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Chapter 12

Grasslands in the borderlands: understanding coupled human-ecological systems and transboundary conservation

Gerardo Ceballos, Rurik List, Ana D. Davidson, Ed L. Fredrickson, Rodrigo Sierra, Lourdes Martínez, Jeff E. Herrick and Jesús Pacheco

In a Nutshell

- Grassland ecosystems in the transboundary Chihuahuan Desert, provide ecosystem services that promote human well-being.
- Overgrazing, water withdrawal, drought-driven climate change, and prairie dog removal threaten the integrity of this important ecosystem.
- The prairie dog, a keystone species, forestalls the invasion of woody species and prevents desertification that now plagues grasslands. However, prairie dogs are threatened and have declined by over 95% throughout their historic range.
- Grassland restoration, control of shrubland expansion, and prairie dog protection are needed to maintain ecosystem services within the transboundary region of the Chihuahuan Desert.
- Research and experience from the Janos research site has important implications for arid and semi-arid grasslands in both the United States and Mexico.
- A new paradigm is needed that better connects human needs such as agricultural production, water availability, and food with the long-term conservation of grassland ecosystems that support these services.
- Better understanding and support of local stakeholders such as agribusiness, cattle growers, and area residents is critical.

Introduction

Grasslands are one of the shared ecosystems that dominate the heart of the North American continent. Among these are the Chihuahuan Desert grasslands that are undergoing a rapid transition to desertified, arid scrub conditions. Policy-driven landuse changes are reducing their capacity to maintain biodiversity, ecosystem services, and human well-being. In northwestern Chihuahua, and adjoining New Mexico, Arizona and Texas, degradation occurred differentially on either side of the border with degradation in the United States preceding that in Mexico, but becoming more pronounced in some parts of Mexico during the last two decades. Degradation patterns in the United States can inform Mexican conservation efforts, while relatively intact Mexican ecosystems provide valuable insights into functional grassland systems. The collaborative socio-ecological study of the patterns and processes governing ecological change is guiding grassland recovery with the goal of maintaining biodiversity that appears necessary to reinstate lost ecosystem services and grassland productivity on which human population's in the transboundary region depend.

As this chapter discusses, prairie dogs in this region exhibit the characteristics of a keystone species and are important ecosystem engineers that maintain northern Chihuahuan grasslands. They are critical for the maintenance of biodiversity and support grassland ecosystem functioning, resulting in important benefits for humans. The natural process of prairie dogs supporting ecosystem function creates ecosystem services essential for human well-being. This process is disrupted by poor land management (i.e., governmental policies that promote cattle overgrazing) resulting in environmental degradation that results in a loss of biodiversity, alteration of ecosystem function, and reduction of ecosystem services. In this chapter we present an approach to overcome the negative cycle of overgrazing, and discuss how this approach could be implemented bi-nationally.

Background

Mexico, the United States, and Canada share a continent governed by a myriad of linked ecological processes that reach across political boundaries. Political decisions within each country may impact ecological processes from local to global scales and transcend political boundaries, affecting a vast array of known and yet unknown ecological services. Grasslands maintain a large and diverse set of living organisms and

ecological processes whose persistence largely depends on the presence of large tracts of native transnational grasslands. This is true of one of the most diverse arid/semi-arid systems in the world, the Chihuahuan Desert, which straddles the United States-Mexican border. However, large-scale land-use changes caused by industrial agriculture, urbanization, development of infrastructure, and desertification are reducing the capacity of the grassland systems of North America to maintain the biodiversity on which important ecosystem services, and ultimately, human populations rely.¹ We present a research approach whose application couples ecological conservation and human needs to conserve grassland systems of northwestern Mexico and southwestern United States.

North American grasslands support uniquely heterogeneous plant and animal communities whose complexity supports high levels of interdependent biodiversity. In many grasslands black-tailed prairie dogs (Cynomys ludovicianus) create ecological niches necessary for the persistence of many continental species like the ferruginous hawk (Buteo regalis) and mountain plover (Charadrius montanus). Similarly, the transboundary region of northern Mexico and the southwestern United States, also evolved a complex array of ecosystems in response to biogeographic properties. Recently, the long-term evolution of these ecosystems was further modified by a political boundary representing a widely divergent sequence of land policies. Due to the long-term evolution and resulting connectivity of these dynamic ecosystems that is further being challenged with large-scale human threats, such as global warming, the United States - Mexico requires coordinated conservation efforts and ecologically sound management practices in both countries. The need for collaborative management is greatly increased by the wall being built to restrict the flow of undocumented workers across the US-Mexican border.

For example, the grassland ecosystem of Chihuahua - New Mexico and Sonora - Arizona, that is maintained by black-tailed prairie dogs provides critical habitat for migrating birds such as golden eagles (Aquila chrysaetos) and burrowing owls (Athene cunicularia), which link this region to the northern Great Plains of the United States and Canada. More locally, populations of pronghorn antelope (Antilocapra americana), bison (Bison bison), and many other species are on the brink of extinction and require a continuous flux of individuals between the two countries for maintaining viable populations that guarantees their long-term survival. Such movement is also required as species adapt to highly variable environments typical of arid- and semi-arid regions.² The Border Wall at the confluence of the

border states of Arizona, Sonora, Chihuahua, and New Mexico varies in its permeability to organisms of differing sizes. North of the Janos-Casas Grande Biosphere the wall is too wide and tall for large mammals to cross and funnels people to the more remote areas heavily used by wildlife, where barbed wire fence marks the international limit. If the wall is expanded or the configuration changes to a solid wall, like the one in eastern Arizona, the movement of non-flying animals could cease altogether.

For nearly two centuries, the main economic activity in northern Mexico and the southwestern United States has been cattle ranching. During this period, livestock management has contributed to significant landscape changes in the region.³ Overgrazing was widespread in the United States in the late 19th and early 20th centuries; ⁴ however, by 1955, the situation had reversed.⁵ Grazing in the US was being better managed, yet overgrazing in Mexico was becoming more prevalent, particularly in response to federal agrarian policies that established communally managed land too small for effective livestock production in landscapes reliant on integrated ecological processes at much larger scales. Furthermore, people in communal Ejidos lacked the skills needed to manage drylands and to provide self governance needed to avert "the tragedy of the commons." Due to the lack of appropriate self governance many Ejidatarios could not adjust cattle numbers in response to environmental conditions; thus, they continuously exceeded the land's carrying capacity. Furthermore, the availability of supplemental feeds allowed Ejidatarios to maintain a large number of cattle during drought years. Supplemental feeds worsened the effects of drought and maintained livestock populations that prevented reestablishment of palatable herbaceous species during post-drought periods. As a result, with the absence of prairie dogs, less palatable species, most notably shrubs, began to replace grasslands.

Private landowners capable of investing into "range improvements" poisoned prairie dogs that suppressed or prevented shrub dominance. The result is a flush of forages followed and almost complete replacement of grasslands with adapted shrubs. For Ejidatarios with less money to spend on "range improvements" overgrazing and prairie dogs resulted in bare ground. A condition more desirable than shrubland conditions.

The establishment of a shrub state increased the aridity of the system with large scale bare ground and shrub dominance increasing erosional soil degradation. The result is a general loss of productive herbaceous species required for pastoralist cultures. In addition an increasingly homogenous, shrub dominated landscape can not sustain overall

biotic diversity and is resulting in a loss of obligate grassland species and ecological processes, such as fire, partially responsible for maintaining grasslands states. Many people, especially young people, have left their homes and migrated to the United States, since the now degraded landscapes no longer support their traditional livelihoods.

The Janos region of northern Mexico, a large valley dominated by grasslands and shrublands at the northwestern corner of the state of Chihuahua is recognized as one of the top priorities for the conservation of North American biodiversity,⁶ but pressures from agricultural development, inadequate management practices, and planning are seriously threatening the biodiversity of this region. Conservation efforts have often failed by not incorporating people as part of the ecological system. Ecological research carried out in the absence of human influence neglects a primary driver of change in the region. Imposing restrictions on resource use without providing economic alternatives requires expensive policing and results in a unsustainable scenario for both conservation and economic development. Economic activities such as agriculture and grazing can benefit from understanding the ecological setting of the region, while being compatible with conservation needs.

The conflict between the conservation of the prairie dog ecosystems and the economic activities in southwestern United States and northern Mexico is a case study of inadequate approaches to conservation biology. In recent years it has become clear that declines in prairie dog populations are negatively impacting biodiversity, ecosystem services, economic activities, and rural communities at large spatio-temporal scales. Coupling the conservation of prairie dogs and rural communities is, perhaps, the only way for maintaining viable local communities. Such coupling requires creation of economic activities at the local and regional levels, while preserving the ecological characteristics that made them possible. In the following paragraphs we describe in detail the complex ecological settings and direct relationships with human well-being. This is a model of a new way of making economic development, conservation, and human well-being compatible.

The combination of prairie dogs, fire, and grazing are considered interactive keystone processes required for many Chihuahuan Desert grasslands.⁷ Among these processes, prairie dog foraging, vegetation sculpting, and construction of extensive burrow systems, transforms landscapes and maintains grasslands. Their mounds, large colonies, and shifting populations create a mosaic of serial vegetation states and resulting

island-like habitat patches. Each patch type differs in biotic composition and biotic and abiotic processes that interact to create emergent ecosystem properties at larger scales. While the resulting heterogeneity may have low biodiversity at the patch scale the biotic diversity is enhanced at the landscape scale.⁸ Active and inactive prairie dog burrow systems provides key habitat for numerous species while prairie dogs themselves are an important prey species.⁹

Despite their importance, prairie dog populations are declining throughout their range;¹⁰ all 5 species are listed or have been petitioned to be listed as threatened or endangered in either the United States or Mexico. While plague, urban development, agriculture, poisoning, and shooting threaten prairie dogs in the United States, the prevailing threats to prairie dogs in Mexico are desertification, agriculture, and, possibly, climate change (predicted to cause increasing frequency and severity of drought in the Chihuahuan Desert region).¹¹ The consequences of their loss throughout the United States have been well-documented, resulting in the decline of many strongly associated species, including the black-footed ferret (Mustela nigripes), burrowing owl, ferruginous hawk, mountain plover, and wift fox (Vulpes velox).¹² Our recent research in the Janos region, comparing mammal abundance over a 13-year period, has demonstrated drastic declines in biodiversity (Fig. 1). These declines can be attributed to extreme land degradation as a result of overgrazing, conversion of native grassland to cropland, combined with natural drought cycles. The 3-fold decline in prairie dog densities, and about 70% decline in prairie dog colony size,¹³ undoubtedly has contributed to the decline in many of these species that are known to utilize prairie dogs as prey or their colonies for habitat, such as the coyote (Canis latrans), kit fox (Vulpes macrotis), badger (Taxidea taxus), and other small mammals, and is further jeopardizing the viability of the black-footed ferret population in the region.

Today, the most significant threat to the persistence of prairie dogs in Mexico (including the Mexican prairie dog, Cynomys mexicanus, in the eastern Chihuahuan Desert) is the expansion of irrigation agriculture for crops such as cotton, potatoes, and corn. Despite a ban to create new wells in the Janos-Casa Grandes Biosphere Reserve, and the legal requirement of an Environmental Impact Assessment to convert native vegetation to agriculture, farmers are illegally drilling new wells and plowing under grasslands and prairie dog towns. Corruption and lack of enforcement

prevent laws from being an effective mechanism for planning sustainable approaches to drilling and land conversion.

Prairie dogs have been exterminated extensively throughout their historic geographic range, under the assumption that they only compete with cattle for food. Depending on management and environmental conditions the interaction between cattle and prairie dogs can be either synergistic or competitive. An example of synergetic interaction between ungulates and prairie dogs may occur in areas of the mixed grass prairie of North America. Here it has been documented that large ungulates, like bison and elk, form "grazing associations" with prairie dogs. In fact, both native and domestic ungulates are often attracted to prairie dog colonies because of the more nutritious forage. Meanwhile, prairie dogs benefit when livestock help to maintain lower stature vegetation that allows greater vigilance for predators.¹⁴

In the Chihuahuan Desert this association may have an even stronger effect on the landscape, resulting in positive effects between prairie dogs and domestic and native ungulates. Ungulates often eat the seed pods of mesquite, a shrub that has replaced large areas of grasslands throughout the Chihuahuan Desert, increasing desertification. While the pods are easily digested, the seeds often pass through the digestive tract unharmed where they are deposited on the soil far from the parent plant. When conditions are right, the seeds germinate, and if the seedlings are not eaten by an animal, and survive a number of other possible calamities, they mature to produce more seed. Eventually, plant by plant, the mesquite replaces the grasses and the amount of forage for ungulates steadily declines, the structure of the vegetation is altered, and the whole system drifts to desertification. Prairie dogs limit the establishment and dominance of woody vegetation and act to maintain grassland systems by removing pods, destroying seedlings, and girdling saplings.¹⁵ Depending on the situation, they either control or suppress mesquite and preserve the grasses for both prairie dogs and ungulates to eat.

The persistence of large prairie dog colonies in northern Mexico is related to the late desertification trends when compared to the southwestern United States. In northern Mexico, Apaches and Mexican Revolutionaries limited the number of people moving into the region during the 19th and early 20th century. During this time, the availability of water limited cattle movements and their dispersal of mesquite seed. After the Mexican land reform act of 1934, more people, livestock, and water developments populated the area once held by very large estates owned by

one person or family (Haciendas). Most likely, the influence of both livestock and prairie dogs expanded as well. The agrarian movement of the 1970's in Mexico promoted the largest increase in people and cattle as Haciendas were expropriated and the land was divided up to form Ejidos, too small to be economically viable with extensive grazing. Overgrazing by cattle led to competition between prairie dogs and cattle for the same grass; competition that worsened with the drought of the 1990's and early 2000's. Private land owners began poisoning prairie dogs in the 1980's providing an opportunity for mesquite to gain dominance, while communal lands underwent a transition from perennial grasses to annual grasses and bare ground with less intensive poisoning campaigns. Our recent studies in Chihuahua have demonstrated that the persistence of prairie dogs has been a key element to maintain grasslands even under severe overgrazing and drought. In areas where prairie dogs have disappeared, mesquite has rapidly invaded. When prairie dog colonies have been restored, mesquite has been exterminated by prairie dogs.

A key issue is to determine if the findings in the Janos region do apply to other places of the northern Chihuahuan Desert. It is very likely that this the case, since the severe desertification of large regions in southwestern United States are partly related to the prairie dog disappearance. (REFERENCE 18 -WETZIN ET AL- MUST BE INSERTED HERE AGAIN, BUT IF I DO THAT, THE NUMERATION CHANGES) The cattle boom of the 1880's encroached into the prairie dog habitat, aided by the United States government-funded poisoning campaigns that eradicated all but a few prairie dog colonies. Mesquite expanded in areas once dominated by prairie dogs and the grassland began to disappear, leading to severe desertification, such as in La Jornada del Muerto, in southern New Mexico.

Discussion

Ecosystem Services

Grassland loss and conservation has significant implications for many ecosystem services. During the past 150 years, tree and shrub-dominated plant communities have replaced grasslands throughout much of the Mexico - United States border region.¹⁶ Patterns and rates of shrub invasion vary with soil, topography, climate, weather, and disturbance history, in addition to changes in the populations and population dynamics of native animals. While the relative importance of these factors is unknown and most vary significantly, there are a number of general trends and patterns that

are widely recognized and occur throughout much of the region. Creosotebush (Larrea tridentata), tarbush (Flourensia cernua) and mesquite (Prosopis spp.) have expanded into grasslands at lower elevations in the Chihuahuan Desert.¹⁷ Mesquite dominates most former black grama grasslands on sandy soils, but is also increasingly found on finer-textured soils. Similar transitions have occurred in the Sonoran Desert with a different mix of species and a greater dominance by succulent species. The transitions are accelerated by, and may be initiated by, overgrazing and drought,¹⁸ although a number of other factors, including climate change, changes in human use, and the eradication of keystone species such as prairie dogs may also play a role in some parts of the landscape.¹⁹

Each of these grass-shrub or tree transitions results in changes in a number of ecosystem processes. These changes are related to the capacity of the ecosystem to support different ecosystem services. While the specific nature of the changes varies with plant community, soils and landscape position, the general relationships are similar throughout the region.

The shift from grasslands to mesquite-dominated shrublands has dramatic effects on ecosystem services. These changes are associated with the changes in ecosystem processes. Fig. 2 shows how the four types of ecosystem services identified by the Millennium Ecosystem Assessment are related to grassland processes in arid and semi-arid lands.²⁰

Water quality is enhanced in the seasonal streams because there is less erosion from shrublands.²¹ This can also increase long-term water quantity available for human use because reservoir siltation is slowed. Water availability for human and wildlife is modified because grasslands increase infiltration and reduce runoff relative to shrublands. This can increase the duration of perennial streamflow and spring production, although a recent review indicates that these benefits are more likely to occur in relatively higher precipitation zones.²²

Air quality is maintained because grasslands have smaller plant interspaces, which limit wind erosion. This is due primarily to the change in spatial distribution with larger plant patches and interspaces. In addition to its health effects, wind erosion can reduce the aesthetic value of many landscapes.

The potential production of food and fiber for pastoral-based societies is generally greater in grasslands, through both domesticated livestock and wildlife. Long-term data from the Jornada Experimental Range in New Mexico, indicate that grasslands at least have the potential to

support greater rates of net primary production than shrublands²³ and herbaceous forage production is uniformly higher in grasslands.

Biodiversity conservation is generally thought to be better supported by grasslands, in part because plant diversity is often greater,²⁴ but also because grasslands are declining in most of the border region. Consequently, grassland loss is increasingly associated with regional declines in biodiversity.

While most environmental services currently valued by human residents of the border region are more effectively supplied by grasslands, there are some services that mesquite-dominated communities provide. Bird diversity can be similar or even higher in shrub-dominated systems (Whitford 1997) due to greater habitat structure. Honey from mesquite shrubs located in areas with shallow water tables is valued for its unique flavor and often sells at a premium of 50% or more above honey derived from other sources. Mesquite beans, too, have value for both humans and wildlife.²⁵

In addition to modifying the current delivery of ecosystem services, mesquite dominance reduces future management options and therefore the ability of managers, including ranchers, governments and conservation organizations, to manage for different ecosystem services. This is because while it is relatively easy to replace grasses with shrubs in most of the border region, it is difficult to establish or re-establish perennial grasses in a shrubland. Therefore, it is difficult, for example, to maximize the ecosystem service of forage production for livestock without significant external inputs.²⁶ These "threshold" transitions are typical of arid and semi-arid ecosystems and are associated with the fundamental changes in the soil-plant-animal relationships and feedbacks discussed above.²⁷ State and transition models are increasingly being used together with soils information to help managers design assessment and monitoring strategies to predict and prevent these threshold transitions.²⁸ While widely applied by land management agencies in the United States, they are currently underutilized by conservation biologists and therefore fail to integrate feedbacks associated with wildlife. These models could be used to both communicate current knowledge about grass-shrub transitions and to help identify knowledge gaps.

Approach to Grasslands Management

Over the last 20 years, the Janos region shrublands has become a premier laboratory for understanding the importance of coupled human-ecological systems in achieving conservation goals. Research in this region, including similar work conducted by the Malpais Borderlands Group

in southwestern New Mexico, , strongly demonstrates the need to understand and maintain a complete compliment of ecosystem processes in order to maintain viable human populations and functional ecological systems.

The legal protection of the Janos region through the ongoing designation by the Mexican government of a half million hectare Biosphere Reserve provides the foundation for the conservation of the region's rich biodiversity. However, to be effective, conservation requires proper management of rural economic activities such as grazing, hunting, and agriculture, and represents the next step of our work in Janos. Adequate management refers to applying the most appropriate techniques for productive activities, taking into account the ecological settings of the region, with sound ecological zoning.

One approach to understanding the desertification process, and, hence, identify potential solutions, is to examine areas that have yet to undergo desertification or where desertification processes have only recently begun. In the Janos Region we can observe how healthy grasslands function and the forces that that initiate and sustain shrub dominance. Janos is a place that only recently began this transition from grassland to desertified shrubland, while still maintaining large prairie dog colonies.²⁹

An advantage of this region is its large size, with extensive prairie dog colony grasslands intermixed with desertified shrubland. Scientists studying shrubs moving into the edge of a grassland, or ecotone in this region may arrive at a much different conclusion with respect to desertification processes than others observing desertification across an entire region. And, unlike other regions that experienced desertification more than 100 years ago, this region appears to have most of the elements of healthy grasslands.

Our goal is to promote the conservation and restoration of the Janos Biosphere Reserve, and develop a model system for promoting both conservation and human well-being that can be replicated in other parts of the Chihuahuan Desert and even similar areas throughout the world. The key management issues to couple economic and human development with conservation of biodiversity are the following ones:

Grassland Restoration

Much of the Janos region has been converted to either mesquite shrubland or desertified annual grassland. Restoration of these areas to perennial grasslands is critical for the conservation of the Chihuahuan desert ecosystems. Scientific evidence indicates that the restoration of

grasslands in the southwestern United States and northern Mexico can benefit from the establishment of prairie dog colonies and better grazing management. Ecological approaches to management may be able to control prairie dog populations when populations become excessive. Such approaches may be developed by better understanding predator-prey dynamics in relation to habitat characteristics and patch structure. Management techniques that mimic those likely to occur during earlier phases of grassland evolution may be able to replace poisoning campaigns that cause large systemic ecosystem shifts that are difficult to manage. By successfully decreasing reliance on subsidized poisoning campaigns funds can be reallocated to enhance productivity of previously desertified grasslands. Groups such as the Malpais Borderlands Group in southern New Mexico and Arizona, provide model systems where collaborative research in Mexico and elsewhere can be applied to large-scale regional management of grassland ecosystems. The Malpais Borderlands Groups already recognizing the importance of fire, grazing, prairie dogs for the long-term management of grasslands and control of shrubs such as mesquite (*Prosopis glandulosa*)

Human Outreach

Although there are many topics that need to be addressed locally and regionally, large efforts have to be concentrated on human outreach. In both Mexico and the United States, there is a strong need to promote ecological awareness using participatory education programs. While such programs are available in the U. S. through federally funded university extension programs few programs are available in Mexico. Establishment of youth and community centered programs are needed in Mexico. Model programs that promote general education and ecological literacy are being designed for the Janos-Casas Grande Biosphere Reserve in the form of a youth conservation corp. Such programs can provide a mechanism for conducting current restoration efforts while establishing an ecologically based land-ethic affecting future generations. Successful implementation of this program may promote the establishment of similar national programs both the U. S. and Mexico. For the Janos-Casas Grande Biosphere Reserve program efforts will center on grassland communities and development of agro-ecological principals that provide economic opportunities while conserving the natural heritage of the region.

Conclusions

Evidence suggests that prairie dogs in conjunction with fire and grazing by large ungulates can improve or maintain regional biodiversity by maintaining open grasslands that benefit pastoralist communities. We

believe that local application of ecological based tools can benefit migratory grassland birds and raptors, in addition to regional bison and pronghorn populations, while benefiting rural populations. For the transboundary region of the southwestern U. S. and northwestern Mexico this will require local efforts to educate ourselves on the complexity of highly evolved ecological systems and to better interact within these systems with an understanding of larger scale interactions. Evidence suggests that we can structure rural economic pursuits to the benefit of larger ecosystems in our region. Our approaches include a strong education effort with persistent cultural effects that views humans as a integral part of the ecosystem.

As mentioned throughout the chapter, the role of prairie dogs to the maintenance of ecosystem services and human well-being is essential, our findings show, for example, that prairie dogs maintain open grasslands, which are more productive ecosystems for cattle, they increase the amount of water percolating to the water table, and they suppress woody plants with the potential to convert shrublands back into grasslands, curbing desertification and helping to maintain soil stability.

The results obtained from Janos over the last decade show that cattle ranching and conservation of prairie dogs are compatible. Lessons learned in the grasslands of the borderlands region of Mexico can be tested for their possible application to many of the nearly 20 million hectares that prairie dogs formerly occupied in North America, where cattle ranching is, as in Janos, the main economic activity.

The Commission for Environmental Cooperation (CCA) has published a Black-Tailed Prairie Dog Conservation Action Plan, which although general and brief, summarizes some of the most relevant actions than can contribute to the recovery of the species. However, for the Action Plan to be of any impact, the CCA would require to promote the coordinated work with the different actors working on grassland conservation across the range, as well as provide funding to advance the most urgent actions increasing research and improving land management in priority areas for the conservation of the species.

Grasslands have played a major role in the history of mankind, from agriculture's origin to their current role as major food producing areas. Because of their the vast importance to past and present cultures efforts to conserve grassland systems will likely benefit future generations. Thus we have the moral obligation to enhance our ability to ensure that the ecological and evolutionary process which give shape to the

rich biodiversity characteristic of North American grasslands, persist into the future.

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