located in the Supervisors office in Tucson.

As we note above, the sheer scope of this project clearly precludes the use of an EA. Therefore, Western Watersheds Project encourages the Forest Service to begin immediately to prepare an EIS.

We look forward to reviewing the next step in this NEPA process for this project.

Sincerely,



Cyndi Tuell
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Western Watersheds Project

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Over the past 100 years, woody shrubs have increased in abundance in many semiarid grasslands around the world, replacing the grasses that are the most valuable forage for livestock. Ecologists have long sought to understand if overgrazing is responsible for shrub invasion and if shrub-invaded areas can be restored back to grasslands. A new study by Zheng et al. (2020, https://doi.org/10.1029/2019JG005439) shows that reversing shrub invasion may be possible. Over a 20-year period, the authors compared areas where grazing was completely stopped to areas where grazing was continued in a shrub-invaded grassland in Inner Mongolia, China. In areas without grazing, grasses gradually increased and shrubs decreased over the study period; in contrast, shrubs remained dominant where grazing continued. As grasses increased, soil texture became finer and less water seeped into the deeper soil layers. This likely benefitted further growth of the shallow rooted grasses over the more deeply rooted shrubs. The result adds to a small number of studies showing that shrub invasion may be less permanent than originally thought

- José Javier Ochoa Espinoza, César Cantú Ayala, Eduardo Estrada Castillón, Fernando González Saldivar, José Uvalle Sauceda, Enrique Jurado, Leonardo ChapaVargas, Edmar Meléndez Jaramillo, and Edgardo Ortiz Hernández. 2017. *Livestock effect on floristic composition and vegetation structure of two desert scrublands in northwest Coahuila, Mexico*. The Southwestern Naturalist, 62(2):138-145. Southwestern Association of Naturalists. https://doi.org/10.1894/0038-4909-62.2.138

Microphyllous and rosetophyllous desert scrub plant communities dominate large parts of the state of Coahuila, Mexico, yet differences in how livestock grazing impacts these two plant communities are not well documented. In order to address this knowledge gap, we assessed livestock impact on plant species composition and vegetation structure in microphyllous and rosetophyllous desert scrublands in this northwestern Mexican state. We collected plant density, frequency, and cover data from sites with and without livestock grazing pressure that were otherwise similar in plant composition. We quantified intersite differences using the importance value index (IVI) and the Bray-Curtis similarity index. The species with the highest IVI for microphyllous scrubland were lechuguilla (Agave lechuguilla), honey mesquite (Prosopis glandulosa), and creosote bush (Larrea tridentata); however, in sites with presence of domestic herbivores, desert willow (Chilopsis linearis) and spiny hackberry (Celtis pallida) also showed high values. Plant species with the highest IVIs in rosetophyllous scrublands were lechuguilla, creosote bush, mariola (Parthenium incanum), and blue grama (Bouteloua gracilis) for both land use types. The Bray-Curtis similarity index between microphyllous desert scrub and rosetophyllous desert scrub was 62%. Moreover, microphyllous scrub with and without livestock had 48% similarity, whereas rosetophyllous scrub sites with and without livestock were 65% similar. Results indicate that livestock grazing significantly modifies plant species composition and vegetation structure in both types of the studied desert scrublands.

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Climate change predictions include warming and drying trends, which are expected to be particularly pronounced in the southwestern United States. In this region, grassland dynamics are tightly linked to available moisture, yet it has proven difficult to resolve what aspects of climate drive vegetation change. In part, this is because it is unclear how heterogeneity in soils affects plant responses to climate. Here, we combine climate and soil properties with a mechanistic soil water model to explain temporal fluctuations in perennial grass cover, quantify where and the degree to which incorporating soil water dynamics enhances our ability to understand temporal patterns, and explore the potential consequences of climate change by assessing future trajectories of important climate and soil water variables. Our analyses focused on long-term (20–56 years) perennial grass dynamics across the Colorado Plateau, Sonoran, and Chihuahuan Desert regions. Our results suggest that climate variability has negative effects on grass cover, and that precipitation subsidies that extend growing seasons are beneficial. Soil water metrics, including the number of dry days and availability of water from deeper (>30 cm) soil layers, explained additional grass cover variability. While individual climate variables were ranked as more important in explaining grass cover, collectively soil water accounted for 40–60% of the total explained variance. Soil water conditions were more useful for understanding the responses of C3 than C4 grass species. **Projections of water balance variables under climate change indicate that conditions that currently support perennial grasses will be less common in the future, and these altered conditions will be more pronounced in the Chihuahuan Desert and Colorado Plateau**. We conclude that incorporating multiple aspects of climate and accounting for soil variability can improve our ability to understand patterns, identify areas of vulnerability, and predict the future of desert grasslands.

The southwestern United States has already experienced significant warming and drying, and has been identified as a hot- spot for increasing aridity as well as increasing variability in temperature and precipitation (Seager et al., 2007; Archer & Predick, 2008; Diffenbaugh et al., 2008). These changes have the potential to push southwestern ecosystems beyond tolerance thresholds, resulting in species loss, declining ecosystem services, and habitat alteration and degradation. Anticipating such consequences requires understanding what aspects of cli- mate drive temporal patterns of vegetation change and how these changes will be manifested on the landscape. This challenge is especially pronounced in ecosystems that are particularly vulnerable to climate change such as desert grasslands. Grasslands are regionally important sources of biodiversity, net primary production, livestock forage, and wildlife habitat (Bahre, 1995; McClaran, 1995; Sala & Paruelo, 1997). Losses of perennial grasses in dryland regions can contribute to destabilization of soils, which in turn results in reduction of nutrient availability and water-holding capacity, and increases soil erosion and dust storm activity (Schwinning et al., 2008; Munson et al., 2011b; Belnap et al., 2014). Therefore, loss of grass cover can trigger ecological state transitions and further vegetation losses in desert regions, which can feedback into further loss of ecosystem function. In addition, grasslands may be particularly at risk to climate change because they contain many shallow-rooted, shorter-lived species, highlighting the need to identify vulnerability or resilience to cli- mate change (Peters et al., 2012; Petrie et al., 2014).

- Pierce, N.A., Archer, S.R., Bestelmeyer, B.T., James, D.K. 2019. *Grass-Shrub Competition in Arid Lands: An Overlooked Driver in Grassland–Shrubland State Transition?* Ecosystems (2019) 22: 619–628 https://doi.org/10.1007/s10021-018-0290-9

Traditional models of state transition in arid lands emphasize changes in disturbance regimes and abiotic feedbacks that promote the degradation of grassland into shrubland, whereas biotic interactions like competition and facilitation are often overlooked. Here, we conducted an experiment to determine whether shrubs have a positive, neutral, or negative effect on grasses and if these interactions may play a role in grassland–shrubland state transition. Prosopis glandulosa shrub neighbors within 5 m of Bouteloua eriopoda grass patches were left intact (controls) or killed with foliar herbicide, and metrics of grass performance were evaluated over 5 years. We saw no evidence of shrub facilitation of grasses. Instead, grass ANPP responded positively to shrub removal in all years, but more so in years with above-average rainfall. Grass allocation to vegetative reproduction and grass patch size also increased when shrub neighbors were removed. These results demonstrate that biotic interference by shrubs upon grasses reinforce and magnify grazing- and drought-induced abiotic feedbacks during grassland–shrubland transitions. Shrub effects on grass should therefore be considered a key process in desert grassland state transitions.

Grassland-to-shrubland state transitions in drylands are the result of changes in disturbance regimes amplified or mitigated by abiotic factors related to climate and soil (Archer and others 2017). For example, livestock grazing coupled with drought reduces fine fuel mass and continuity, thus reducing the probability of fire—a disturbance that historically kept woody plants in check (Higgins and others 2007). In the absence of fire, shrubs can establish and progress to more advanced life-history stages (Higgins and others 2000). At the same time, rates of erosion typically increase with declines in grass cover in arid grasslands, depleting soil resources and concentrating them below developing shrub canopies, as well as increasing disturbance to grasses by burial and abrasion, which constitutes a positive abiotic feedback that impedes future grass recovery while promoting shrub survival (Schlesinger and others 1996; Okin and others 2009)