Sky Island Grassland Assessment: Identifying and Evaluating Priority Grassland Landscapes for Conservation and Restoration in the Borderlands

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Animas Valley, New Mexico Photo: TNC

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Executive Summary

Sky Island grasslands of central and southern Arizona, southern New Mexico and northern Mexico form the “grassland seas” that surround small forested mountain ranges in the borderlands. Their unique biogeographical setting and the ecological gradients associated with “Sky Island mountains” add tremendous floral and faunal diversity to these grasslands and the region as a whole. Sky Island grasslands have undergone dramatic vegetation changes over the last 130 years including encroachment by shrubs, loss of perennial grass cover and spread of non-native species. Changes in grassland composition and structure have not occurred uniformly across the region and they are dynamic and ongoing. In 2009, The National Fish and Wildlife Foundation (NFWF) launched its Sky Island Grassland Initiative, a 10-year plan to protect and restore grasslands and embedded wetland and riparian habitats in the Sky Island region. The objective of this assessment is to identify a network of priority grassland landscapes where investment by the Foundation and others will yield the greatest returns in terms of restoring grassland health and recovering target wildlife species across the region.

As a first step in identifying priority landscapes, we integrated two recent assessments of grassland condition to characterize the historical extent and current condition of grasslands across the Sky Island region. These assessments—the Apache Highlands Grassland Assessment (AHGA) and the New Mexico Rangeland Assessment (REA)—used similar condition classes and an expert-based approach to map the spatial extent of grasslands by condition class. For this analysis, the two assessments were combined into one spatial dataset by grouping finer-scale REA condition classes up to AHGA classes. Five condition types or classes resulted from the integration: (1) no to low woody increase, native grassland; (2) medium woody increase, native grassland; (3) no to low woody increase, non-native grassland; (4) medium woody increase, non-native grassland; and (5) high wood increase, former grassland. The combined spatial data set does not have sufficient information to identify grasslands in Mexico outside of the Apache Highlands ecoregion. To represent these grasslands, we used the Instituto Nacional de Estadística y Geographía land cover map which contains no information on current condition or spatial extent of former grasslands; these grasslands were classified as “undetermined”.
Experts in the U.S. and Mexico identified 13,902,000 acres as current or former grassland which corresponds to almost half of the area we analyzed. Furthermore, grasslands were highly connected historically, allowing wide-ranging species, like bison, pronghorn and grassland birds, as well as species with more limited dispersal capabilities, like black-tailed prairie dogs, to move freely within and between these habitats.

Only 2.6 million acres, or 19% of these grasslands, are still dominated by native grasses and remain relatively open and shrub free. Approximately 4.9 million acres, or 35%, have experienced more shrub encroachment but still fall into classes that are considered restorable with prescribed fire and other relatively cost-effective methods. However, shrub cover and associated soil erosion has exceeded a threshold on over 3.2 million acres, producing an irreversible type conversion from grassland to shrubland on almost one quarter of the historic grasslands and savannas in this region. The spread of non-native perennial grasses within grasslands has also been substantial. Boer lovegrass and, to a greater extent, Lehmann lovegrass are common on at least 1.5 million acres such that non-native grasslands with little to moderate woody increase comprise 11% of the area’s current and former grasslands. Implications of this

spread are mixed, with some wildlife species more impacted than others. Native grasses remain present in many invaded areas, albeit at lower density.

To assist in the identification and evaluation of priority Sky Island grasslands, we summarized existing information from a variety of sources on the distribution of sensitive grassland species and riparian-aquatic species that occur in wetland habitats embedded within grasslands which were identified as targets and priority species by NFWF and others. In addition, we summarized occurrence information for natural communities that have declined significantly over the last 100^{+} years due primarily to human impacts: ciénega wetlands, sacaton riparian grasslands, and sandy black grama grasslands. Occurrence records for grassland and riparian-aquatic sensitive species were obtained from the Natural Heritage Programs in Arizona and New Mexico.

As a second step, we assembled several experts to both expand our understanding of grasslands across the region and to explicitly delineate priority grassland landscapes. Participants were asked to map areas they viewed as particularly promising for sustaining the region's grasslands over the long term, drawing on their own knowledge and a variety of supporting information provided at the workshop. Spatial data sets provided to participants included the integrated grassland condition assessment described above, soil classifications, species occurrence locations, land management responsibility and protection status, and results of various groups' efforts to identify priority conservation areas for other purposes. We seeded the discussion with suggested criteria for identifying, delineating, and evaluating these priority landscapes but participants were free to map as they saw fit. Suggested criteria included size of grassland blocks, ecological condition of those blocks, presence of embedded streams and wetlands and target wildlife species, fragmentation versus connectivity of grassland habitat, presence of intractable threats, and enabling conditions for long-term conservation success such as local community partnerships.

Once polygons were drawn and met with group agreement, participants filled out a matrix of conservation value and feasibility for each. Criteria evaluated included many of the same ones used to inform the drawing of the polygons, but this exercise required participants to rate criteria for each site as low, medium, or high and, where necessary, explain those ratings. This group effort provided additional sources of information about distributions of target species and sensitive communities as well as enabling conditions for conservation.

Participants identified twelve priority grassland landscapes (polygons), almost all containing substantial blocks of "high-quality grassland" that the combined grassland assessment had identified within the region (83% of overall acreage in native no to low woody increase classes), as well as substantial acreage of surrounding grassland patches deemed "restorable" (moderate woody increase). Landscapes differed in the amount and proportion of open intact grasslands within them. Four landscapes stand out as particularly noteworthy with over 150,000 acres of open intact grassland each: Upper San Pedro Mexico, Animas Valley-Sierra San Luis, Playas Valley-Janos Plain and Burro Cienega-Hachita landscapes.

The 12 priority polygons also succeeded in capturing many of the target biological features associated with grasslands in the region. All but two patches of riparian sacaton grassland identified were included in the final polygons and ciénegas were well distributed in all but four of the priority landscapes. Looking at the occurrence of species of interest across these polygons

revealed the value of the network as a whole. Some species like pronghorn and Chiricahua leopard frog (in embedded wetland habitats) are widespread, occurring in 10 out of 12 priority landscapes, while other targets occur in just one or two polygons. Of the 20 rare fish identified, 17 are found in three polygons or fewer, with most of these species living in just one or two stream systems each. Four landscapes are particularly notable in regard to native fish: San Bernardino Valley and Animas-Sierra San Luis with 7 and 9 species, respectively, of Yaqui drainage fish, and Empire-Cienega-Sonoita and Aravaipa-Muleshoe-Willcox with 10 and 11 species, respectively, of Gila drainage fish.

A broader look at rare species in the region further demonstrated how well this network of polygons captured known locations for species dependent on grasslands or their embedded riparian habitats. Half of the species evaluated had >75% of their recorded locations falling inside these polygons. Less than a third of the species had the majority of their locations outside our network of polygons and only 1 species (with one occurrence) did not occur in *any* grassland polygon.

Landscapes vary dramatically in land ownership/management patterns, as well as in protected status. Overall, private lands dominate the priority grassland landscapes. The degree to which these lands are managed for the benefit of wildlife and watersheds depends on the inclinations, abilities, and actions of individual citizens and community groups. Some landowners have chosen to put formal protections like conservation easements in place; these acres are considered "private protected" along with lands owned by organizations or foundations such as The Nature Conservancy, Animas Foundation, and Cuenca Los Ojos Foundation, whose primary mandate is conservation. Priority landscapes with the greatest amount and proportion of private protected acres are the San Rafael Valley (19% of grasslands in landscape); San Bernardino Valley (17%), Animas Valley-Sierra San Luis (50%) and Playas Valley-Janos Plains (18%). In 2009, the Mexican federal government designated 1.26 million acres of private land in Mexico as the Janos Biosphere Reserve; if this designation provides protection from threats, including agricultural conversion, this raises the proportion of protected grassland in this landscape to 86%.

Most priority grasslands include substantial acreage managed by US federal agencies, with the Bureau of Land Management being responsible for about 20% of grassland acres north of the border and the US Forest Service responsible for an additional 10%. Nearly all of these lands are managed for "multiple use," which includes the needs of wildlife and watersheds but may not give priority to them. Efforts of local community partnerships like the Malpai Borderlands Group, Sonoita Valley Planning Partnership and the Altar Valley Conservation Alliance to influence management of public lands can be effective at raising the emphasis on these values.

More than a quarter of US grasslands acres are under the jurisdiction of State Land Departments and managed for revenues from lease or sale; we considered these lands to be unprotected though some areas have conditions and advocates that would make land conversions more difficult. Proposals for formally protecting State Trust lands in Arizona for the benefit of both local communities and wildlife have been narrowly defeated in referendum votes. However, proponents continue to pursue these efforts, which would protect approximately 119,000 acres of grassland in the priority landscapes.

The overall protected status of grasslands in the priority landscapes varies dramatically. Considering private protected, local protected and federal lands together, over two-thirds of grasslands in the Animas-Sierra San Luis and North Peloncillos landscapes are protected, while over 40% of grasslands in the Altar-Tumacacori and San Rafael Valley landscapes are protected. In contrast, grasslands in the Upper San Pedro Mexico and Buenaventura landscapes have little to no permanent, formal protection. This makes areas that are protected, like Rancho Los Fresnos in the Upper San Pedro landscape, more important and vulnerable.

Grassland and riparian restoration is ongoing in all of the priority landscapes. However, the scale and scope of restoration activities appear to be greater in landscapes with established community partnerships involving private landowners, federal, state and local agencies, academic researchers, and private conservation groups and foundations. Priority landscapes with established local partnerships and active restoration programs include: Altar-Tumacacori, Empire-Cienega-Sonoita, San Bernardino Valley, Animas-Sierra San Luis, Playas Valley-Janos Plains, Aravaipa-Muleshoe-Willcox and Upper San Pedro in Mexico.

Finally, the last section of the report summarizes information for each of the twelve priority grassland landscapes that provides context and support for how the experts rated metrics of conservation value for each landscape and qualities that may not have been captured in these ratings. This includes information on geographical location, grassland size, current condition and connectivity across valley bottoms and with other priority landscapes. Embedded riparian wetland habitats are also identified for each landscape and other special biological features highlighted including the presence of NFWF conservation targets and other sensitive grassland and wetland species. Finally, we summarize the threats, land management responsibility, protected status, ongoing land protection efforts, and human enabling conditions that contribute to the feasibility of future conservation efforts in these landscapes.

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I. Sky Island Grasslands and Savannas: Historical Extent and Current Condition

Introduction

The grasslands of central and southern Arizona, southern New Mexico and northern Mexico, referred to here as Sky Island grasslands, form the "grassland seas" that surround small forested mountain ranges, often transitioning into desert scrublands as elevations drop, or into foothill woodlands or chaparral as elevations rise. These grasslands provide watershed services such as flood control and aquifer recharge across the region, and continue to support dozens of species of concern. At the continental scale, Sky Island grasslands form a unique setting where large blocks of Great Plains and Chihuahuan Desert grasslands east of the Rockies and Sierra Madre Mountains extend over a low spot in the Continental Divide. This ecotone geography and the ecological gradients associated with "Sky Island mountains and grassland seas" add tremendous floral and faunal diversity to the region as a whole (McClaran and Van Devender 1997). These grassland landscapes are often recognized as distinct places by their respective human communities as well, who self-organize to varying degrees in order to benefit from and protect the ecological and economic values of these places.

Sky Island grasslands have undergone dramatic vegetation changes over the last 130 years including encroachment by shrubs and trees, loss of perennial grass cover and spread of non-native species (e.g. Humphrey 1987; Bahre 1991). The causes for these vegetation changes have been the subject of some debate and range from changes in regional climate to human impacts including poorly managed livestock grazing and suppression of wildfires (Humphrey 1958; Hastings and Turner 1965; Cable 1967; Wright 1980; Bahre 1985, 1995; Swetnam 1990; Archer et al. 1995; Brown et al. 1997; McPherson and Weltzin 2000).

Changes in grassland composition and structure have not occurred uniformly across the borderland region (Bahre 1991; Bahre and Shelton 1993), nor are they solely the consequence of past climatic events or human impacts but are ongoing today (Archer 1989; Ceballos et al. 2010). For example, in the upper San Pedro River basin, there was a 16% loss of grasslands to mesquite woodland from 1970 to 1990 resulting in increased fragmentation of the remaining grassland there (Kepner et al. 2000). In a long-term study at Portal, Arizona, shrub density increased three-fold from 1977 to 1995 presumably as a result of increased winter precipitation regionally which favored shrub establishment (Brown et al. 1997). However, no detectable shrub increases occurred in large areas of grassland habitat, some within 20 km of the Portal site, over the same time period.

Although the above studies, as well as others, have documented vegetation change to grasslands *locally*, there have been only a few attempts to characterize the extent of change or assess the current grassland condition of borderland grasslands at broader scales (Cox and Ruyle 1986; Gori and Enquist 2003; Enquist and Gori 2008; Yanoff et al. 2008). These assessments are critically important for tracking grassland loss and degradation across broad geographies and for setting conservation and restoration priorities regionally (e.g., Marshall et al. 2004).

In 2009, The National Fish and Wildlife Foundation (NFWF) launched its Sky Island Grassland Initiative, a 10-year plan to protect and restore grasslands and embedded wetland and riparian habitats in the Sky Island region (Figure 1). The Initiative emphasizes grassland restoration,

protecting threatened land and water, and restoring populations of target wildlife species (NFWF 2009). The Foundation anticipates millions of dollars to achieve these goals and expects to leverage additional funds in federal, state and private funds. The question is: where will this investment by the Foundation and others yield the greatest returns in terms of restoring grassland health and recovering target wildlife species across the region?

This report attempts to answer this question at a regional scale by integrating two recent spatial assessments of the historical extent and current condition of Sky Island grasslands and savannas as well as compiling information on the occurrence of grassland-dependent wildlife and species of concern. Using this information and an expert-based approach, we identify 12 priority landscapes where the potential for restoring grasslands to full health and recovering target species have the greatest probability of success. We identify and evaluate these priority landscapes based on their size, landscape context, number of target species and natural communities and human enabling conditions for long-term conservation success. The latter includes the existence of partnerships, such as local cooperative groups dedicated to sustaining their landscape, land protection efforts and ongoing ecological restoration and management. Finally, for each of the priority landscapes, we summarize their current grassland condition, restoration opportunity, ecological features, critical threats, land management responsibility, and on-going efforts by the human community living in these landscapes and partners to protect and restore the ecological and economic values of these places.

Available Information on Historical Grassland Extent and Current Condition

The Sky Island region identified by NFWF is comprised of portions of six ecoregions defined by The Nature Conservancy based on Bailey (1995, 1998): the Apache Highlands; Chihuahuan Desert; Arizona-New Mexico Mountains; Sonoran Desert; Sierra Madre Occidental Pine-Oak Forests and Sonoran-Sinaloan Transition Subtropical Dry Forest (Figure 1).

Two recent assessments of historical grassland extent and current condition form the basis of the Sky Island Grassland Assessment (SIGA) and cover most of the historical and remaining grasslands and savannas in the Sky Island region. They are the Apache Highland Grassland Assessment (AHGA; Gori and Enquist 2003) and the New Mexico Rangeland Ecological Assessment (REA; Yanoff et al. 2008). The AHGA defined a series of grassland condition classes using expert opinion and the peer-reviewed literature to define threshold values for shrub cover (see references in McPherson 1970). Mapping of these condition classes was done by 24 range management specialists from federal and state agencies, academic institutions and non-governmental organizations for the U.S. and a combination of experts and LANDSAT satellite imagery analysis for Mexico. Mapping was approximately at a 1:100,000 to 1:250,000 scale. AHGA condition classes were defined by percent woody plant cover, compared to historical condition, and whether the grass species were native, non-native, upland or riparian. The AHGA considered fire to be a major natural disturbance that controlled woody plants and maintained grass dominance historically (Humphrey 1958; Bahre 1985; McPherson 1995; McPherson and Weltzin 2000).

AHGA condition classes in the project area were defined as:

1. Native grassland and savanna with low woody cover (<10%)

2. Non-native grassland and savanna with low woody cover (<10%) where non-native perennial grasses, specifically Lehman's and Boer lovegrass (*Eragrostis lehmanniana* and *E. curvula*) are common or dominant.
3. Bottomland sacaton (*Sporobolus wrightiii*, *S. airoides*) grassland
4. Woody-invaded native grassland and savanna with medium woody cover (10-35%, with cover of mesquite or juniper, *Prosopis* and *Juniperus*, <15%)
5. Woody-invaded non-native grassland and savanna with medium woody cover (10-35%, with cover of mesquite or juniper <15%)
6. Former grassland and savanna with high woody plant cover (>15% cover mesquite and juniper combined and/or >35% total woody cover; perennial grass cover always <3% and usually <1%); type conversion from grassland or savanna to shrubland.

The New Mexico Rangeland Ecological Assessment (REA) was limited to southern New Mexico and includes the northeastern portion of the Sky Islands project area. Mapping was completed by 70 experts at approximately 1:23,000-1:100,000 scale. The main ecoregion mapped by the REA was the Chihuahuan Desert and its transition with the eastern Apache Highlands (Figure 1). Condition classes in the REA are vegetation states in the state-and-transition models that accompany ecological site descriptions developed by the USDA Natural Resources Conservation Service (NRCS 2009). Ecological sites are land units defined by historical and current vegetation, ecological dynamics, soils, hydrology, landform and climate. The state-and-transition models synthesize the above information from experts and the scientific literature and describe the patterns and causes of transitions between plant communities within an ecological site.

REA condition classes are similar to those of the AHGA in that most altered classes reflect increases in woody plant cover over historical condition. However, REA classes are finer-scale, being associated with ecological sites, and distinguish grassland from savanna. In addition, they stress *relative* rather than *quantitative* woody cover, the distribution of grasses between or under woody plants, and non-vegetative indicators such as soil erosion. They also potentially allow for higher woody cover than the AHGA in some historical and woody-encroached savannas, although this is difficult to quantify since ecological site descriptions used in the REA do not specify woody cover thresholds between condition classes or states. In addition, the role of fire in maintaining historical grass dominance is not as consistently emphasized in the ecological site descriptions underlying the REA, compared to the AHGA, because increases in shrub and tree cover is not always related to fire in the Chihuahuan Desert. The REA did not map non-native grasslands or savannas in the project area, although the spread of Lehmann and Boer lovegrass into grasslands of southwest New Mexico is was limited before 2007 (Gori and Enquist 2003; Schussman et al. 2006).

The REA distinguished grassland and savanna condition classes based on the following characteristics, some of which are correlated with one another:

1. Grassland versus savanna
2. Continuous to connected grass patches versus grass cover low between and concentrated under woody plants
3. Woody cover increases low, moderate (woody invaded or encroached), or high (woody dominated or converted).

4. Grass composition dominated by long-lived perennial grasses versus sparse ruderal perennial or annual species.
5. Soil erosion low, variable or high.
6. Bottomland sacaton grassland

For this analysis, the two assessments were combined into one spatial dataset by grouping the finer-scale REA condition classes up to AHGA classes, as shown in Table 1. Because of their small areal extent, bottomland sacaton grasslands mapped in the AHGA and REA were included in the BGA's Native Grassland and Savanna in most of the following analyses unless otherwise indicated. For areas in southwest New Mexico that were mapped in both the AHGA and REA, AHGA mapping results were used in Major Land Resource Area (MLRA) 41 while REA results perennial grass cover always <3%; type conversion from grassland or savanna to shrubland

Table 1. Sky Island Grassland Assessment condition classes and the original AHGA and REA classes.

Original Assessment Class	Source	Sky Island Assessment Class
Native grassland & savanna with low woody cover [a]	AHGA	No or low woody increase, native grassland & savanna
Native grassland with or without ruderal grasses	REA	"
Native savanna with or without ruderal grasses	REA	"
Bottomland sacaton (*Sporobolus wrightii, S. airoides*) grassland	AHGA REA	"
Woody-invaded native grassland & savanna with medium woody cover [b]	AHGA	Medium woody increase, native grassland & savanna
Woody-invaded native grassland with or without ruderal grasses	REA	"
Woody-encroached native savanna with or without ruderal grasses	REA	"
Non-native grassland & savanna with low woody cover, where non-native perennial grasses, Lehmann and Boer lovegrass, are common or dominant [a]	AGHA	No or low woody increase, non-native grassland & savanna
Non-native grassland & savanna with medium woody cover, where non-native perennial grasses, Lehmann and Boer lovegrass, are common or dominant [b]	AHGA	Medium woody increase, non-native grassland & savanna
Former grassland & savanna with high woody cover [c]	AHGA	High woody increase, former grassland & savanna
Woody-dominated former grassland	REA	"
Woody-dominated former savanna	REA	"
Highly eroded former grassland	REA	"
Highly eroded former savanna	REA	"

[a]Woody cover < 10%
[b]Woody cover 10-35%, with cover of mesquite or juniper, *Prosopis* and *Juniperus*, <15%
[c]Woody cover >15% cover mesquite and juniper combined and/or >35% total woody cover;.

were used in MLRA 42 (Figure 1; NRCS 2006). The combined spatial data set does not identify grasslands in Mexico outside of the Apache Highlands ecoregion. To represent these grasslands, we used the Instituto Nacional de Estadística y Geografía (INEGI) land cover map which contains no information on the condition of current grasslands or on the spatial extent of former grasslands.

Using the combined data set we summarized the historical extent and current condition of grasslands and savannas across the project area subject to the caveats identified above for Mexico (Figures 2, 3).

A number of other, publically available vegetation cover maps exist for the study area including Brown and Lowe (1982), Southwest ReGAP (2005) and LANDFIRE (2009). We did not use these spatial layers in this analysis for the following reasons. Southwest ReGAP only maps grasslands and savannas in the US portion of the Sky Island region, while Brown and Lowe (1982) depicts them in US and Mexico, but both provide no information on the condition of these current grasslands, nor do they identify former grasslands that have undergone a type conversion to shrubland.

LANDFIRE maps the condition of current grasslands in the US portion of the study area within land units called biophysical settings. We did not use these data for several reasons. First, LANDFIRE spatial data are restricted to the US. Second, the LANDFIRE models are functionally different than the ESD models in describing vegetation dynamics and they yield estimates of reference conditions and ecological departure that do not conform well to one another spatially when compared within HUC 8 or HUC 10 watershed units (Yanoff et al. 2008). The ESD state-and-transition models describe, rather than quantify, ecological dynamics between reference and non-reference states while LANDFIRE uses probabilistic, quantitative models to predict the proportions of vegetation succession classes that would occur under reference condition. The frequency of disturbances, like fire, drought, wet periods, and livestock grazing, and their interactions with one another are too poorly known and unpredictable in semiarid ecosystems to generate reliable quantitative results (Bestelmeyer et al. 2004). Third, LANDFIRE grassland models do not incorportate non-linear ecological thresholds of shrub encroachment whereas ESD models do. When these thresholds are crossed a substantial empirical literature indicates that a return to reference condition (e.g., to vegetation states that are grass vs. shrub dominated) is no longer possible (Archer 1989; Buffington and Herbel 1965; Hennessey et al. 1983; Valone et al. 2002). By failing to consider these irreversible thresholds, the LANDFIRE models significantly underestimate the extent of former grasslands.

Target Grassland Species, Communities and Species of Concern

To assist in the prioritization of Sky Island grasslands, we summarized existing information on the distribution of grassland species and riparian-aquatic species that occur in streams and wetlands within grasslands in the project area (Table 2). These target species include those identified in NFWF's Sky Island Business Plan such as black-tailed prairie dog, pronghorn, bison, Aplomado falcon, Baird's sparrow, Chiricahua leopard frog, and Gila chub (NFWF 2009). In addition, we summarized occurrence information for several natural communities that have declined significantly (>90% from historical extent) over the last 100^{+} years due primarily to human impacts: ciénega wetlands, sacaton riparian grasslands and Chihuahuan black grama

grasslands on sandy and shallow sandy ecological sites (Hendrickson and Minckley 1984; Humphrey 1960; Yanoff et al. 2008). Finally, we obtained location information for all globally sensitive plant and animal species and subspecies from the Natural Heritage Programs in Arizona and New Mexico for the Sky Island region. We screened all of these records to identify grassland and riparian-aquatic species (Appendix 1). Heritage data were not available for Sonora and Chihuahua. Globally sensitive species were those with global ranks of G1 to G3 and subspecies with ranks of T1 to T3. These species and subspecies are identified in Appendix 1 along with the global rank definitions.

Table 2. Spatial data collected and data sources for the biodiversity analysis of Sky Island grasslands. Spatial data and databases available from authors.

Biological Feature	**Data Source**
Ciénega	Ciénega database and spatial layer developed by TNC-AZ based on literature, agency reports, expert knowledge & field reconnaissance; database includes information on ciénega location, ecological data (e.g. present of native fish, vegetation characteristics), hydrological and geological features, river that the ciénega is associated with, and position within floodplain (Minckley et al. *in press*)
Sacaton riparian grasslands	Mapped by experts, AHGA (Gori & Enquist 2003; Enquist & Gori 2008) and REA (Yanoff et al. 2008)
Black grama grasslands	Mapped by experts, historical extent and current condition on Sandy & Shallow Sandy ecological sites; REA (Yanoff et al. 2008)
Prairie dog (*Cynomys ludovicianus*) colonies	Database and spatial layer developed by TNC-AZ based on literature, agency reports & expert knowledge.
Pronghorn (*Antilocapa americana mexicana*)	Spatial layer developed by TNC-AZ based on Brown & Ockenfels (2007), AZGFD (2010), Correon & Lafon (2012), List & Valdez (2009), SEMARNAT 2009 and expert knowledge
Jaguar (*Panthera onca*)	Spatial layer developed by TNC-AZ based on agency reports and expert knowledge
Bison (*Bison bison*)	Spatial layer developed by TNC-AZ based on agency reports and expert knowledge
Mexican gartersnake (*Thamnophis eques megalops*)	Location information cited in Center for Biological Diversity's listing petition (2003) and Rosen et al. (2001)
Sensitive grassland & riparian/aquatic species	Spatial information on species occurrences provided by NM Natural Heritage Program, and AZ Game & Fish Heritage Program; sensitive grassland and riparian-aquatic species have global ranks of G1-G3 and T1-T3; occurrence information for many of these species in MX was provided by experts.

Limitations of the Sky Islands Grassland Assessment

The BGA used the best available information on the historical extent grasslands and savannas and their current ecological condition that could be applied over large portions of the Sky Islands project area. However, several limitations of the BGA should be considered when interpreting the results.

As noted, the AHGA and REA differed somewhat in their classification schemes which may have led to inconsistencies in how grasslands and savannas were assigned to condition classes in

this combined assessment. Since quantified vegetation cover influenced AHGA condition classes more than the REA, the condition of areas with similar vegetation may have been interpreted differently by experts contributing to the two assessments. More importantly, REA mapping was not field verified for accuracy. In contrast, the AHGA included a comprehensive accuracy assessment using 182 field sampling points and data from 52 long-term monitoring plots in the US portion of the Apache Highlands ecoregion in order to verify the original expert map. Experts correctly identified grassland condition classes in 181 of 234 sampling points, an overall accuracy rate of 77%. This rate compares favorably to those for land cover maps without condition classes derived from analysis of Landsat satellite imagery which range from 57% to 78% (e.g., Lauver and Whistler 1993; Ringrose et al. 1999; Kepner et al. 2000; Halvorson et al. 2001). In addition, the initial expert map was corrected and improved based on data from field sampling points as well as additional field mapping done during 17 reconnaissance trips. As a result, the accuracy of the final AHGA map was greater than 77%. Given this result, we assume that expert mapping in the REA also had a high level of accuracy since all experts had considerable knowledge of local range conditions. However, because the mapping was done at a finer-scale than the AHGA, its overall accuracy rate may be lower. Still the REA is the most comprehensive mapping of grassland condition and historical extent available for New Mexico especially in MLRA 42 (Figure 1).

In addition, some REA savanna classes may have allowed for higher levels of woody cover than did the AHGA, when classifying savannas with no or low, medium, or high woody cover increases. However, these differences may have less to do with differences in methods than to climate differences in the ecoregions on which these assessments were focused. The Chihuahuan Desert and its transition with the Apache Highlands in New Mexico, where the REA is centered, is drier than the Apache Highlands to the west and may support higher shrub cover in some historical and woody-encroached savanna types (e.g., NRCS 2009). This is especially the case where savannas occur on shallow, gravelly and rocky soils. Climate and precipitation likely influenced the historical role that fire played in Apache Highland grasslands and savannas, where higher grass cover (fine fuels) and greater annual productivity may have resulted in more frequent wildfires and lower woody cover compared to the Chihuahuan Desert.

The historical extent and current condition of grasslands in Mexico is poorly understood. The AHGA mapped 1.2 million acres of grasslands in Mexico as undetermined condition and the extent of former grasslands was likely underestimated due to the lack of expert knowledge in many areas (Gori and Enquist 2003). The same holds true for grasslands and savannas in other ecoregions in Mexico where we used the INEGI land cover layer to identify current grasslands but lack information on their condition or grassland extent historically. These grasslands of undetermined condition represent a potential expansion of restoration opportunity in the project area. In addition, although the SIGA deferred to the REA in MLRA 42 (Southern Desertic Basins, Plains and Mountains) and to the AHGA in MLRA 41(Southeastern Arizona Basin and Range) in areas where the two assessments mapped conflicting conditions, these conflict areas also represent an information gap.

The biodiversity analysis uses species occurrence information obtained from the Natural Heritage Programs in Arizona, New Mexico and Sonora. These databases do not track the occurrence of some important indicators of Sky Island grasslands including black-tailed prairie

dogs, pronghorn antelope, bison, most grassland sparrows, loggerhead shrike, eastern meadowlark, bunch grass lizard and ornate box turtle (NFWF 2009). Information for many of these species is available in grey-literature reports and from experts, but locating this information across state and national boundaries and compiling it in a spatially explicit manner has not been attempted for these species. To assist in this effort, we developed spatial layers for the occurrence of prairie dogs, pronghorn, and bison in the Borderlands. In addition, the availability of species occurrence data to Natural Heritage Programs is not uniform across the project area and varies depending on the species, how exhaustively an area has been surveyed, and whether surveyors submit their information to the programs. For example, we obtained no database records for Mexican garter snake at either Las Cienegas National Conservation Area or the San Rafael Valley, Arizona, but Rosen et al. (2001) found small populations at both localities. Thus, species occurrence records indicate only that the species was observed at a site (on a specific date), but the absence of records cannot be interpreted to mean that a species is not present. Finally, species occurrence records normally contain no information on population size, distribution, trend, age structure, and genetic diversity, all of which are important for evaluating biodiversity patterns.

In summary, the BGA is broad-scaled and regional in scope and, while it depicts general patterns in grassland and savanna historical extent and current condition, it is not appropriate for use at finer-scales or at specific locations, for example, to plan and prioritize restoration treatments.

Results and Discussion

Throughout this section we will refer to “grasslands and savannas” collectively as “grasslands” as a way to streamline the presentation of results.

Historic Distribution of Grasslands

Experts in the U.S. and Mexico identified 13,902,000 acres as current or former grassland which corresponds to 47.7% of the area we analyzed (Table 3). We assume that this represents a conservative figure for the historic distribution and extent of grasslands in this area. Furthermore, grasslands were highly connected historically, allowing wide-ranging species, like bison, pronghorn and grassland birds, as well as species with more limited dispersal capabilities, like black-tailed prairie dogs, to move freely within and between these habitats (Figure 2).

Open and Shrub-Invaded Grasslands

The summary statistics for the number of acres in the various grassland condition classes underscores the extent of vegetation changes that have occurred in the Sky Islands region (Table 3). Over 2,623,000 acres or 18.9% of current and former grasslands still remain relatively open and shrub-free (Figure 3). Approximately, 4,884,000 acres or 35.1% of current and former grasslands have experienced more shrub encroachment but still fall in classes where this change is considered reversible with prescribed fire or other brush control methods (e.g., medium woody increase and mix of low and medium woody increase classes). However, shrub cover and associated soil erosion has exceeded a threshold on over 3,275,000 acres producing a type conversion from grassland to shrubland on almost one quarter of historic grasslands and savannas in this region. Such areas are considered difficult if not impossible to return to open grassland states on any substantial scale (Hennessey et al. 1983; Valone et al. 2002; Gibbens et

al. 2005), though small patches might conceivably be recovered with heavy investment of resources.

Non-Native Grasslands

The spread of non-native perennial grasses within grasslands has also been substantial (Table 3). Boer lovegrass and, to a greater extent, Lehmann lovegrass are now common or dominant on at least 1,505,000 acres such that non-native grasslands with no to little woody increase or medium woody increase comprise 11% of the area's current and former grasslands. When the AHGA was completed in 2003, non-native grasslands were restricted to Arizona. However, Lehmann lovegrass appears to be spreading into southwestern New Mexico as it is now present in long-term grassland monitoring plots where it had not previously been recorded (Sundt 2009). Implications of this spread are mixed, with some wildlife species more impacted than others (e.g. Bock et al. 1986, Albrecht et al. 2008). Native grasses remain present in many invaded areas, albeit at lower density. Fire regimes and hydrology can be affected but are not as radically transformed as is the case with many plant invasions (Emmerich and Cox 1992).

Target Grassland Species, Communities and Species of Concern

The distribution of ciénegas, sacaton riparian grasslands and black grama grasslands on sandy and shallow sandy soils are shown in Figure 4, highlighting the extreme rarity of these natural communities compared to their historic extent. Similarly, Figure 4 summarizes the occurrences of NFWF target species—black-tailed prairie dog, pronghorn, bison and jaguar.

In addition, we summarized occurrence records that we received from the NM and AZ Heritage Programs for 22 sensitive grassland species or subspecies with global ranks of G1-G3 and T1-T3; this includes 12 plants species or subspecies, 2 invertebrates, 1 reptile, 5 birds and 2 mammals, all of which depend on high-quality open or restorable grasslands (Appendix 1). Similarly, we summarized occurrence records for 45 sensitive riparian and aquatic species and subspecies that occur in streams, wetlands and riparian areas that are embedded in grassland watersheds. These include 13 plants, 7 invertebrates, 17 fish, 4 amphibians, 1 reptile, and 3 riparian birds. Most NFWF high-priority species that will benefit from grassland protection and restoration efforts are included among these sensitive species.

This information was used during the experts workshop and after to evaluate the conservation values of priority grassland landscapes and to assess their relative contribution in sustaining sensitive grassland and riparian aquatic species across the Sky Island region.

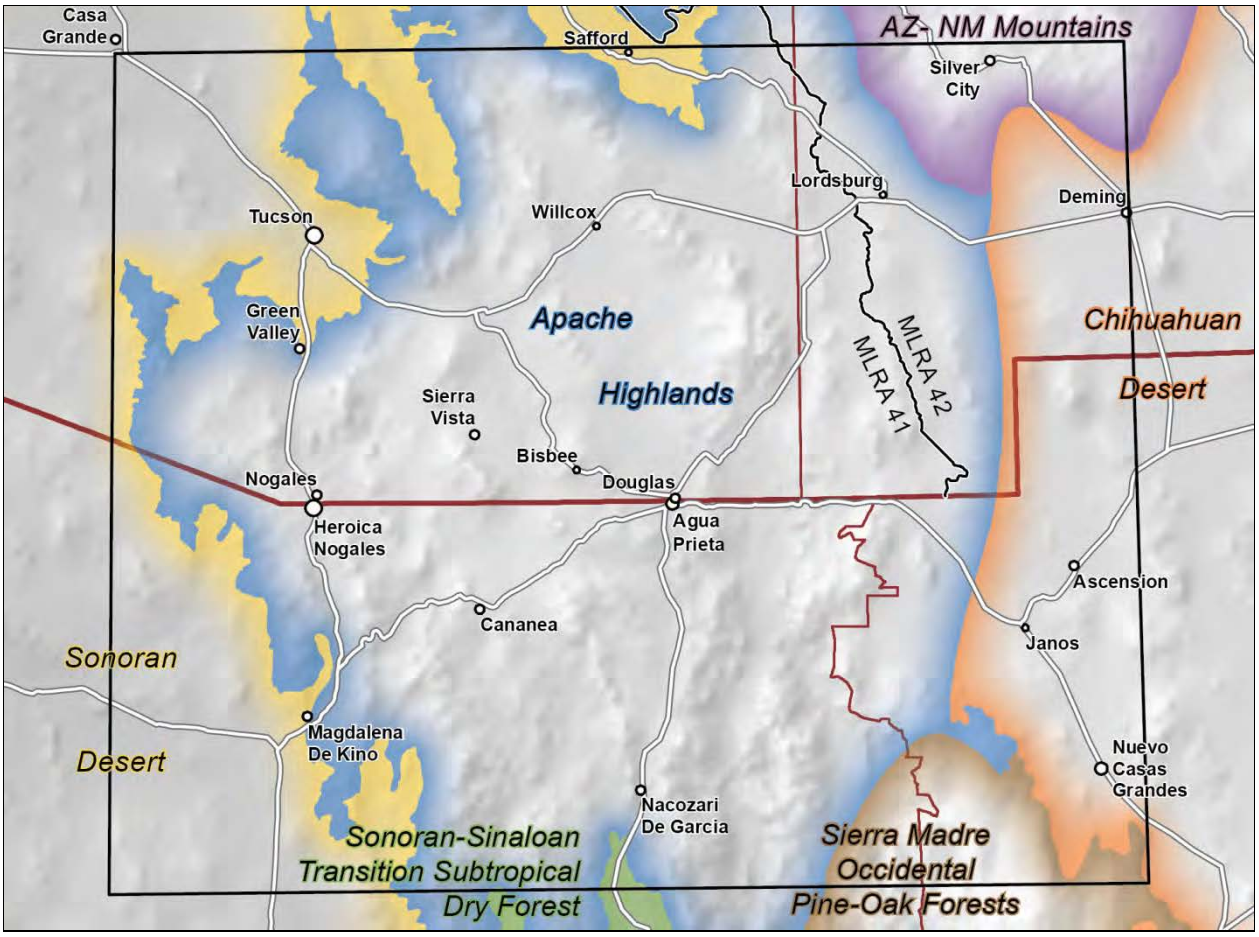


Figure 1. Locator map showing the Sky Island focal area, its component ecoregions and Major Land Resource Areas 41 and 42 in the US.

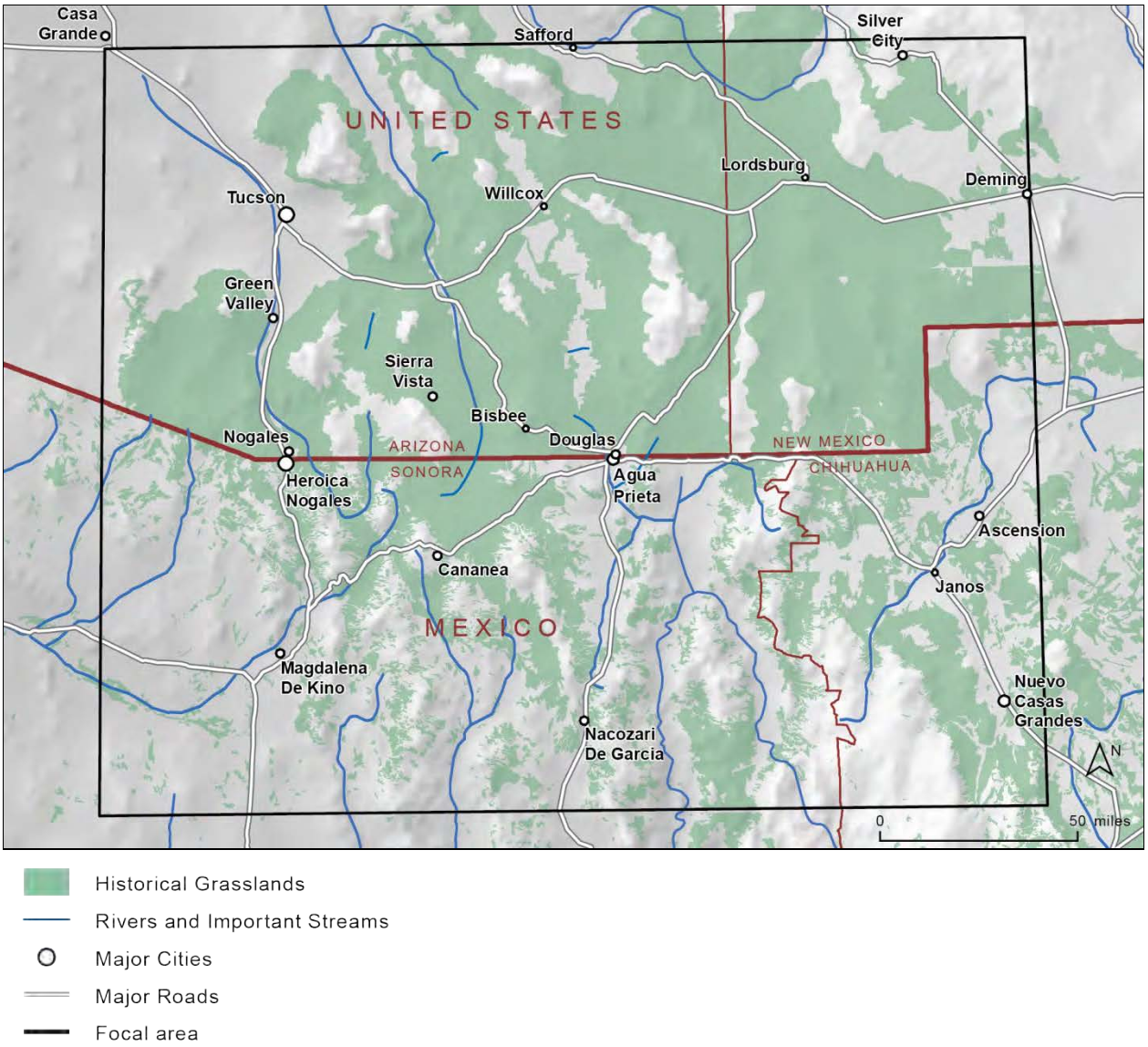


Figure 2. The extent of historical grasslands and savannas in the Sky Island focal area.

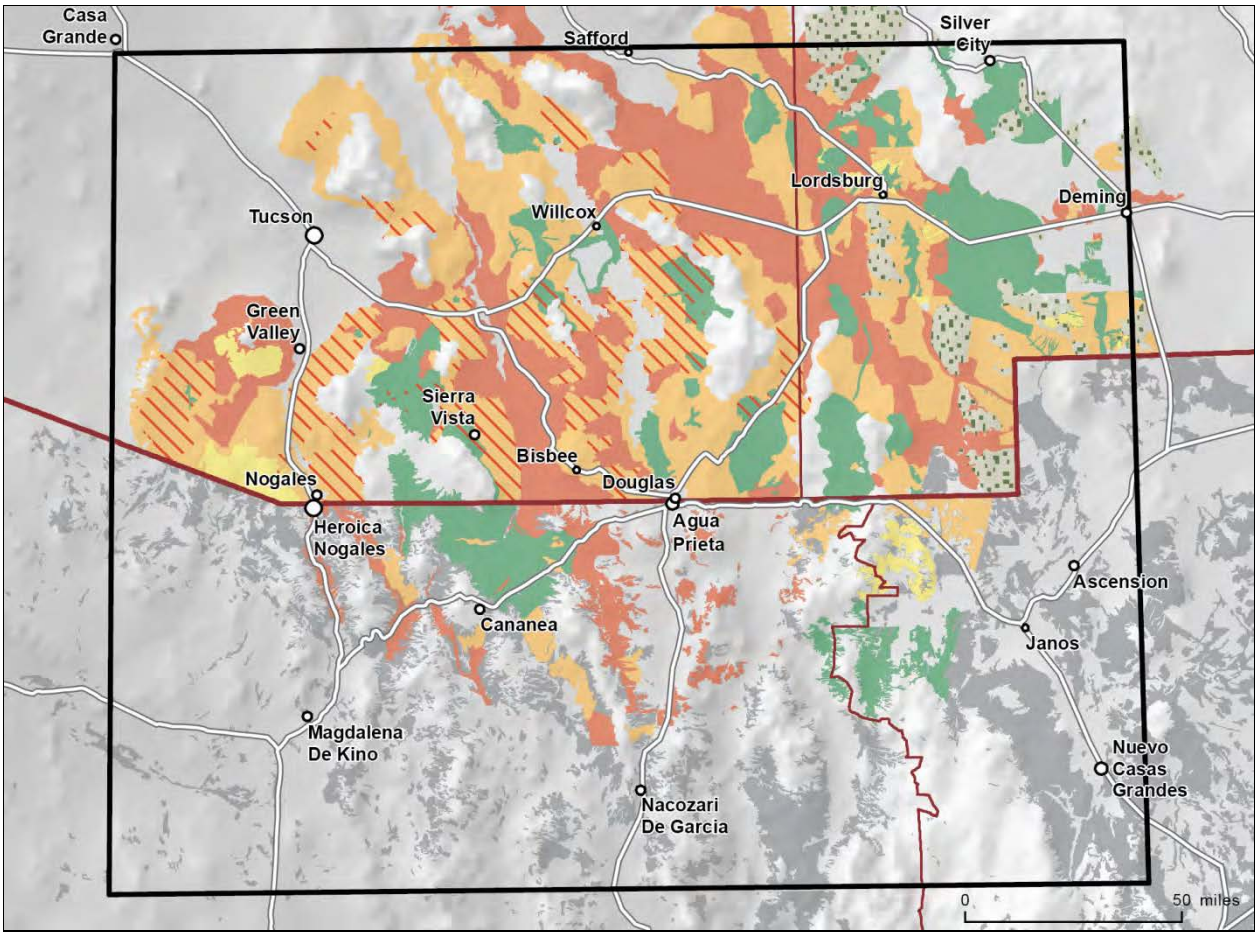


Figure 3. Current condition of grasslands and savannas in the Sky Island focal area.

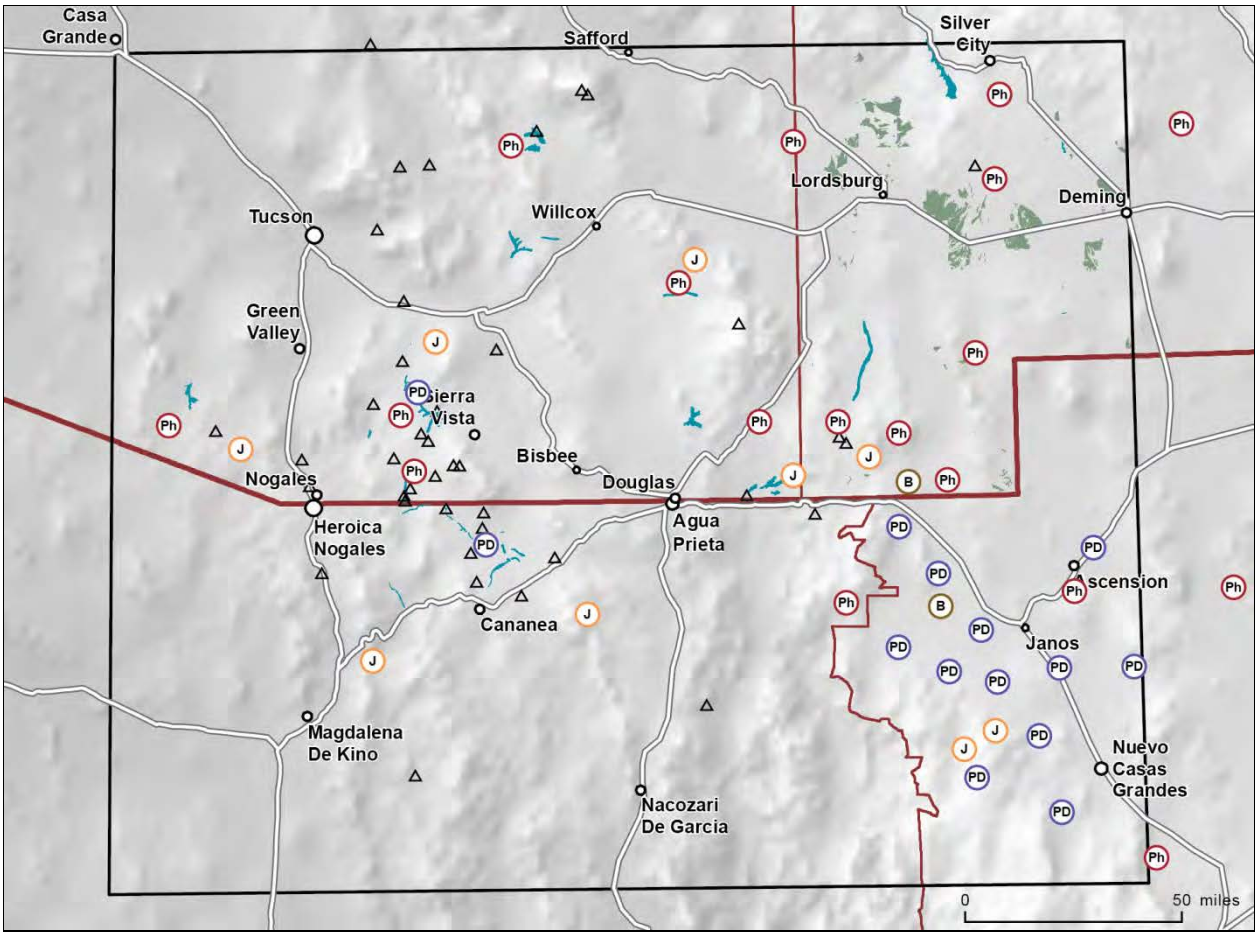


Figure 4. Distribution of target species identified by the National Fish and Wildlife Foundation and sensitive natural communities that have declined significantly in the Sky Island region.

Table 3. General statistics for grasslands in the Sky Island region, U.S. and Mexico (see Figure 1 for Area of Interest).

Grassland Type	# Patches	Total Acres	Minimum Patch Acres	Maximum Patch Acres	Mean Patch Acres	% All Grasslands
No to low woody increase, native grassland	102	2,144,488	2	413,964	21,024	15.4
No to low woody increase, native savanna	48	478,953	< 1	71,801	9,978	3.4
Medium woody increase, native grassland & savanna	138	3,212,191	< 1	472,949	23,277	23.1
No to low woody increase, non-native grassland & savanna	11	162,417	629	43,909	14,765	1.2
Medium woody increase, non-native grassland & savanna	19	1,342,952	471	259,264	70,682	9.7
High woody increase, former grassland & savanna	185	3,275,463	< 1	1,176,874	17,705	23.6
Mix of low and medium woody increase, native grassland & savanna	26	328,574	4	110,992	12,637	2.4
Undetermined grassland & savanna	5,764	2,956,650	< 1	369,224	513	21.3

TOTAL US-MX GRASSLAND/SAVANNA ACRES: 13,901,688

% ENTIRE AREA OF INTEREST 47.7%

II. Highlighting Opportunities to Sustain Grassland Communities

In the process of compiling available studies and other written works that attempt to document grassland condition, extent, and features, we recognized that these sources did not entirely capture the collective knowledge that we knew to exist for the region. We also recognized that automated analytical methods were not going to be able perform the kind of regional prioritization and triage analysis that we felt was necessary to focus conservation investments in places they would do the most good for grassland conservation. We addressed this by convening experts in a workshop, and by pulling together additional data as we found them before and after this workshop.

Experts Workshop Methods

In September 2010, we assembled several experts to both expand our understanding of grasslands across the region and to explicitly delineate focal areas. Participants included: Angel Montoya, Peregrine Fund and US Fish and Wildlife Service; Dan Robinett, NRCS retired; Miles Traphagen, Turn of The Century Monitoring Inc.; and from The Nature Conservancy: Gita Bodner, Dave Gori, Peter Warren, and Steven Yanoff, assisted by Anne Bradley and Lara Miller.

Objectives of the experts workshop:

1. Review existing information on historic distribution and current condition of Sky Island grasslands; distribution of grassland-dependent species, embedded riparian and aquatic species and sensitive plant species, including those targeted in the NFWF Sky Island Business Plan; and human threats and conservation opportunities.
2. Highlight priority grassland landscapes. Refine site evaluation criteria, use these and expert knowledge to identify areas in the Sky Island region where investment by NFWF and others will have the greatest impact on protection, restoration & recovery of grasslands and grassland-dependent species over the next 10-years and into the future.
3. As time allows, discuss how to identify priorities and opportunities for restoration actions within these priority grasslands.

Participants were asked to draw lines on maps to encompass areas they viewed as particularly promising for sustaining the region's grasslands over the long term, drawing on their own knowledge and a variety of supporting information provided at the workshop. These were all accessible throughout the workshop, but participants chose to use some more than others. We seeded the discussion with suggested criteria for identifying, delimiting, and evaluating such "priority grassland landscapes." Participants were free, however, to draw polygons and describe attributes of these delineated areas as they saw fit. Suggested criteria (Box 2a) included size of grassland blocks, ecological condition of those blocks, presence of embedded streams and wetlands, presence of target wildlife species, fragmentation versus connectivity of grassland habitat and of natural vegetation more broadly, presence of intractable threats, and existence of conservation efforts such as local community partnerships. Spatial data sets provided to

Box 2a. Rationale for workshop and suggested criteria for identifying, delineating and evaluating priority grassland landscapes

Borderland Grassland Assessment for Conservation Investment

Goal: The goal of this assessment is to provide broad-scale information to guide decisions about investment in grassland conservation that will maximize the long-term success of those investments. In other words, what are the characteristics of a grassland landscape that make it more or less likely to survive as an intact, functional ecosystem for the indefinite future. We envision this as a triage process in which some grasslands landscapes may be so highly degraded, fragmented, or otherwise compromised that there is little chance of their survival as functional grassland, others may have a reasonable chance of sustaining some grassland values but will require substantial work, and some may be largely intact but need maintenance and alleviation of threats in order to insure the long-term value of land protection and land health investments.

Starting Point: The basic organizing structure for this assessment is a delineation of the major grassland landscapes in the borderlands region, most of which are defined by the valleys within which they occur. The boundaries of these grassland valleys may be more-or-less defined by their watersheds, but the functional grasslands units do not always follow watershed boundaries. These landscapes are typically recognized as distinct places by their respective communities, who self-organize to varying degrees in order to benefit from and protect the values of these places.

Criteria: There are several criteria that can be used to identify, characterize, and compare grassland landscapes for the purpose of evaluating their prognosis for long-term viability. These include some ecological characteristics and some socio-economic characteristics.

Size: Generally bigger is better. Those sites that have relatively intact, healthy grassland usually have an intact core of at least 50,000 acres or so. Smaller patches of grassland also have value, but are less likely than large patches to maintain key processes like fire, or to support viable populations of grassland-dependent wildlife species over the long term.

Grassland condition: The best sites have a core of high quality native grass, often with an extensive area of lesser quality but restorable grassland. Presence of rare or vulnerable grassland types is desirable, such as sacaton bottomland or Chihuahuan sandy black grama grassland.

Fragmentation/intractable threats: How much conflicting land uses occur in the area such as irrigated agriculture, urban/residential development, extensive road network, or other threats that may be impossible to alleviate.

Connectivity: Related to fragmentation, but focused on the continuity and extent of natural communities across the valley landscape from one mountain range to another, and along the length of the valley (usually north-south). Although degree of connectivity within a grassland valley landscape is the primary concern, a secondary consideration is the degree of connectivity to other grassland landscapes (which historically were interconnected). This between-landscape connectivity may be important in sustaining wildlife movements.

Wildlife: How well are grassland dependant wildlife represented in the site? This could include everything from bison and pronghorn to sparrows, lizards and snakes. Which NFWF target species are known to occur here? What do we know about the importance of this site to the species?

Embedded Riparian: Perennial springs and streams, and associated aquatic species (i.e. fish, frogs) are often associated with healthy grassland watersheds, and may be an indicator of over-all landscape condition. Presence of such wetland habitats elevates the value of grassland landscapes for conservation and communities.

Other Special Values: Do we know of any other species such as sensitive plant species (G1 to G3) or habitat values that occur or are unique to a site?

Local Community Partnership: Long-term success of grassland conservation may depend on having effective local community organizations working toward this goal. What partners are currently active in this area, and how effective to they appear to be in advancing community investment into maintaining healthy grasslands?

Box 2b. Spatial information provided to participants during experts workshop

General:

1. NFWF 's priority area-of-interest (AOI) for their Sky Islands Grasslands Initiative.
2. Basic layers like Roads, Cities, Counties, States, Drainages, Features, state and federal Parks, Watersheds (Subcuencas for MX, HUCs for U.S), etc.

Grasslands and Historical and Current Condition:

3. **Working Grassland Valleys:** Draft locations of important grasslands, as depicted in the NFWF business plan. These can be a start for the workshop.
4. **Historical Vegetation and Current Condition**
   This is the information described in detail in Chapter 1, from the merging of TNC's two grassland assessments. Condition based on expert input in TNC's Apache Highlands and New Mexico Rangeland Ecological assessments. NM-REA in turn drew from NRCS ecological site descriptions. Emphasizes woody encroachment and native or non-native grasslands. *An example is Medium Woody Increase – Native.*
5. **WWF Intact Areas**
   Intact habitat blocks from WWF Ecoregional Analysis for the Chihuahuan Desert, which includes most of the NFWF AOI. See the WWF Ecoregional Analysis report [participants looked at bid did not use extensively]
6. **Landfire FRCC AZ** and **NM** – Fire Regime Condition Class, a percent-area measure of ecological departure from reference condition with increasing departure coded 1 to 3. For U.S. only. [not used]

Species:

1. **Species US (Heritage)**
   Locations of rare (G1-G3, T1-T3) and ESA listed species from Natural Heritage programs for the U.S. only. Includes grassland and embedded riparian species.
2. **Species MX**
   Species from TNC ecoregional plans for Mexico. These data are not current and are designed for internal use only. Includes grassland and non-grassland species.
3. **Habitat (ReGAP)** for **Aplomado Falcon**, **Baird's Sparrow**, **Black-Tailed Prairie Dog**, **Chiricahua Leopard Frog**, **Jaguar**, **Pronghorn** and **Rufous-Winged Sparrow**
   Occupied and potential habitat from SW ReGAP for U.S. only
4. **WWF Species and Vegetation Sites**
   Important areas for conservation of animals, plants and key vegetation habitats including grasslands. From WWF Ecoregional Analysis for the Chihuahuan Desert, which includes most of the NFWF AOI. See Appendix C in the WWF Ecoregional Analysis report and the WWF database. [participants looked at but did not use extensively]

Conservation Plans:

5. **World Wildlife Fund Conservation Areas**
   Priority conservation sites from the WWF Ecoregional Analysis for the Chihuahuan Desert. The WWF's ecoregional boundary includes most of the NFWF AOI. See the WWF Ecoregional Analysis report for site descriptions. [participants looked at but did not use extensively]
6. **The Nature Conservancy Portfolio Areas**
   Priority conservation sites from the several TNC Ecoregional Analyses that span the NFWF AOI. See TNC Ecoregional Analysis reports for site descriptions. [participants looked at but did not use extensively]

Other Soils and Vegetation:

1. **Soils US (SSURGO) with links to Ecological sites**
   NRCS mapped soils for U.S. only. Labeled by Symbol and has Map Unit Key so soil and other data such as ecological sites can be looked-up in the SSURGO database.
2. **ReGap Vegetation** and **Landfire Current Veg** – Current vegetation type, U.S. only. [not used]
3. **INEGI series iv Vegetation** – Current vegetation type for MX only.
4. **Landfire Potential Veg US –** Historic/potential vegetation for US only [not used]

participants, in a series of hardcopy maps or GIS layers projected on screen as requested, are shown in Box 2b. These included information on vegetation classifications, grassland condition assessments, soil classifications, species occurrence locations and habitat models, land protection

status, and results of various groups' efforts to identify priority conservation areas. For two polygons, participants chose to further refine boundaries after the workshop by examining additional information, including Google Earth imagery and ground-based photographs.

Participants were encouraged to consider identifying areas according to valleys in which core grassland blocks occur. Grassland patches in the borderlands region naturally occur in valleys, as "grassland seas" surrounding forested mountain ranges and often transitioning into scrublands or desert vegetation types as soils change or elevations drop, or into foothill/mountain slope woodlands or chaparral vegetation types as elevations rise. The boundaries of these grassland valleys may be more-or-less defined by their watersheds, but the functional grasslands units identified do not always follow watershed boundaries, as many extend over low watershed divides between isolated mountain ranges. These landscapes are typically recognized as distinct places by their respective communities, who self-organize to varying degrees in order to benefit from and protect the ecological and economic values of these places.

Lastly, once polygons were drawn and met with group agreement, participants were asked to fill out a matrix of conservation value and feasibility for each polygon. Criteria evaluated included many of the same ones used to inform the drawing of the polygons, but this exercise required participants to rate criteria for each site as low, medium, or high and, where necessary, explain those ratings. This was done as a group effort, with discussion of rankings as we went. Filling out the matrix together also spawned discussions about the characteristics of each grassland landscape, which we attempt to capture in Section III.

Experts Workshop Results and Discussion

Participants largely agreed on locations of "best" remaining grassland landscapes (Figure 5, including most of those identified in the NFWF business plan which were delineated using the AHGA and a less comprehensive process (NFWF 2009). They recommended modifications of some boundaries based on additional knowledge about locations of valued features (e.g. extending the Janos polygon north into the Playas valley to reflect movements of a wild bison herd) or ongoing conservation efforts (e.g. expansion of Muleshoe-Aravaipa polygon to include an area known as the Bonita grassland where landowners are combating shrub invasion). Experts suggested addition of polygons (e.g. Buenaventura) to incorporate areas that met many of the suggested criteria but whose values have not been widely known among practitioners in this region. The group also recommended dropping two polygons (Santa Cruz and San Pedro-US) that had been previously demarcated but rated low in grassland-specific values (see Table 4 below). Parts of the initial Santa Cruz polygon that still have substantial grassland patches were added to the Altar Valley polygon, with which experts identified relatively high landscape connectivity (an impression substantiated by the multi-year movements of a wandering jaguar known as Macho B). In two cases, participants chose to further refine polygon boundaries by examining additional information after the workshop. Overlaying draft polygons on Google Earth proved especially useful for modifying boundaries to exclude highly modified areas such as center-pivot agriculture in Chihuahua.

The twelve final polygons incorporated almost all the substantial blocks of "high-quality grassland"—no to low woody increase—that the combined grassland condition assessment had identified within the region (Figure 5); as well as substantial acreage of surrounding grassland

patches deemed “restorable”—moderate woody increase. Overlaying polygons on maps of grassland habitat condition highlight places where blocks of open grassland are vulnerable to fragmentation by habitat degradation, as well as key opportunities to protect or restore connections for species such as pronghorn whose movement patterns are known to be affected by habitat changes such as shrub encroachment (Brown and Ockenfels 2007). These polygons also succeed at encompassing many of the other target biological features associated with grasslands (Figure 6**)**. For example, all but two patches of riparian sacaton grassland identified in grassland condition assessments were included in final polygons. The two that were not included are relatively isolated from other grassland blocks, one being on the southwestern edge of Borderland grasslands in general where terrain changes to highly dissected Sonoran scrub, and the other being on the northern end of the NFWF area of interest where terrain rises towards the Mogollon Plateau. This latter site is near the Burro Cienega-Hachita polygon but is separated from that polygon by a large open pit mine, to which it is adjacent.

Delineations of these major grassland landscapes did largely conform to units defined by individual valleys. This evaluation bore out previous observations that the largest remaining blocks of open grassland tend to be in mid-elevation valley bottoms (e.g. San Rafael, Sonoita plains, Animas). Grassy hills do contribute substantial blocks in some areas (e.g. Tumacacori & Sierrita portions of the Altar polygon). In others (North Peloncillos, both Sulphur Springs polygons), grassland habitat primarily occurs on bajada or foothills terrain above lowlands that have undergone vegetation and/or land use conversions. We applied the valley names most commonly used by local communities to refer to these areas. This led to hybrid names in some polygons, e.g. the Empire-Cienega-Sonoita polygon that spans a low watershed divide in an area that has been referred to by any of these three names throughout its past. Participants discussed the possibility of combining nearby polygons but eventually decided that the smaller units more accurately reflect differences in enabling conditions for conservation, that is, differences in community culture or development threats among nearby polygons. However, they did suggest grouping nearby polygons into connected “complexes.”

Comparing polygons to maps of land management (shown with resulting polygons in Figure 7) and protection status (Figure 8) helped participants evaluate aspects of connectivity and conservation feasibility. These maps also highlight places where grassland blocks are vulnerable to fragmentation by human infrastructure and disturbance, as well as key opportunities to protect long term connectivity of natural vegetation for the many wildlife species that are less restricted to grassland habitats per se but are affected by more dramatic changes on the landscape such as proliferation of roads, houses, mines, or intensive agriculture. Several different jurisdictions, for instance, combine to provide protection across nearly the entire San Rafael valley in the US; adding easements or other conservation status to the last remaining large block of unprotected private land at the top of the valley would secure the ongoing value of these previous investments. Successfully completing long-standing efforts to bring publicly-identified parcels of Arizona State Trust land into conservation status would greatly benefit five of the twelve priority grassland landscapes identified here. Conserving these State Trust lands would, for example, safeguard the core grassland block in the center of the Empire-Sonoita Valley, and secure wildlife connectivity from here across the I-10 corridor, Catalina-Rincon Mountains, and the San Pedro River to the Aravaipa-Muleshoe landscape.

Overlaying polygons on land management also highlights the role of particular institutions in sustaining grasslands across the region. For instance, these maps suggest that if the US Forest Service wants to invest in keeping open grasslands open, this agency might focus on areas within the San Rafael polygon; if the agency's goals is to restore recoverable grassland, working in the Altar-Tumacacori might provide the best opportunities. This overlay provides guidance at the level of individual landscape as well. While each of these landscapes include a mix of public and private lands, success in landscapes like the Empire-Sonoita Valley depends heavily on management effects on public lands. Outcomes in landscapes such as the Animas-San Luis Valley depend almost entirely on the actions of private landowners. These implications are discussed more in Chapters 3 and 4.

In the process of filling out the evaluation matrix for these polygons, participants largely agreed on ratings for most characteristics in most places (Table 4, Matrix of Conservation Value and Feasibility in Grassland Landscapes). Where there was initial disagreement, discussing the reason for each rating was usually enough to bring the group to consensus on a final rating. In lesser-known areas, experts tended to defer to whomever was most familiar with that landscape. All participants acknowledged, however, that these ratings do not tell the full story for any individual landscape, that additional knowledge might alter ratings, that circumstances in a landscape can change through time, and that ratings might be changed intentionally by focused conservation interventions.

Examining statistics of all these polygons together highlights differences among landscapes, as well as revealing the value of this network of sites as a whole.

Ecological Condition Across Polygons

Each landscape includes a substantial area of open, intact grassland with additional acreage in restorable condition. Landscapes differ, however, in the amounts and proportions of these grassland conditions (Table 5, Figure 10), as well as the exact nature of these areas and opportunities for maintaining and restoring them (Chapter 3; this chapter also includes a grassland condition assessment for Buenaventura not shown here).

Management Responsibility and Protected Status

Landscapes vary dramatically in land ownership/management patterns, as well as in protected status (Table 6). Overall, private lands dominate this region's grasslands. The degree to which these lands are managed for the benefit of wildlife and watersheds therefore depends on the inclinations, abilities, and actions of individual citizens and the community groups they form. Some landowners have chosen to put formal protections like conservation easements in place; these acres are listed under "Private Protected" along with lands owned by institutions such as The Nature Conservancy whose primary mandate is conservation. These numbers do not reflect lands whose owners choose to manage them for conservation but have not recorded official protections; some of these are described in Chapter 3.

Most polygons include substantial acreage managed by US federal agencies, with the Bureau of Land Management being responsible for about 20% of grassland acres north of the border and the US Forest Service responsible for an additional 10%. Nearly all of these lands are managed for "multiple use," which includes but may not give priority to needs of wildlife and watersheds.

Efforts of communities to influence management of public lands can be effective at raising the emphasis on these values. With regard to land protection, these lands generally stay in the public domain, though occasional sales or exchanges do occur. Land use changes such as leasing for transmission lines, mines, or energy production are permitted on most public lands, though lands with the added protection of wilderness status or other special designations are converted less often; this distinction among levels of protection is reflected in Figure 8.

More than a quarter of US acres are under the jurisdiction of State Land Departments and managed for revenues from lease or sale; these lands fall into an intermediate category between public and private lands since they are largely managed by adjacent private landowners who lease them for grazing, yet incentives to maintain them in good ecological condition are arguably lower than for private lands. There are currently no mechanisms for protecting State lands from development or other land-use changes, yet the process by which they are sold and developed generally takes longer than private land sales. State Trust lands with leases held by conservation landowners, e.g. those tied to private lands with conservation easements, have some de-facto protection in that attempts to sell these lands would face additional opposition and in some cases trigger nullification of easements (Malpai Borderlands Group, n.d.). Nevertheless, these protections have no official legal recognition, and are not depicted in maps shown here. Previous mechanisms that enabled state lands to be exchanged for federal or private and then put into protected status are no longer active. Proposals for protecting State Trust lands in Arizona have been narrowly defeated in referendum votes (see 2006 initiative overview by Lincoln Institute, Sonoran Institute for maps from 2008 effort that are included in Figure 8). However, proponents continue to pursue these efforts, which would protect approximately a half million acres across the state including 119,000 acres of grassland in this focal area. State Trust lands for which protection has been proposed form major pieces in the conservation puzzle for three landscapes, and less extensive but still strategically important pieces in three more (see Chapter 3 protection maps).

Biodiversity/Element Occurrence Analysis by Priority Grassland

Looking at the occurrence of species and communities of interest across these polygons reveals the values of each landscape as well as the values of the network as a whole (Table 7). Some species are widespread while others occur in just one or two polygons. The fact that most landscapes host pronghorn, with few herds occurring outside these polygons, suggest that this species is a good indicator of large, healthy grasslands. The presence of Chiricahua Leopard frogs across almost all sites reflects the prevalence of wetlands embedded in these grasslands. Each of these populations faces threats, though some more than others; the fact that frog populations are replicated across multiple landscapes provides a measure of security for the species. And because these landscapes cover much of the species' designated critical habitat and official recovery units (USFWF 2012), securing the species in these landscapes could be enough to justify eventual de-listing of the species. Listing fish species supported by these embedded wetlands further highlights the value of the *network* of sites, each with its own complement of fish. Of the 20 rare fish listed, 17 are found in three polygons or fewer, with most of these species living in just one or two stream systems each.

A broader look at rare species in the region (explored further in Appendix 1) demonstrates how well this network of polygons captures known locations for species dependent on grasslands or

their embedded riparian habitats. Figure 11 summarizes these results; half of the species evaluated had >75% of their recorded locations falling inside these polygons. Less than a third of the species had the majority of their locations outside our network of polygons.

Discussion of Ecological Gradients and Options for Investigating Ecological Conditions at Finer Scales

Discussion among participants drew out observations about a number of ecological gradients present across the region. On the west side of the NFWF Sky Island focal area, grasslands have affinities with Sonoran Desert flora and fauna, and a tendency towards a slightly higher proportion of annual rainfall coming in winter. On the east side, grasslands have Chihuahuan Desert affinities, and a tendency towards a slightly higher proportion of annual rainfall coming in summer; the San Pedro River is the approximate dividing line between Sonoran and Chihuahuan Desert grasslands. As one moves into higher elevation valleys, grasslands have more Plains affinities (Animas Valley, San Rafael Valley, Buenaventura grasslands, upper elevations of Empire/Sonoita valley). These higher elevation areas have historically been more resistant to shrub invasion than lower valleys and hills. In some cases this has been attributed to cold air settling into higher valleys during winter cold snaps (Mueller 1988) and limiting establishment of mesquites (Glinski and Brown 1982; McClaran and Van Devender 1997; Warshall 2005).

Due to the region's Sky Island topography, each polygon also includes transitions into higher-elevation woodland and chaparral habitats of its associated mountain range(s). On lower-elevation ranges such as the Tumacacori and Sierrita Mountains, grassland and savannah habitats can be found more-or-less to the tops of the mountains, with pockets of other vegetation such as oak woodlands that themselves have large grass components. Higher ranges such as the Chiricahua Mountains host grasslands mostly on their flanks; polygons were therefore drawn to skirt the forested mountain tops. Mountainous terrain divides some of these polygons from one another, e.g. Pedregosa Mountains separating the San Bernardino and Southern Sulphur Springs polygons. Wooded higher elevation terrain presumably reduces connectivity for some open-land species such as pronghorn but not for habitat generalists such as jaguar. The elevation at which grasslands transition into other habitat types has changed through time, e.g. with woodlands spreading across valleys during the last ice age (Betancourt et al. 1990). Current and future climate changes may well shift these zones again, most likely moving grasslands up-slope yet undoubtedly including some surprises in precisely how and where these shifts take place (e.g. via complex dynamics described by McPherson and Weltzin 2000).

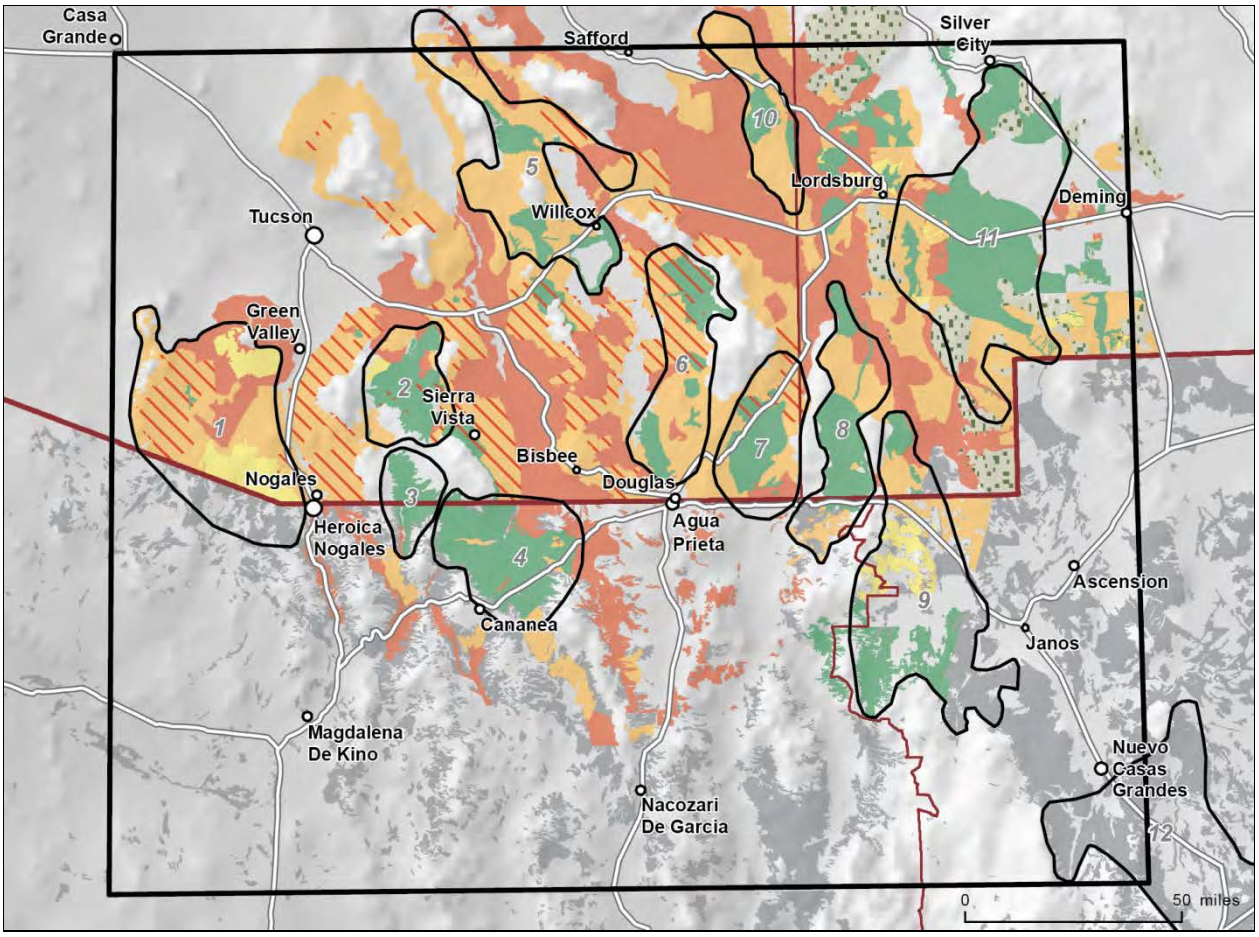
Identifying grassland blocks within this NFWF focal area also highlighted transitions that occur at the edges this area. At the western and northwestern edges, low-lying lands transition into true Sonoran Desert. To the southwest, terrain drops off quickly into highly-dissected desert and thorn scrub habitats; these may have small patches of grassland, e.g. along river floodplains or ridge tops, but no large blocks of grassland habitat. On the east and southeast edges, this area grades into classical Chihuahuan Desert, with a combination of grassland and desert scrub habitats. This includes a number of closed-basin valleys whose gentle slopes reduce water-born soil erosion, and may therefore sustain grasslands at lower levels of precipitation than is typical in steeper terrain. Discussions of grassland polygons in the NFWF focal area suggested connections with grassland conservation efforts further to the south and east into the core of the Chihuahuan Desert ecoregion, e.g. Buenaventura.

Looking at dominant ecological sites (Figure 9) across the region gives a sense of the diversity of grassland types captures by this network of sites; priority landscape polygons harbor at least 99 different ecological sites. However, it is difficult to draw more fine-grained conclusions from this data for several reasons. These ecological site maps are based on a collection of soil surveys done county-by-county; many soil map units change at county boundaries, they do not cover National Forest lands which have their own separate soil/vegetation maps, and none extend into Mexico. Ecological Site Descriptions (ESD's) make fine distinctions among vegetation, soil, and climate settings. No system has been developed for generalizing ecological sites into related groups, so it is difficult to compare degrees of ecological similarity among landscapes.

Closer examination of ecological site maps (ESM's) within landscapes, however, can provide many insights into conservation value and management (Section III, Appendix 2). ESM's based on soil maps are a valuable starting point for closer looks at where highly-valued habitats such as sandy black grama grasslands (Figure 3) or sacaton flats (Tiller et al 2012) occur. They can be used to inform land management generally by delving into each ESD's information about that site's value to wildlife, response to grazing and drought, vulnerability to wind and water erosion, natural fire regime, etc. Information on soils can be used to determine what restoration methods would be appropriate, e.g. the presence of buried clay layers might be used as an indication that ground-disturbing brush control such as grubbing might cause unintended consequences by bringing clay to the surface where it can inhibit grass growth. ESM's can be used to stratify sampling for research and monitoring to better understand ecosystem responses to management (e.g. Gori and Schusman 2005, Mackinnon et al. 2011, Toevs et al., 2011). Field work can refine these maps to more closely represent what exists on the ground (e.g. maps in BLM 2003).

Taking this approach one step further can produce "state maps" that describe ecological condition of focal areas in detail by breaking each ecological site into its component states and mapping these (Bestlemeyer et al. 2009, 2011; Steele et al. 2012). Examples of this approach range from broad efforts to tap into expert knowledge across large areas (Yanoff et al. 2008, described in Section I), to systematically cover hundreds of square miles (collaboration between the Bureau of Land Management and Jornada Experimental Range), to document conditions across individual ranches (Sartor and Gori 2012; Jornada Experimental Range 2012), and even more concentrated efforts to evaluate conditions across high-value habitats (Tiller et al. 2012). In theory, the more detailed these efforts are the more they can inform management decisions. For example, mapping where soil erosion has occurred can reveal areas in which removing shrubs may not encourage grass growth because the organic layers on which grasses are particularly dependent have been lost (Sartor and Gori 2012). The extensive field reconnaissance of Tiller et al. (2012) not only revealed areas where erosion was undermining health of sacaton flats but also pin-pointed locations of over a hundred gully features that could be treated to control erosion.

As with any decision support tool, however, the ultimate benefits of ecological site and state maps depend on how they are used by managers. Ecologists are accustomed to exploring the nuances and causes of what they find, and may be reluctant to simplify these findings and turn them into actionable recommendations for managers. Managers may not have systems in place to consider these additional layers of information in their restoration planning, and may have decision criteria that diverge from—or even conflict with—factors considered by mapping. To make good on the promise of site- and state mapping, more examples are needed of projects that succeed in using these maps to improve restoration and management outcomes, and that evaluate these outcomes in an adaptive management cycle to improve both mapping and management.



No to Low Woody Increase

Mix of No to Low and Medium Woody Increase

Medium Woody Increase

High Woody Increase

Undetermined

Savanna, No to Low Woody Increase

Non-Native Grasses Common

2 Priority Grassland

Priority Grasslands

1 Altar - Tumacacori
2 Empire - Cienega - Sonoita
3 San Rafael
4 Upper San Pedro, Mexico
5 Aravaipa - Muleshoe - Willcox
6 Southern Sulphur Springs
7 San Bernardino
8 Animas - Sierra San Luis
9 Playas Valley - Janos Plains
10 North Peloncillos
11 Burro Cienega - Hachita
12 Buenaventura

Figure 5. Priority grassland landscapes and current condition of grasslands and savannas.

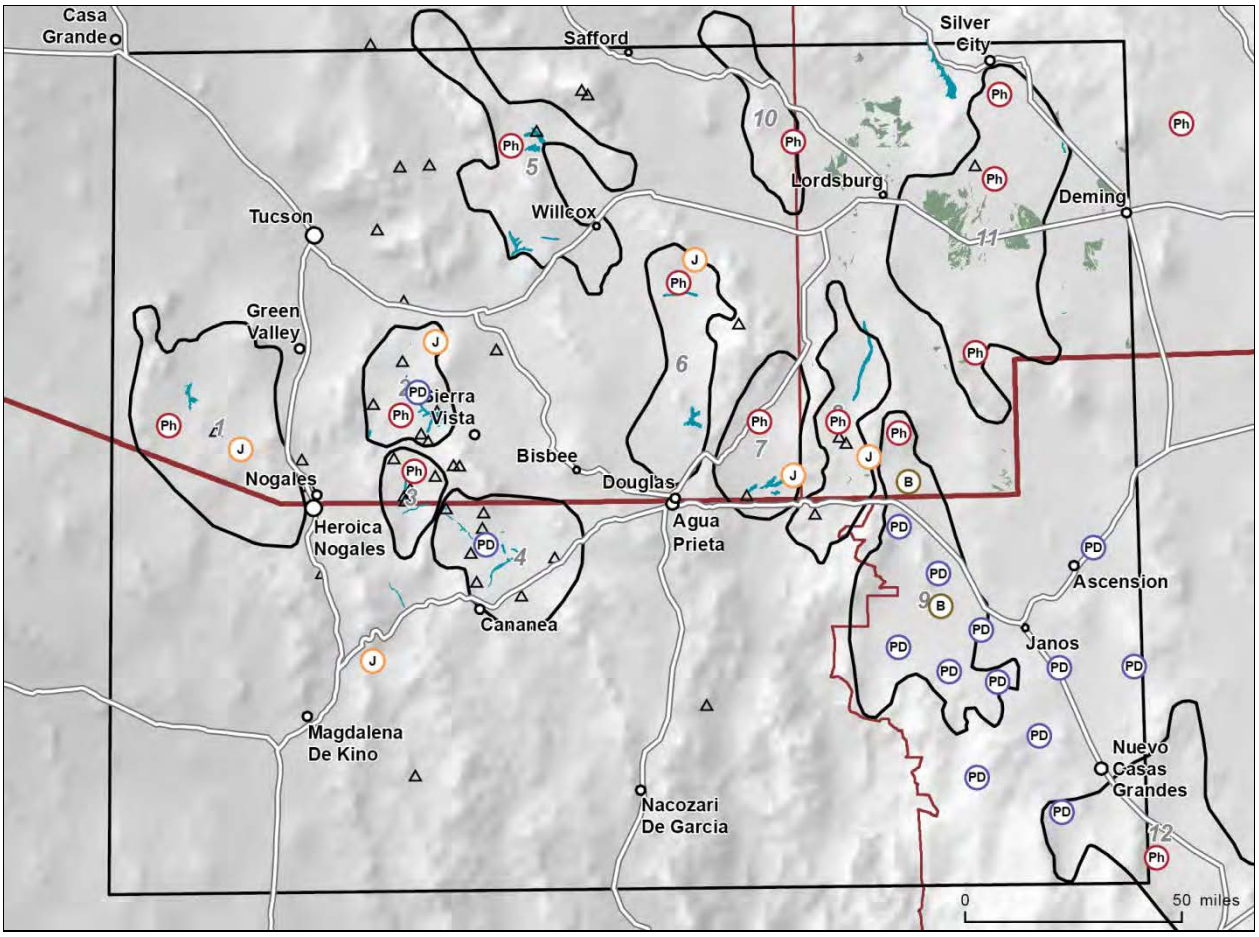


Figure 6. Priority grassland landscapes and the distribution of NFWF target species and sensitive natural communities.

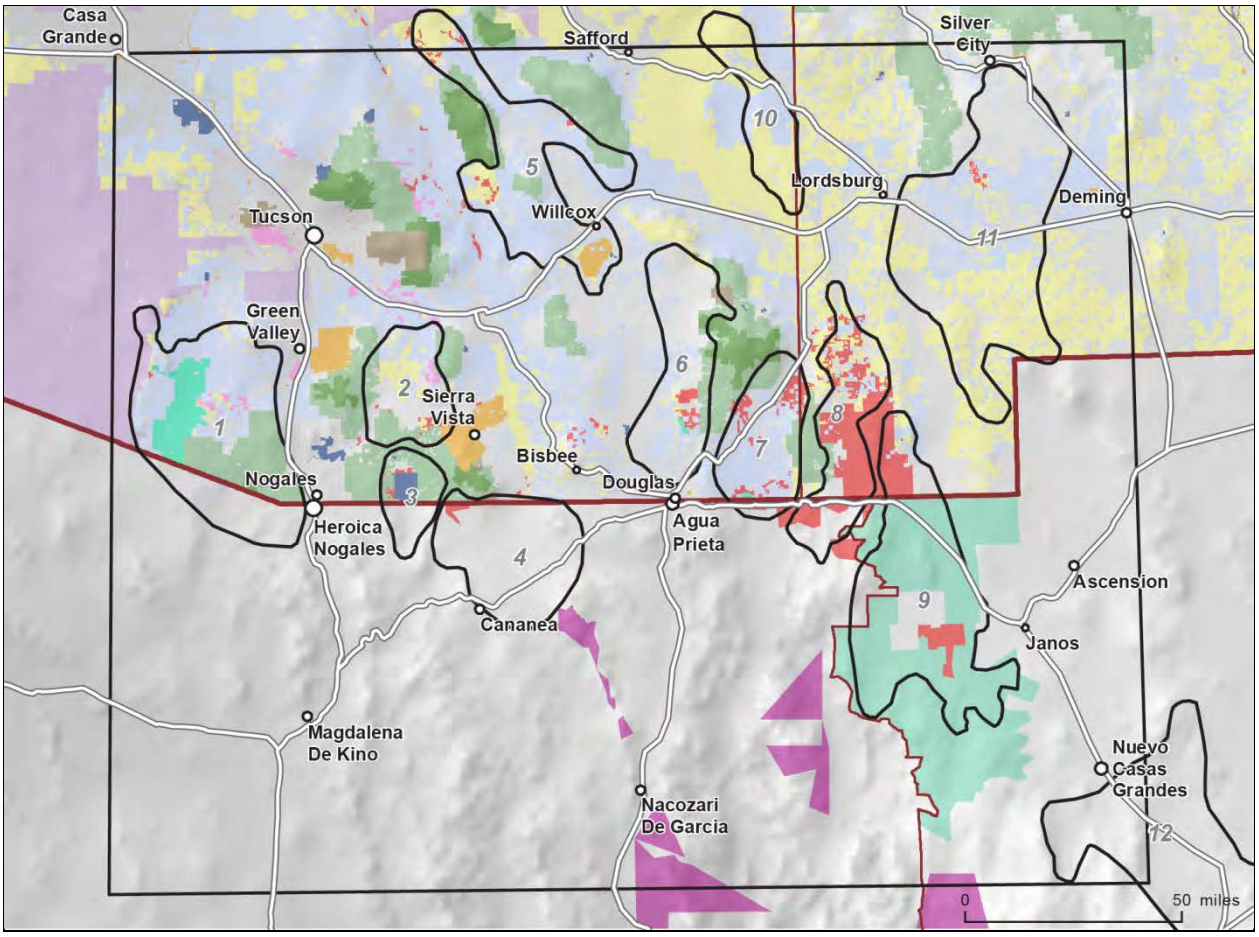
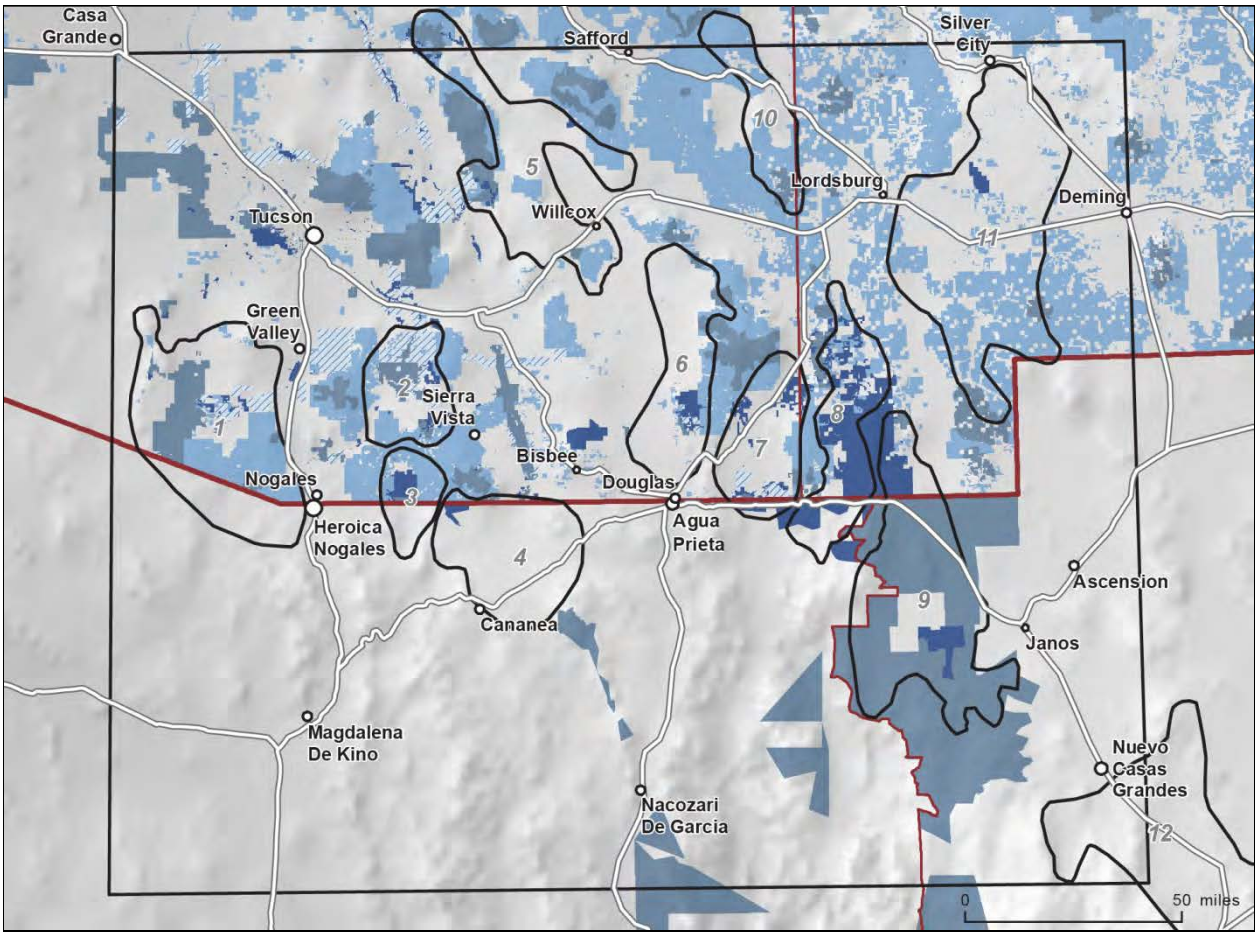


Figure 7. Land management responsibility and priority grassland landscapes.



No formal protection

Protection efforts pending

Public land

Public land with additional protection

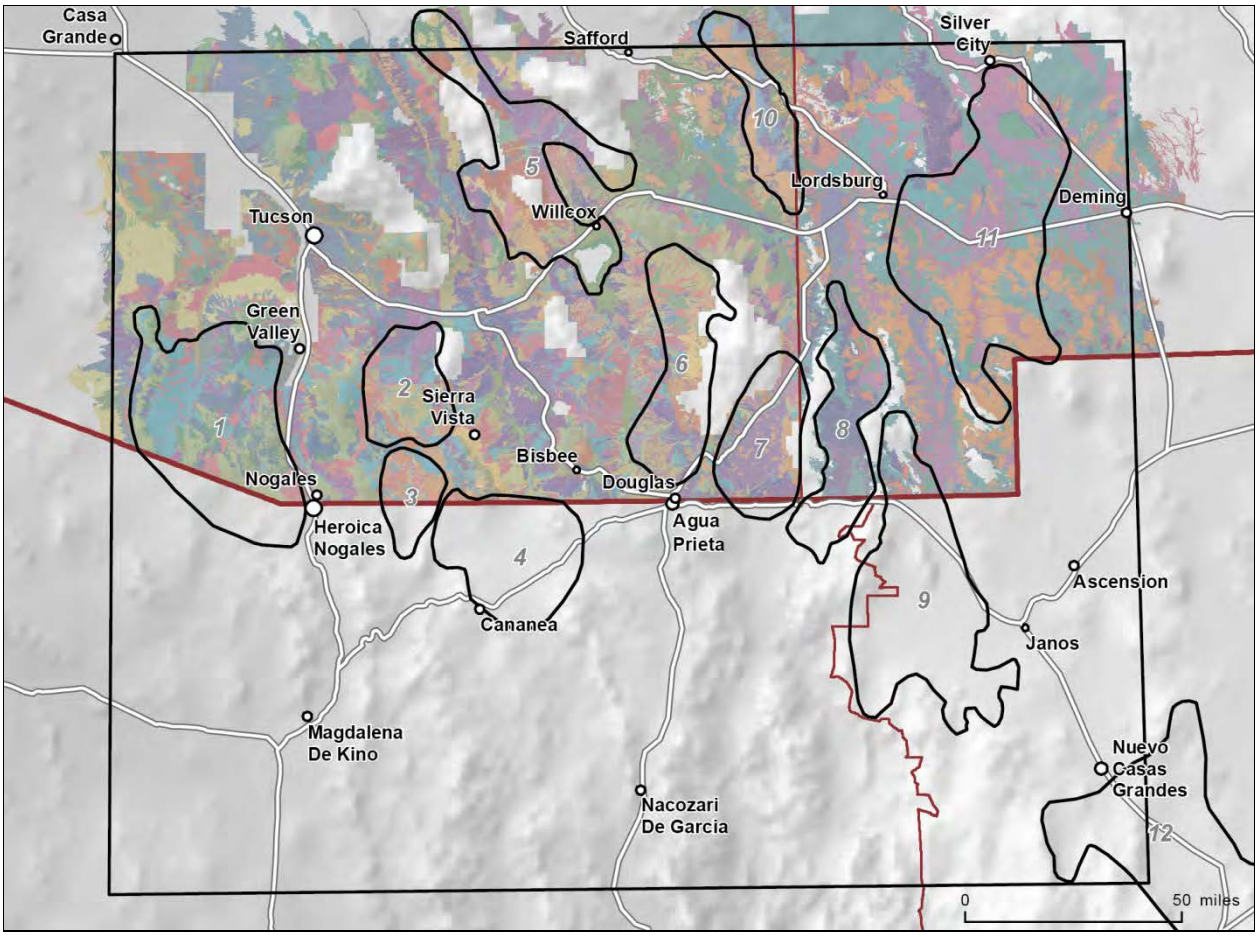
Private conservation land and easements

2 Priority Grassland

Priority Grasslands

1 Altar - Tumacacori
2 Empire - Cienega - Sonoita
3 San Rafael
4 Upper San Pedro, Mexico
5 Aravaipa - Muleshoe - Willcox
6 Southern Sulphur Springs
7 San Bernardino
8 Animas - Sierra San Luis
9 Playas Valley - Janos Plains
10 North Peloncillos
11 Burro Cienega - Hachita
12 Buenaventura

Figure 8. Land protection status and priority grassland landscapes.



Priority Grasslands

1 Altar - Tumacacori
2 Empire - Cienega - Sonoita
3 San Rafael
4 Upper San Pedro, Mexico
5 Aravaipa - Muleshoe - Willcox
6 Southern Sulphur Springs
7 San Bernardino
8 Animas - Sierra San Luis
9 Playas Valley - Janos Plains
10 North Peloncillos
11 Burro Cienega - Hachita
12 Buenaventura

Figure 9. Dominant ecological sites in the US portion of the Sky Island focal area and priority grassland landscapes.

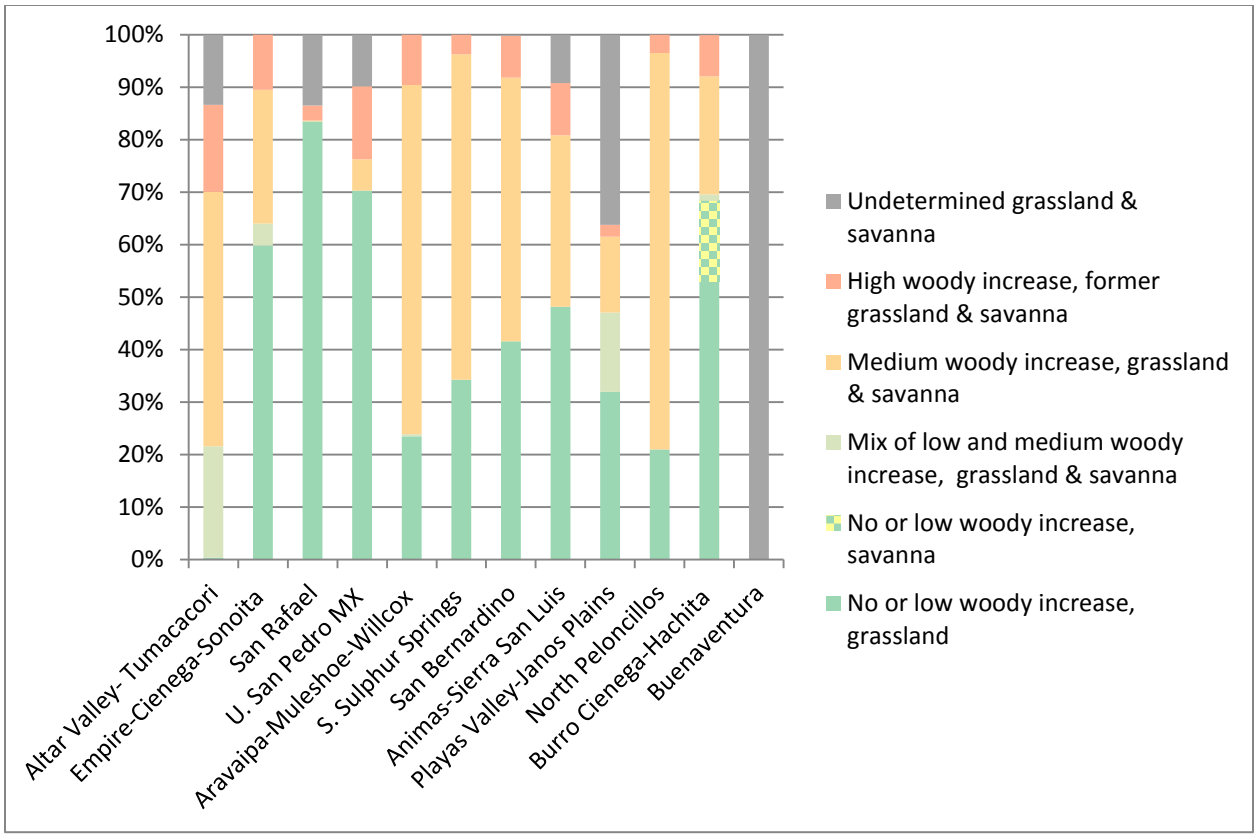


Figure 10. Relative abundance of grasslands and savannas in the different condition classes in priority grassland landscapes.

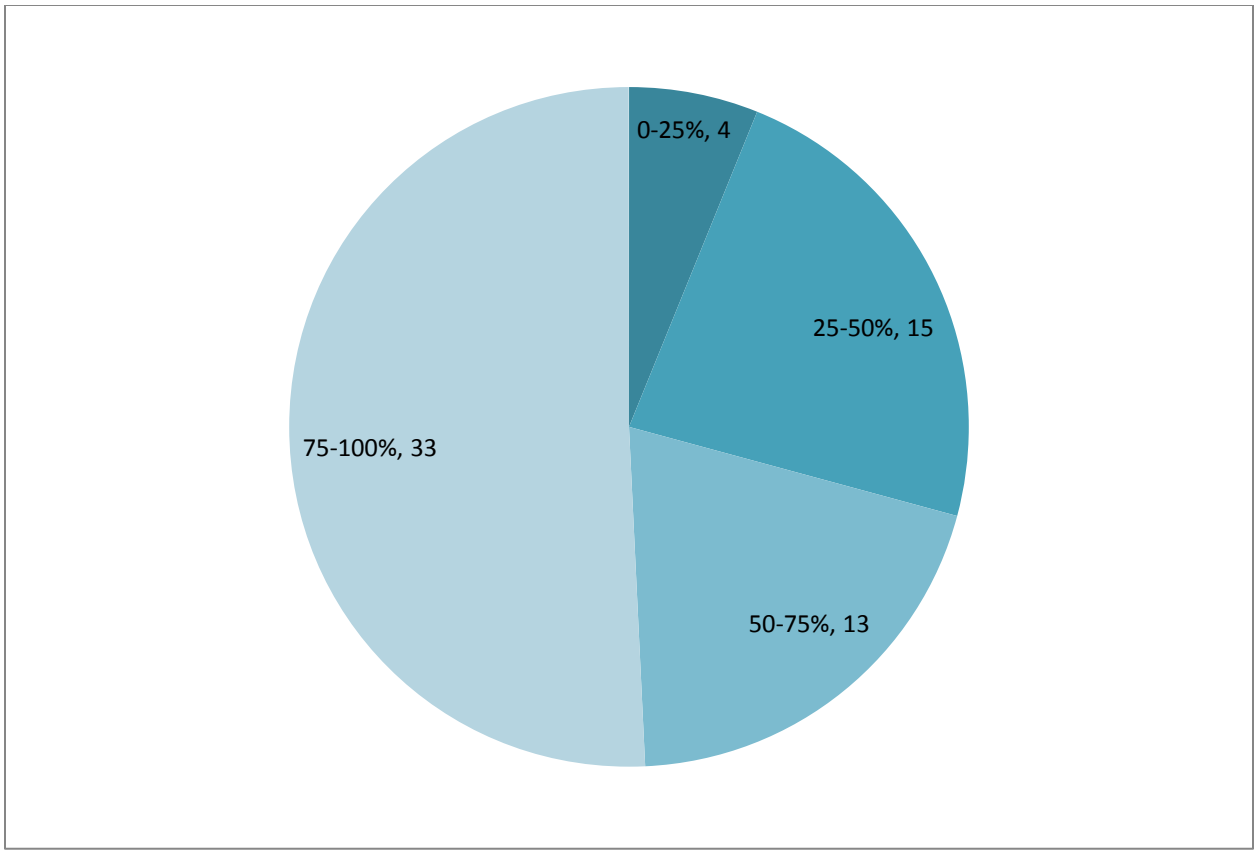


Figure 11. Proportion of occurrence records for sensitive grassland and riparian-aquatic species within priority grassland landscapes. Nearly half of the 67 species evaluated (n = 33) had more than 75% of their occurrence records within priority grassland landscapes identified in this study. The number of species in each of the four categories is given after the percentage ranges.

Table 4. Conservation value and feasibility of success for Sky Island grassland landscapes.

Grassland Conservation Value												
Landscape name	Altar--Tumacacori	Empire-Cienega-Sonoita	San Rafael	Upper San Pedro MX	Aravaipa-Muleshoe-Wilcox	Southern Sulphur Springs	San Bernadino	Animas-San Luis	Playas-Janos Plains	North Pelon-cillos	Burro Cienega-Hachita	Buenaventura
Polygon map #	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
Intact landscape												
Size of potential grassland block	High	High	Med	High	High	Med	Med-high	High	High	Low	High	High
Connectivity* across single valley	High	High	High	High	Med	Low	High	High	High	Med	High	High
Connectivity* with other grassland landscapes	Med-low	High	High	High	Med-low	Low	High	High	High	Med	Med	High
International connectivity, north-south	High	Med-low	High	High	Low	Low	Med	High	High	Low	High	Med-low
Existing habitat quality												
Grassland	Med	High	High	Med-high	High	Med	High	High	High	Med-high	High	High
Riparian grassland	Med-high	High	High	High	Med-high	Med	Med	High	Med	Low	Med	?
Associated wetland habitats	High	High	High	High	High	Med-high	High	High	Low	Low	Med-high	Med
Summary rating	29	32	33	34	25	17	30	35	29	17	30	31
Conservation Feasibility (see next page)												

Table 4 (cont.) Conservation value and feasibility of success for Sky Island grassland landscapes.

Grassland Conservation Feasibility												
Landscape name	Altar--Tumacacori	Empire-Cienega-Sonoita	San Rafael	Upper San Pedro MX	Aravaipa-Muleshoe-Wilcox	Southern Sulphur Springs	San Bernadino	Animas-San Luis	Playas-Janos Plains	North Pelon-cillos	Burro Cienega-Hachita	Buenaventura
Polygon map #	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
Progress to date												
Land protection	High	High	High	Low	Med	Med-low	Med-high	High	Med-high	Med	Med-low	Low
Ecological land management	High	High	Med-high	Low	Med	Med-low	High	High	Low	Low	Med	Low
Intractable threats (low = 5)	Med	Med	Low	Med	Med	Med	Low	Low	Med	Low	Low	Med
Summary rating	13	13	14	5	9	7	14	15	8	9	10	5

High = 5, Med-high = 4, Med = 3, Med-low = 2, Low = 1

Ranking Criteria based on size, condition, conservation importance of species present, and landscape context. See section III text, this report, for descriptions of embedded wetlands considered in ratings, description of threats, names and selected activities of known partners active in each landscape.

Shading indicates adjacent landscapes that experts considered merging but chose to instead identify as complexes.

* Connectivity ratings here are based on proximity of grassland blocks to one another via areas of similar grassland habitat; this is meant to relect how grassland-obligate, terrestrial animals such as pronghorn would perceive connectivity. For species that readily travel across non-grassland habitats usch as forest or scrublands, these connectivity ratings could be considerably higher.

Table 5. Summary of grassland condition for priority landscapes in the Sky Island region.

Grassland Type	Total Grassland Acres, NFWF AOI	Total Grassland Acres in Priority Landscapes	% Grasslands in Priority Landscapes	Altar Valley-Tumacacori, Acres (%)	Empire-Cienega-Sonoita Acres (%)	San Rafael Acres (%)	U. San Pedro MX Acres (%)	Aravaipa-Muleshoe-Willcox Acres (%)
No to low woody increase, native grassland	2,144,488	1,803,064	84.1	3,123 (0.4)	120,589 (49.6)	79,538 (81.9)	315,344 (70.3)	133,744 (23.2)
No to low woody increase, native savanna	478,953	151,162	31.6	0	0	0	0	0
Medium woody increase, native grassland & savanna	3,212,191	1,531,336	47.7	215,914 (26.9)	42,650 (17.6)	168 (0.2)	21,985 (4.9)	341,188 (59.3)
No to low woody increase, non-native grassland & savanna	162,417	117,389	72.3	0	24,681 (10.2)	1,458 (1.5)	0	1,468 (0.3)
Medium woody increase, non-native grassland & savanna	1,342,952	402,729	30.0	171,934 (21.5)	19,283 (7.9)	0	4,888 (1.1)	41,321 (7.2)
High woody increase, former grassland & savanna	3,275,463	460,708	14.1	133,117 (16.6)	25,504 (10.5)	2,769 (2.9)	62,352 (13.9)	55,277 (9.6)
Mix of low and medium woody increase, native grassland/savanna	328,574	284,975	86.7	170,001 (21.2)	10,320 (4.2)	0	0	2,455 (0.4)
Undetermined grassland & savanna	2,956,650	625,945	21.2	107,084 (13.4)	0	13,129 (13.5)	44,080 (9.8)	0
Total	13,901,688	5,377,308	38.7	801,173	243,027	97,062	448,649	575,453

Table 5 (cont.). Summary of grassland condition for Priority Landscapes in the Sky Island region.

Grassland Type	S. Sulphur Springs Acres (%)	San Bernardino Acres (%)	Animas-Sierra San Luis Acres (%)	Playas Valley-Janos Plains Acres (%)	North Peloncillos Acres (%)	Burro Cienega-Hachita Acres (%)	Buenaventura Acres (%)
No to low woody increase, native grassland	81,785 (19.0)	112,604 (34.3)	185,635 (48.1)	190,604 (32.0)	57,997 (21.0)	522,101 (53.0)	0
No to low woody increase, native savanna	0	0	0	0	0	151,162 (15.3)	0
Medium woody increase, native grassland & savanna	152,558 (35.3)	114,607 (34.9)	126,003 (32.7)	85,852 (14.4)	208,905 (75.5)	221,506 (22.6)	0
No to low woody increase, non-native grassland & savanna	65,995 (15.3)	23,787 (7.3)	0	0	0	0	0
Medium woody increase, non-native grassland & savanna	114,999 (26.6)	50,304 (15.3)	0	0	0	0	0
High woody increase, former grassland & savanna	16,182 (3.8)	26,197 (8.0)	38,379 (10.0)	13,480 (2.3)	9,633 (3.5)	77,818 (7.9)	0
Mix of low and medium woody increase, native grassland/savanna	0	0	0	90,197 (15.1)	0	12,002 (1.2)	0
Undetermined grassland & savanna	0	630 (0.2)	35,653 (9.2)	216,190 (36.2)	0	799 (0.1)	208,380 (100)
Total	431,519	328,129	385,670	596,323	276,535	985,388	208,380

Table 6. Extent of current and former grasslands and savannas (acres) in the priority landscapes by land manager.

Priority Landscape	Total Landscape Acres	Total Grassland Acres	US Grassland Acres	BLM	USFS	State Trust Land	Local/State Protected	State Land with Protection Efforts Pending	Private Protected (NGO, CE)	Private	Other
Altar-Tumacacori	935,512	801,173	693,199	13,924	195,615	217,748	10,767	29,057	557	194,931	138,529
Empire-Cienega-Sonoita	300,361	243,027	243,027	46,013	34,987	8,233	7,316	56,922	7,308	82,250	0
San Rafael	163,829	97,061	52,019	0	20,700	400	3,557	0	18,815	53,588	0
U. San Pedro MX	512,518	448,650	17,143	1,089	5,061	1,930	0	645	9,402	429,373	1,150
Aravaipa-Muleshoe-Wilcox	699,837	575,452	575,452	45,966	50,253	283,302	306	6,845	16,078	145,429	27,273
Southern Sulphur Springs	476,368	431,519	431,519	8,826	35,944	81,233	60	4,565	21,273	276,351	3,268
San Bernardino	371,911	328,129	327,030	7,442	34,475	151,426	0	21,318	55,073	56,027	2,368
Animas-San Luis	427,388	385,670	305,046	5,5726	8,859	38,439	0	0	193,541	89,106	0
Playas Valley-Janos Plains	922,129	596,324	103,015	10,532	0	13,165	0	0	105,082	467,545	0
North Peloncillos	277,173	276,535	276,535	187,111	0	74,571	0	0	0	14,853	0
Burro Cienega-Hachita	1,206,476	985,373	984,267	378,087	128	248,698	0	0	5,160	353,299	0
Buenaventura	1,078,370	666,123	0	0	0	0	0	0	0	666,123	0
TOTAL	7,371,871	5,835,035	4,008,251	754,716	386,022	1,119,144	22,005	119,352	432,289	2,828,875	172,587

Table 7. NFWF Sky Island target species and high priority species likely to benefit from grassland protection and restoration in priority landscapes. Target species are designated as Type = A and species likely to benefit as Type = B. An "X" indicates that species has been recorded at the site. Data used to populate the table came from Natural Heritage Program (NHP) databases for Arizona, New Mexico and Sonora; expert knowledge; and published and grey-literature reports including reports cited in Table 2. In general, the lack of records for a species at a site may not mean that the species is absent but may be a function of insufficient survey effort. See text and NFWF Sky Island Business Plan for more information (NFWF 2009).

		Priority Grassland Landscape [1.]											
Common Name	Type	A-T	E-C-S	SR	U. SP	A-M-W	S. SS	SB	A-SL	PV-JP	NP	BC-H	BV
Jaguar	A	X	X					X	X				
Bison	A								X [2.]	X			X
Pronghorn	A	X	X	X		X	X	X	X	X	X	X	
Black-tailed prairie dog	A		X		X				X	X			X
Chiricahua leopard frog	A	X	X	X	X	X	X	X	X	X		X	?
Aquatic Amphibians & Reptiles													
Sonoran tiger salamander	B			X	X								
Lowland leopard frog	B	X	X	X		X		X	X	X			
Mexican garter snake	B	X	X	X				X					
Native Fish													
Sonora chub	B	X											
Gila topminnow	B	X	X	X								X	
Gila chub	B		X	X		X							
Gila longfin dace	B	X	X	X	X	X							
Desert sucker	B		X	X		X							
Sonoran sucker	B	X	X	X		X							
Desert pupfish	B		X			X							
Yaqui topminnow	B						X	X	X				
Yaqui chub	B						X	X	X				
Yaqui catfish	B						X	X	X				
Yaqui sucker	B							X	X				
Yaqui longfin dace	B						X	X	X				
Ornate shiner	B								X				

Common Name	Type	A-T	E-C-S	SR	U. SP	A-M-W	S. SS	SB	A-SL	PV-JP	NP	BC-H	BV
Mexican roundtail chub	B								X				
Mexican stoneroller	B						X	X	X				
Beautiful shiner	B							X	X				
Roundtail chub	B					X							
Spikedace	B					X							
Loachminnow	B					X							
Speckled dace	B		X			X							
Grassland Reptiles													
Desert massasauga	B						X	X					
Grassland Birds													
Aplomado falcon	B				X				X	X		X	
Grasshopper sparrow	B	X	X	X	X	X	X	X	X	X		X	X
Baird's sparrow	B	X	X	X	X	X	X	X	X	X		X	X
Botteri's sparrow	B			X	X				X				
Cassin's sparrow	B		X	X	X	X	X			X		X	X
Rufous-winged sparrow	B												X
Loggerhead shrike	B		X	X	X	X	X	X	X	X		X	X
Eastern meadowlark	B		X	X	X	X	X	X	X	X		X	X
Masked bobwhite quail	B	X											X
Western burrowing owl	B		X	X		X			X	X			X
Mammals													
White-sided jackrabbit	B								X	X			X

1. Landscape abbreviations are: A-T = Altar-Tumacacori; E-C-S = Empire-Cienega-Sonoita; SR = San Rafael Valley; U. SP = Upper San Pedro in Mexico; A-M-W = Aravaipa-Muleshoe-Willcox; S. SS = Southern Sulphur Springs Valley; SB = San Bernardino Valley; A-SL = Animas Valley-Sierra San Luis; PV-JP = Playas Valley-Janos Plains; NP = Northern Peloncillos; BC-H = Burro Cienaga-Hachita; BV = Buenaventura.
2. The bison presence reported for Animas-Sierra San Luis refers to the same herd that crosses the international border in the adjacent Playas Valley-Janos Plains polygon.

III. Priority Grassland Landscapes: Biological Values and Conservation Feasibility

The following section describes the geographical location of each of the priority grassland landscapes and broadly summarizes their conservation values. These values include: grassland size, current condition, connectivity across valley bottoms with adjacent mountain ranges, north-south connectivity across the international border, and connectivity with other priority landscapes. In addition, as part of this characterization, we identify associated (embedded) riparian and wetland habitats and highlight other special biological features, including the number and identity of NFWF conservation targets and other sensitive grassland, riparian and aquatic species. Finally, we summarize the threats, land management responsibility, land protection efforts, and human enabling conditions that contribute to the feasibility of future conservation efforts in these landscapes.

Altar-Tumacacori Grasslands

This 935,000 acre landscape includes the Altar Valley grasslands to the west and the Tumacacori Highlands to the east. The Altar Valley is an approximately 600,000 acre watershed that extends from the Baboquivari Mountains on the west to the Sierrita Mountains on the east, and from the international border on the south to the community of Three Points on the north. The rugged Tumacacori Highlands contain extensive grasslands on the slopes and alluvial fans of the Pajarito, Tumacacori and Atascosa Mountains in the US and the Sierra Cibuta in Mexico. Grassland connectivity between mountain ranges and north-south connectivity across the international border are high throughout the landscape (Figure 12, Table 4).

Grassland and Savanna Condition

The best-condition grasslands occur in two locations north of the international border. Both were mapped as a mix of no to low and medium woody increase condition classes (170,000 acres; Figure 12, Table 5). Grasslands and savannas throughout the landscape have been impacted by shrub encroachment including extensive areas with medium woody increase (216,000 acres) as well as former grasslands with high woody increase that have converted to shrubland especially at lower elevations (133,000 acres). An active prescribed burn program involving private ranchers, Pima County, National Resources Conservation Service (NRCS), Buenos Aires National Wildlife Refuge and TNC has reduced shrubs and restored many acres of grassland since the AHGA was completed in early 2003 (see below). Extensive introduction and spread of non-native grasses has occurred primarily at higher elevations in the Altar Valley. The AHGA mapped a single sacaton riparian grassland in the Altar Valley; follow-up surveys by Pima County identified a large number of additional sacaton grasslands there. More than 107,000 acres of undetermined grasslands occur in Mexico, making further assessment of grassland extent and condition south of the border a priority.

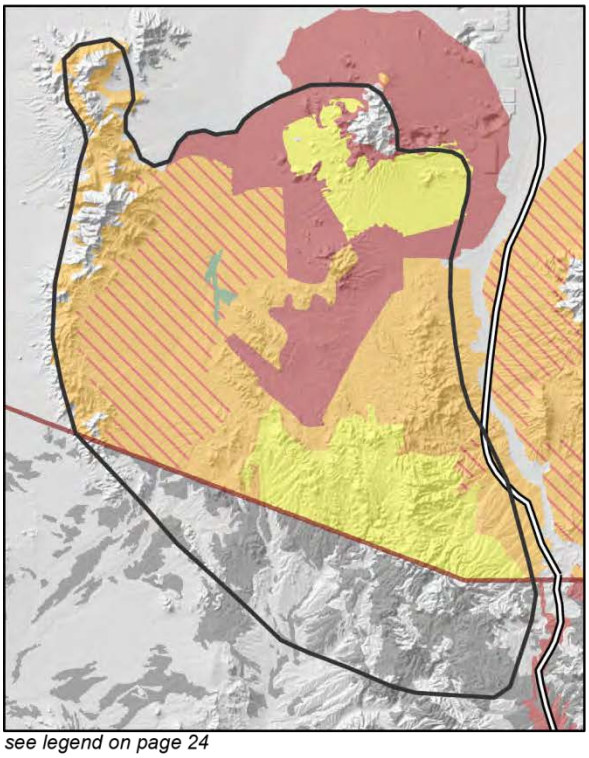
At a finer-scale, current and former grasslands and savannas occur on a diversity of soils within the landscape, supporting 22 dominant ecological sites, each with varying grass, herb, shrub and tree species compositions in reference and non-reference condition (Appendix 2, NRCS 2009).

Other Biological Features

Arivaca Creek is a major tributary to the Altar Valley with Arivaca Cienega located at the top of this watershed (Figure 12). Other significant wetland features that support a suite of sensitive riparian and aquatic species include Sycamore Creek and California Gulch. A total of 12 NFWF

Figure 12. Altar-Tumacacori Grasslands

Current Grassland Condition



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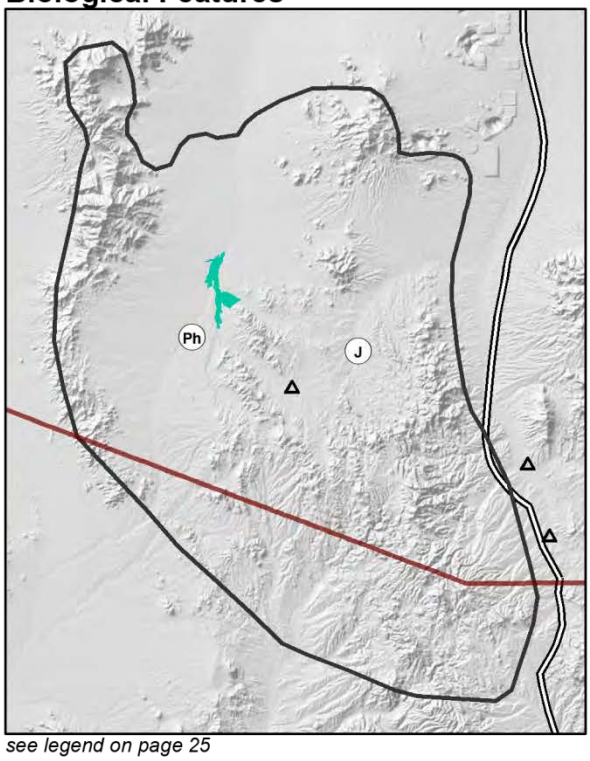
Biological Features



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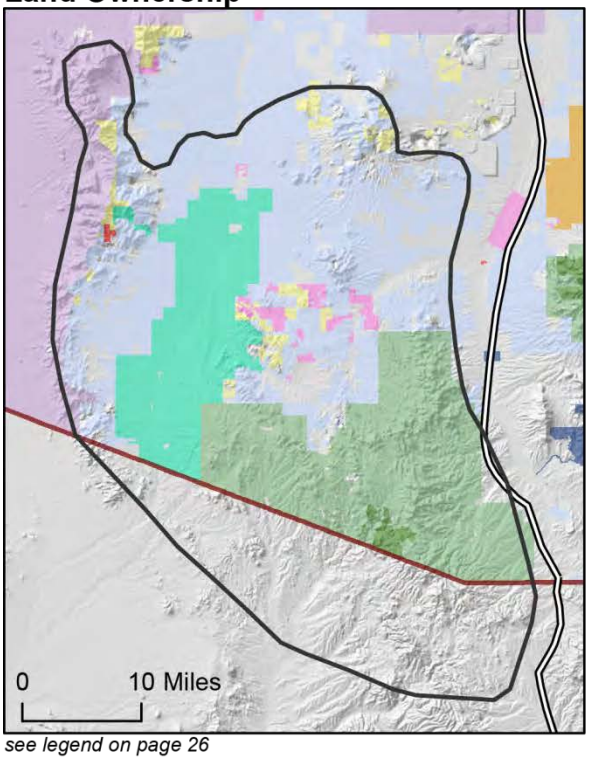
Land Ownership



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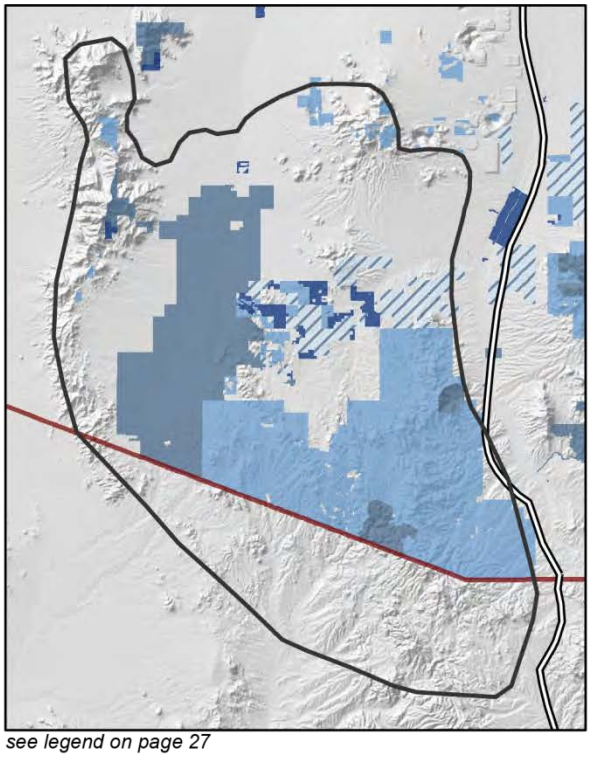
Protection Status



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target and high-priority species occur within the landscape including masked bobwhite quail, Sonora chub, and Chiricahua leopard frog (Table 7). In addition, 15 sensitive grassland and riparian plant species occur in the landscape such as Pima pineapple cactus, Santa Cruz beehive cactus, beardless chinch weed, Huachuca golden aster and Santa Cruz striped agave (Appendix 1). Pronghorn also occur in Altar Valley.

Threats

The Altar Valley remains relatively free of development in its middle and southern portions, but the north end of the valley is in the expanding urban margin of the Tucson Metro area, and residential subdivision is spreading into the valley. Residential development is also expanding along the Santa Cruz River at the east side of the landscape although Forest Service land along much of this edge will restrict development from moving further to the west.

Partnerships, Restoration and Land Protection

A substantial proportion of the landscape has been protected (Figure 12, Table 6). The Altar Valley Conservation Alliance (AVCA) is a local rancher-led land trust that has been operating for over ten years and is involved in both land protection and land management. The AVCA has protected a number of small tracts with conservation easements as has TNC. In addition, Pima County has made substantial investment in land protection through its Open Space Program, having acquired nearly 11,000 acres of private land and managing another 130,000 acres of state lease in the Altar Valley. US Fish and Wildlife Service owns and manages the 138,000-acre Buenos Aires National Wildlife Refuge where it conducts a very active prescribed fire program and participates in prescribed burning on neighboring ranches. The NRCS has been closely involved in planning and funding restoration projects such as erosion control, brush control, and prescribed fire on private ranches in the valley. The AVCA worked with local, state and federal agencies to create the first cooperative Fire Management Agreement of its kind in Arizona in 2007. Since then, the AVCA has been actively conducting fire planning with TNC assistance. The US Forest Service owns and manages over 196,000 acres of grasslands including the Goodding Research Natural Area. Over 359,000 acres of grassland in this landscape are protected as federal, County or private land, which is almost 45% of all current and former grasslands in the landscape.

Empire-Cienega-Sonoita Grassland

This 300,000 acre landscape is comprised of expansive grasslands that cross a low divide and form the upper watersheds of three major drainages: Sonoita Creek, Cienega Creek and the Babocomari River. To the north, the Empire Valley encompasses the watershed of Cienega Creek, which flows north to Tucson. The valley reaches from the Santa Rita Mountains on the west to the Whetstone Mountains on the east, and from the community of Sonoita on the south to the Empire Mountains on the north. The upper watersheds of Sonoita Creek and the Babocomari River lie to the south of Empire Valley and include the Santa Rita and Mustang Mountains to the north and the Canelo Hills and north end of the Huachuca Mountains to the south. Sonoita Creek flows south, then west to its confluence with the Santa Cruz River, while Babocomari River flows east to the San Pedro River.

Grassland and Savanna Condition

There are many areas of open native grassland scattered across the three valleys and adjacent mountain foothills (120,600 acres or 49.6% of current and former grassland), although most of

the high-quality grassland is located in the Empire and Babocomari valleys. There are also excellent stands of sacaton in the bottoms of Cienega and Sonoita creeks and the Babocomari River. However, woody plants are increasing in all three valleys (42,600 acres, or 17.6%), and non-native grasses are spreading in many places (Figure 13, Table 5). At a finer-scale, current and former grasslands and savannas occur on a diversity of soils and in three precipitation zones representing 25 different dominant ecological sites within the landscape (Appendix 2).

Other Biological Features

The landscape supports many grassland-dependent species including pronghorn, black-tailed prairie dog, grasshopper sparrow, Baird's sparrow, western burrowing owl, and Huachuca golden aster (Figure 13, Table 7). A male jaguar has also been recently recorded in one of the adjacent mountain ranges. In addition, there are a number of cienegas and sacaton grasslands in the headwaters and along the major streams that drain this landscape, including Empire Gulch, Cienega Creek, Sonoita Creek and the Babocomari River. These streams (and cienegas) in the aggregate support a total of 5 native fish species, including Gila topminnow and Gila chub, Chiricahua and lowland leopard frogs, Mexican garter snake, Southwestern willow flycatcher, Huachuca water umbel and Canelo Hills ladies tresses orchid.

Threats

Residential subdivision and scattered vineyards are spreading in the upper portions of all three watersheds near the community of Sonoita where increasing water use is likely to threaten flows in Cienega Creek.

Partnerships, Restoration and Land Protection

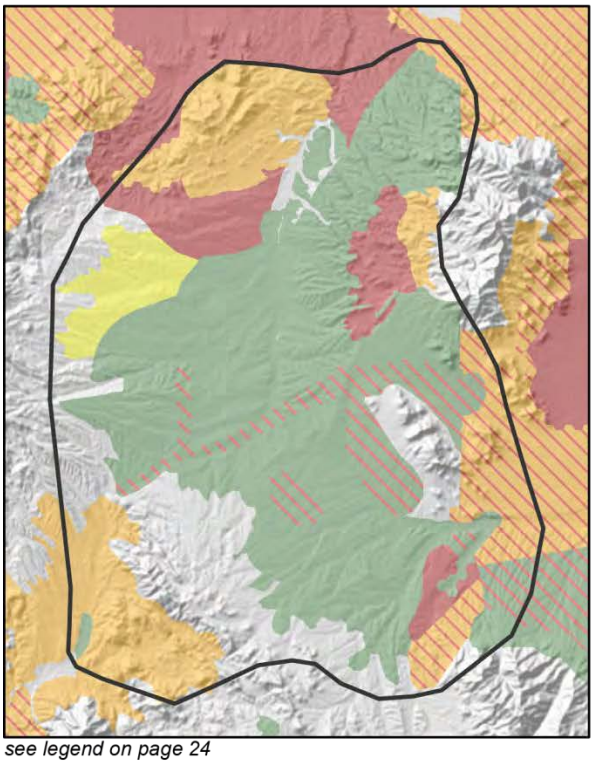
The Bureau of Land Management and private landowners own the majority of the valley bottom grasslands in the three valleys (Figure 13, Table 6). In the Empire Valley, BLM has management responsibility not only on its own lands but also on adjacent State Trust lands in the Las Cienegas National Conservation Area (47,000 acres). BLM has an active restoration program in which TNC is a partner. The US Forest Service manages montane land on both sides of the valley, which includes native foothill grasslands that are in good condition. Pima County owns a strategic property on the east side of the valley, the Sands Ranch, that connects BLM with USFS land in the Whetstones. The Sonoita Valley Planning Partnership is a forum that brings local residents together to discuss conservation issues, but they have little capacity to carry out conservation projects.

In the Babocomari and Sonoita Creek watersheds, high quality grasslands and restorable grasslands are owned and managed primarily by US Forest Service and private landowners. The US Forest Service has an active restoration program on its lands which include montane grasslands in the Canelo Hills and foothills of the Huachuca Mountains.

A large proportion of the Empire Valley is protected, with USFS lands in the mountains, BLM lands in the valley bottom and Pima County lands in between (Figure 13, Table 6). However, there is a 10,000 acre block of private land extending from Sonoita to the northwest into the Santa Rita Mountains which could compromise conservation in the valley if it is not protected. In addition, nearly 57,000 acres of State Land on the north and east sides of the Empire Valley and in the adjacent Babocomari drainage are designated as conservation lands and will have increased protection if voters approve the Arizona State Trust Land Initiative. A significant (and increasing) proportion of the grassland in upper Babocomari watershed is also protected,

Figure 13. Empire-Cienega-Sonoita Grassland

Current Grassland Condition



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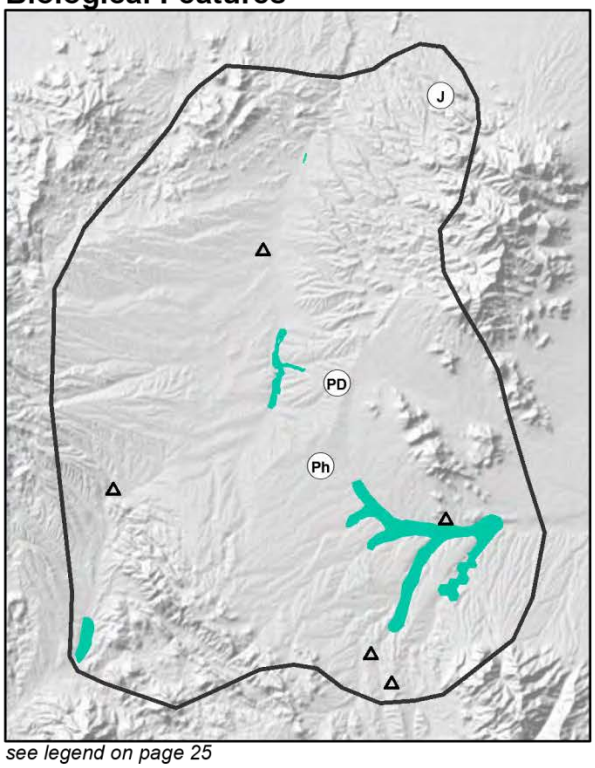
Biological Features



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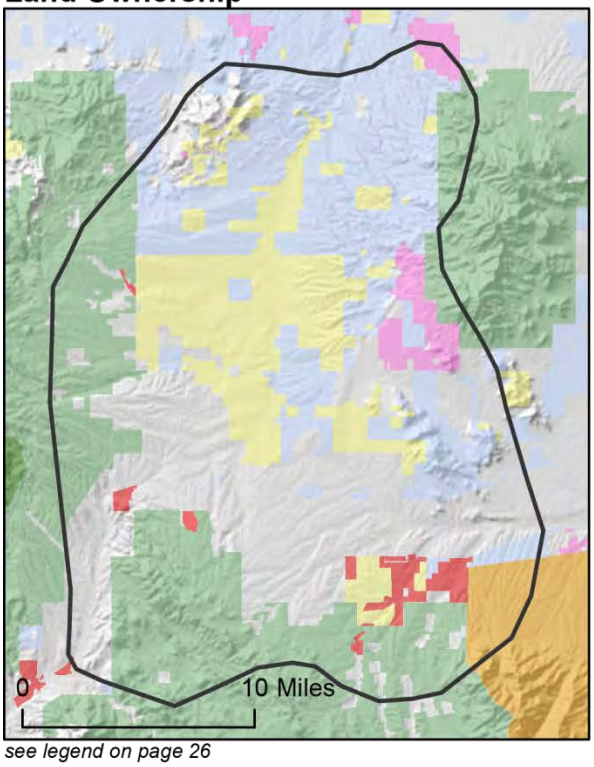
Land Ownership



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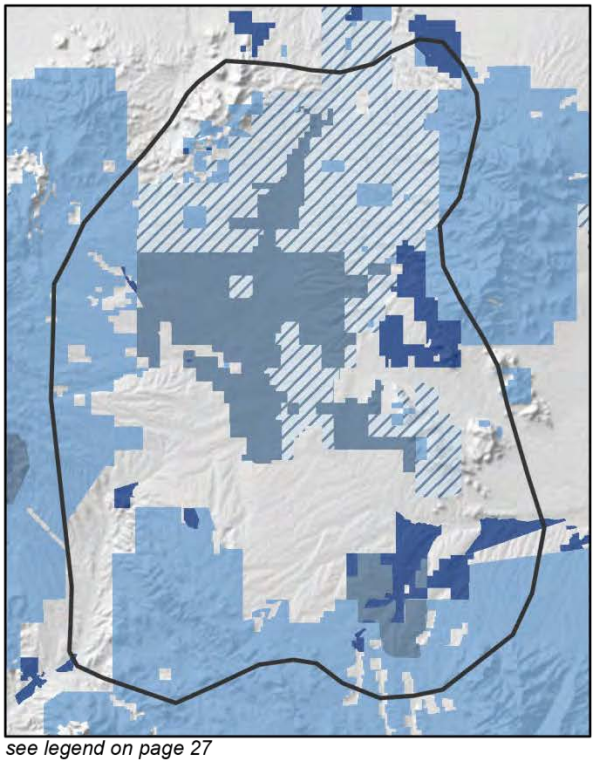
Protection Status



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including nearly 7,000 acres of conservation easements and private protected land within the Audubon Research Ranch, which is owned and managed by National Audubon Society, as well as adjacent USFS land in the Canelo Hills and Huachuca Mountains. In the landscape as a whole, over 95,500 acres (nearly 40%) of current and former grassland are permanently protected.

BLM is conducting an active grassland monitoring and restoration program in which TNC is actively involved on the Las Ciengas National Conservation Area.

San Rafael Valley

The San Rafael Valley is the upper watershed of the Santa Cruz River, and is defined by the crest of the Patagonia Mountains on the west, the Huachucas on the east and the Canelo Hills on north. The 164,000 acre watershed includes over 94,000 acres of grassland that lie on the valley bottom and lower slopes of the surrounding mountains and hills. The Santa Cruz River flows south into Mexico where grassland extent decreases and, to some extent, condition declines.

Grassland and Savanna Condition
Grassland condition within the landscape is excellent with 79,500 acres (82%) having no or low woody increase (Figure 14, Table 5). Lehmann's lovegrass is common in a small area on the north end of the valley and has started showing up along the roads and in scattered, small patches of one or more plants throughout the valley bottom. In addition, there are two occurrences of sacaton riparian grassland, one in the US, the other in Mexico. The San Rafael Valley has contiguous habitat connectivity north across the Canelo Hills to the Empire-Cienega-Sonoita Grassland and southeast, across a low-elevation grassland divide, to the Upper San Pedro Grassland in Mexico. Thus, connectivity to adjacent mountain ranges, to adjacent priority landscapes and north-south across the international boundary is high.

At a finer-scale, current and former grasslands and savannas occur on a diversity of soils and in two precipitation zones within the landscape, representing17 dominant ecological sites (Appendix 2).

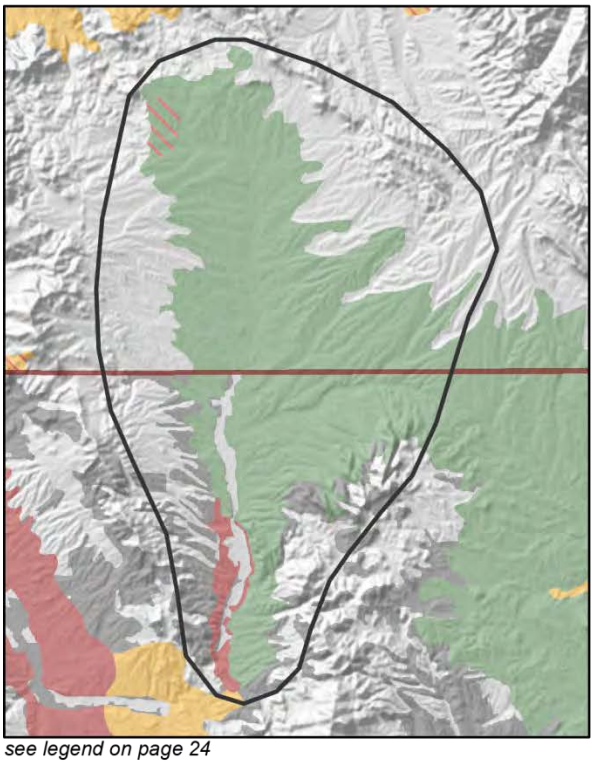
Other Biological Features
There are four cienegas within the San Rafael grassland and the landscape is rich in grassland and riparian-aquatic species (Figure 14). These include grassland-dependent plants like Huachuca golden aster and wooly fleabane; cienega species like Huachuca water umbel, Madrean ladies' tresses orchid, and Sonora tiger salamander; and NFWF targets and high priority species such as Chiricahua leopard Frog, Mexican garter snake, Gila topminnow, Gila chub and three other native fish species. A pronghorn herd also occurs in the valley (Table 7; Appendix 2).

Threats
There are relatively few threats to the valley, which is largely protected on the US side except for one 5,000 acre ranch at the north end of the valley. Ejidos and large, private ranches occur in Mexico and there is little evidence of land use conversion there. Mining exploration continues to be a concern on both sides of the border.

Partnerships, Restoration and Land Protection
A conservation easement was acquired by AZ State Parks on the San Rafael Ranch (17,574 acres) along with the 3,550-acre San Rafael State Park (Figure 14, Table 6). TNC holds a

Figure 14. San Rafael Valley

Current Grassland Condition



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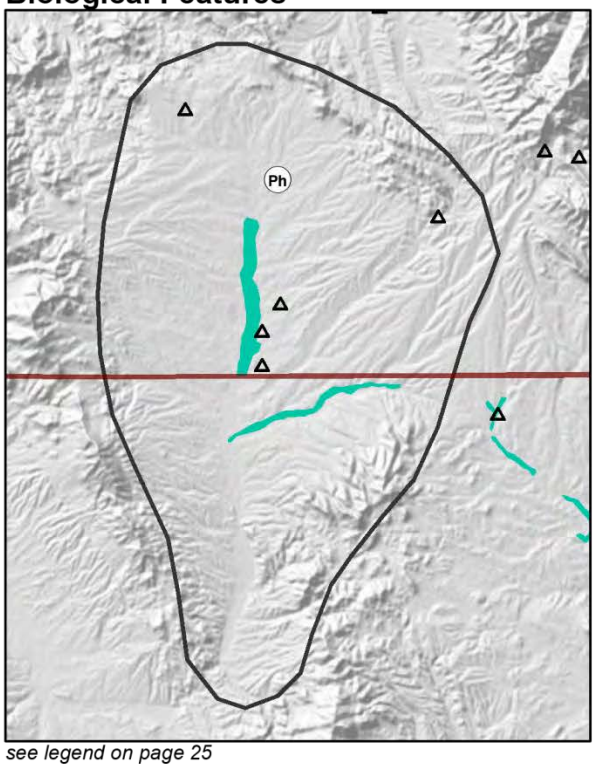
Biological Features



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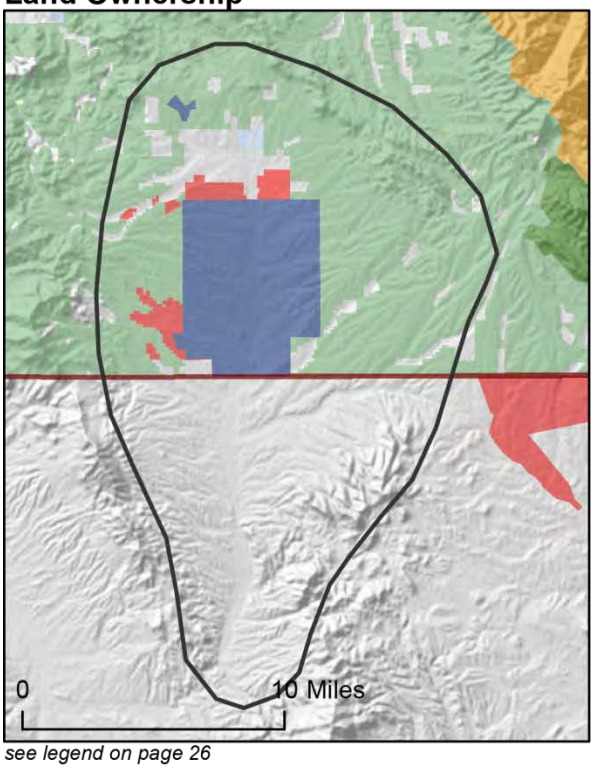
Land Ownership



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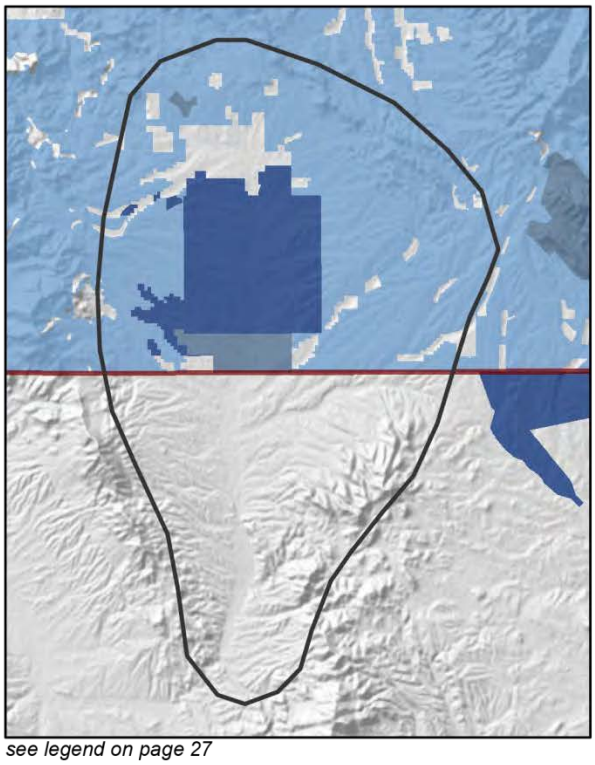
Protection Status



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conservation easement on another ranch in the valley and several small conservation easements were acquired by the Arizona Land and Water Trust. In addition, the USFS manages nearly 21,000 acres of grassland in the landscape. Altogether, over 83% of grasslands in the US portion of the landscape are protected and 43% of grasslands are protected overall. The entire upper watershed is managed by the USFS which has recently completed the Greater Huachuca Cooperative Fire Plan with assistance from TNC in order to accelerate fire management and fuels treatments across the landscape. This effort became a model for the Coronado National Forest FireScape Program which is developing multi-jurisdictional programmatic fire plans for other Sky Island mountain ranges. The US Fish and Wildlife Service (USFWS) is working with the owner of the San Rafael Ranch to develop a Habitat Management Plan for the property.

Upper San Pedro Valley in Mexico

The Upper San Pedro Valley grassland spans well over 500,000 acres from the Sierra San Jose on the east to the Sierra Mariquita on the west, and from the Sierra Los Ajos on the south to the Huachuca Mountains on the north. The grassland largely ends at the international border due to habitat fragmentation caused by residential development and shrub conversion on the east side of the Huachuca Mountains and an increase in elevation on the west side of the valley, resulting in a transition from grassland to woodland and forest. However, the grasslands extend to and connect with adjacent mountain ranges in all directions within the landscape, and are contiguous with the San Rafael Valley. For this reason, experts ranked the connectivity across a single valley, north-south connectivity across the border, and connectivity with other grassland landscapes all as high.

Grassland and Savanna Condition
Most of the grassland is native with no or low woody increase, 315,300 acres (70%), although nearly 22,000 acres have experienced medium woody increase, but are still restorable (Figure 15, Table 5). Only 62,300 acres of former grassland (14%) have been converted to shrubland in the landscape. Located as it is in the upper San Pedro watershed, the landscape still has numerous cienegas and sacaton riparian grasslands.

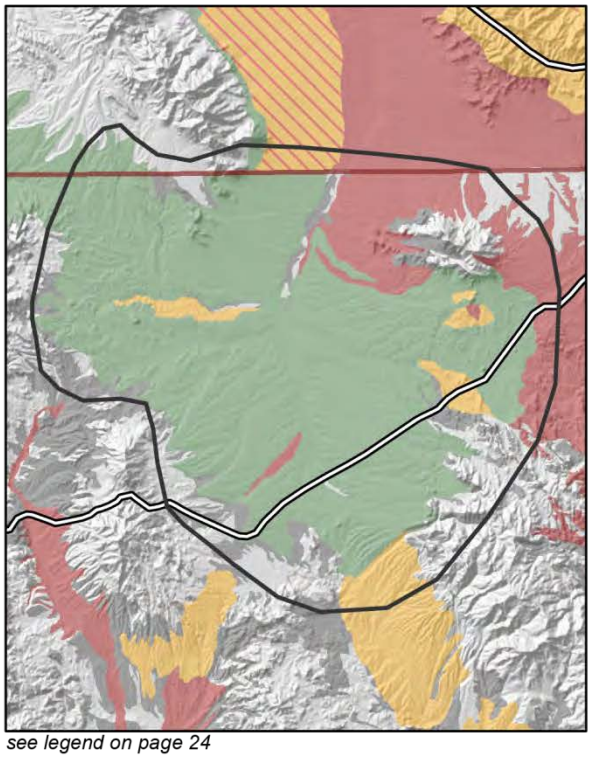
At a finer-scale, current and former grasslands and savannas occur on a variety of soils and in two precipitation zones within the landscape, representing 14 dominant ecological sites (Appendix 2). Because soils and ecological sites have not been mapped in Mexico, this is a conservative estimate of the number of different grassland types within the landscape.

Other Biological Features
The Upper San Pedro Valley supports several sensitive grassland and aquatic plants (Huachuca golden aster, wooly fleabane, beardless chinch weed and Huachuca water umbel) as well as a number of NFWF target and priority species: Chiricahua leopard frog, Sonoran tiger salamander and longfin dace (Figure 15, Table 7). When TNC purchased the Los Fresnos Ranch in 2005, it had a healthy Gila chub population; however surveys in 2006-2007 failed to locate the species but recorded abundant non-native fish. In general, the biological features of the landscape have not been well surveyed and additional surveys by taxonomic experts are critically needed.

Threats
The Upper San Pedro grasslands are mostly unprotected, and therefore are potentially vulnerable to development. However, development pressure in Mexico is low at this time. The mine at

Figure 15. Upper San Pedro in Mexico

Current Grassland Condition



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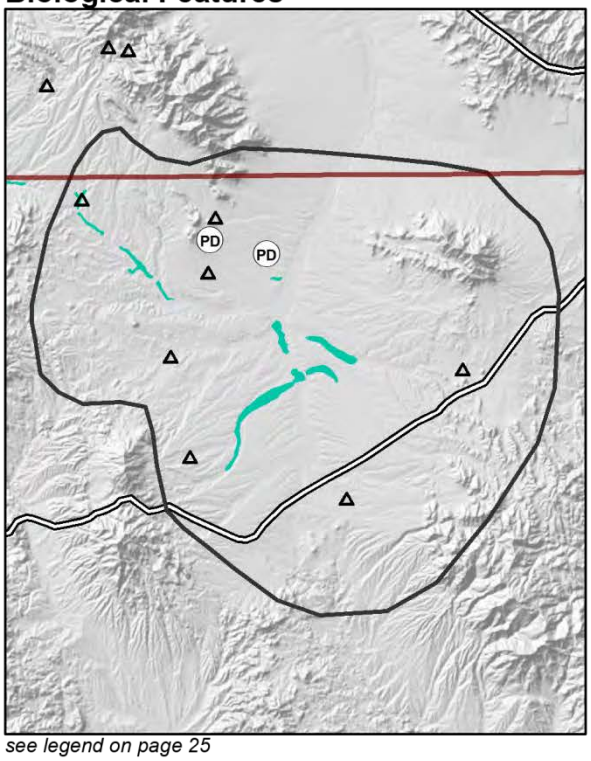
Biological Features



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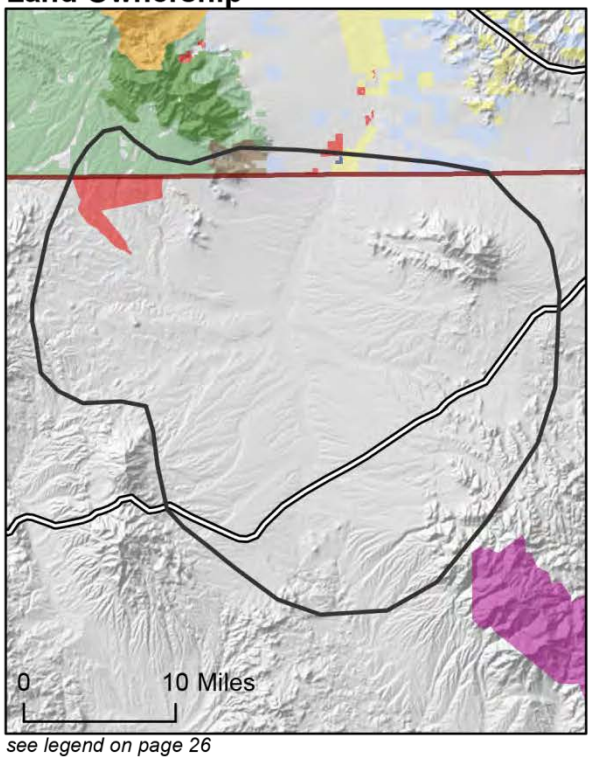
Land Ownership



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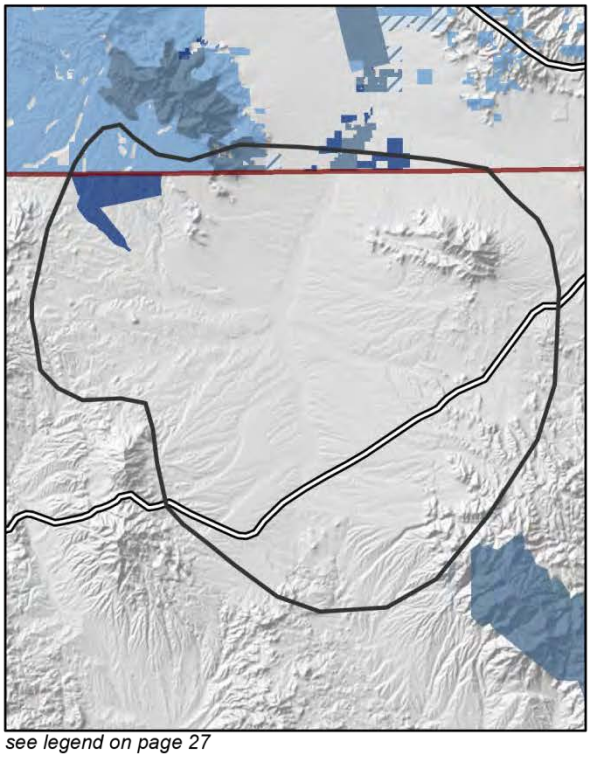
Protection Status



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Cananea presents a permanent threat to water quality due to the potential for a tailings spill which has occurred in the past, and the continued release of untreated sewage by the town.

Partnerships, Restoration and Land Protection
The Conservancy is working in the landscape with two private conservation groups. BIDA (Biodiversidad y Desarrollo Armónico) has conducted outreach with landowners and continues to engage in riparian habitat restoration projects with interested landowners. Naturalia manages Rancho Los Fresnos under a cooperative agreement with TNC who purchased the 10,000-acre ranch for its aquatic and grassland habitats. There is no other protected land in the landscape (Figure 15, Table 6). TNC is using Rancho Los Fresnos to demonstrate management activities such as prescribed burning and erosion control with Mexican state and federal agencies including IMADES (Instituto del Medio Ambiente and el Desarrollo Sustentable del Estado de Sonora) and SEMERNAT (Secretaría de Medio Ambiente y Recursos Naturales).

Aravaipa-Muleshoe-Willcox Grasslands

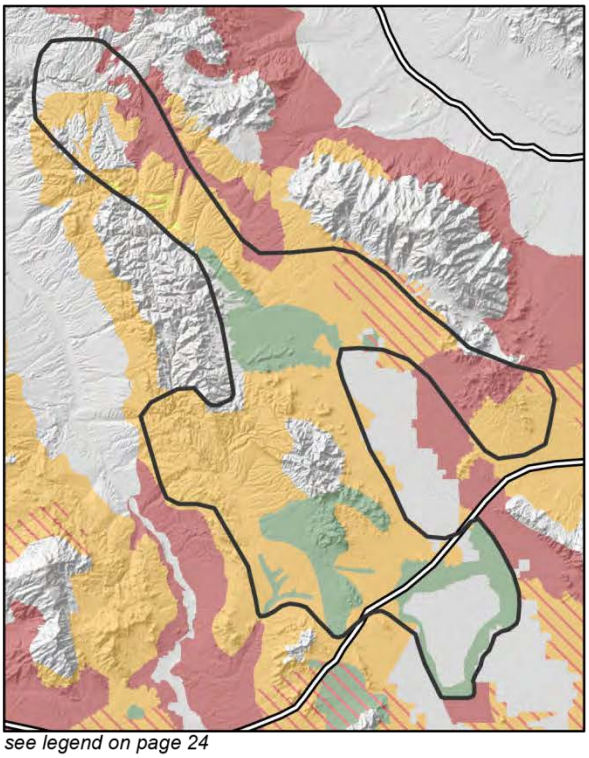
Grasslands in this expansive 700,000-acre landscape stretch from Willcox Playa in the south, northwest through Allen Flat and the foothills of the Winchester Mountains, across the upper Hot Springs watershed in the Galiuro Mountain foothills, and then east into the Upper Sulphur Springs and Aravaipa valleys. Aravaipa Valley lies to the north of a low (grassland) divide that separates the two valleys, and extends from the Galiuro Mountains on the west to the Pinaleño and Santa Teresa Mountains on the east. The Upper Sulphur Springs Valley lies to the south and extends from the Winchester Mountains on the west to the Pinaleño Mountains on the east. Grassland connectivity from Wilcox Playa northwest to the Winchester and Galiuro Mountains is high. However, connectivity across the Aravaipa and upper Sulphur Springs valleys is low due to habitat degradation (shrub conversion, historic heavy livestock grazing) and fragmentation (agricultural conversion), leading experts to rank overall connectivity between adjacent mountain ranges as medium for the landscape. Connectivity with other grassland landscapes and north-south connectivity across the international boundary were ranked as medium-low and low, respectively. The landscape encompasses a number of significant perennial streams (and watersheds) including Aravaipa Creek, Bass Creek, Double R Creek, Hotsprings Canyon and Redfield Creek, which support some of the best native fish assemblages remaining in the Gila River Basin.

Grassland and Savanna Condition
Grassland condition is variable across the landscape with over 135,000 acres (23%) of high-quality open grassland occurring here (Figure 16, Table 5). Most grasslands are shrub-invaded but restorable (382,500 acres or 67%), although extensive shrub conversion has occurred on over 55,000 acres (10%) primarily in the Aravaipa and upper Sulphur Springs valleys. Four sacaton riparian grasslands were mapped by experts in this landscape, and a cienega, Hooker Cienega, also occurs here.

At a finer-scale, current and former grasslands and savannas in this landscape occur on a variety of soil types and in four precipitation zones, together representing 4 dominant ecological sites (Appendix 2).

Figure 16. Aravaipa-Muleshoe-Willcox Grasslands

Current Grassland Condition



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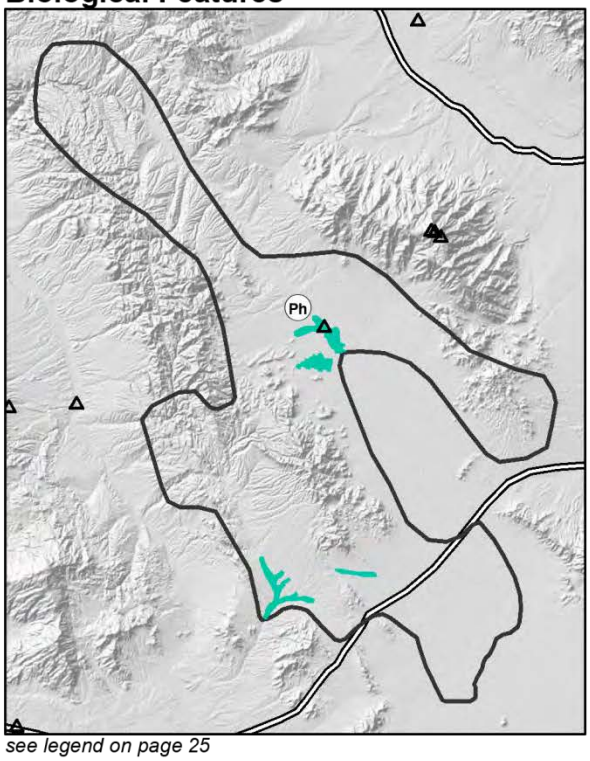
Biological Features



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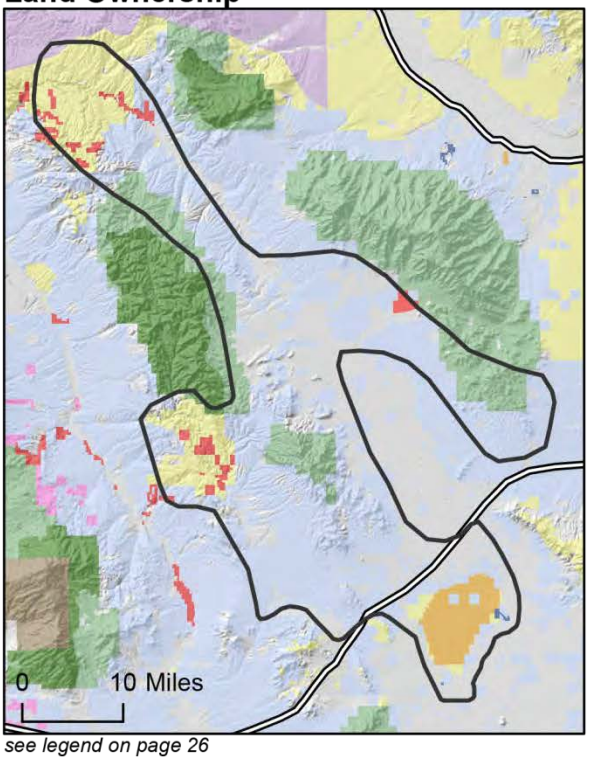
Land Ownership



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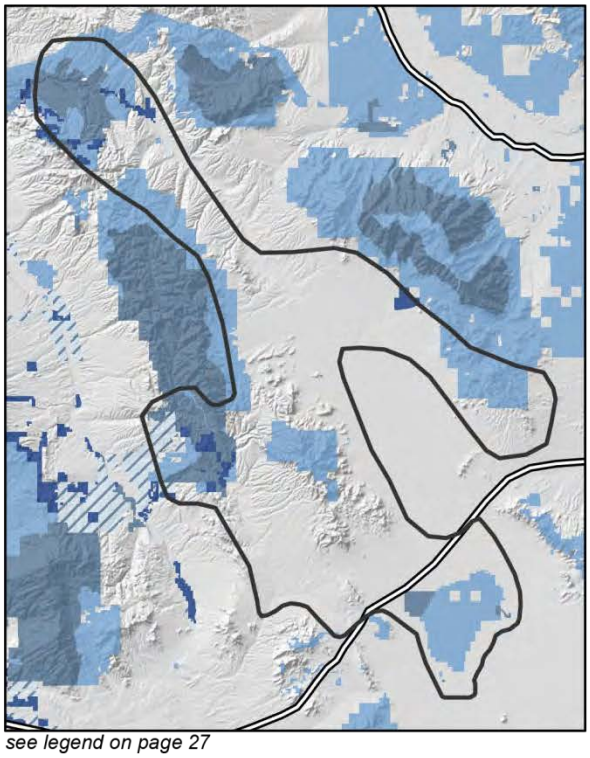
Protection Status



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Other Biological Features
The landscape supports a pronghorn herd and healthy populations of a number of globally rare and declining fish species including spikedace, loach minnow, round-tail chub, Gila chub, and Sonoran sucker, in addition to more common species such as longfin dace, speckled dace, and desert sucker (Table 7). Gila topminnow, desert pupfish, spikedace and loachminnow were introduced into several springs and streams on TNC's Muleshoe Ranch Cooperative Management Area (CMA) in 2007 and populations of all these species still persist. In addition, there are 7 sensitive riparian and grassland plants that occur here, including playa spider plant, Fish Creek fleabane, Aravaipa sage, Aravaipa wood Fern and Toumey agave (Appendix 1). Chiricahua leopard frog also occurs here.

Threats
Residential use and agricultural development is spreading north up the Aravaipa Valley and in the Upper Sulphur Springs Valley, and highway and utility corridors have been repeatedly proposed for the region.

Partnerships, Restoration and Land Protection
The Conservancy works with the USFS and BLM to cooperatively manage the Muleshoe Ranch CMA and Aravaipa Canyon Preserve (nearly 100,000 acres), and has been active for many years in protecting private land around Aravaipa Canyon and the Muleshoe Ranch CMA (13,800 acres; Figure 16, Table 6). However, a number of strategically-located ranches remain unprotected and vulnerable to development. The mountains ranges surrounding this landscape, including their foothill grasslands, are managed by the USFS and, to a much lesser extent, the BLM, although most of the grasslands are either private-owned (145,000 acres) or State Trust Land (283,000 acres). Together, less than 20% of current and former grasslands are permanently protected on federal land, with private conservation easements and on TNC preserves.

TNC is experimenting with native grass seed production on the Aravaipa Canyon Preserve, and has used prescribed fire for grassland and watershed restoration at Muleshoe Ranch CMA and Aravaipa since the early 1990's.

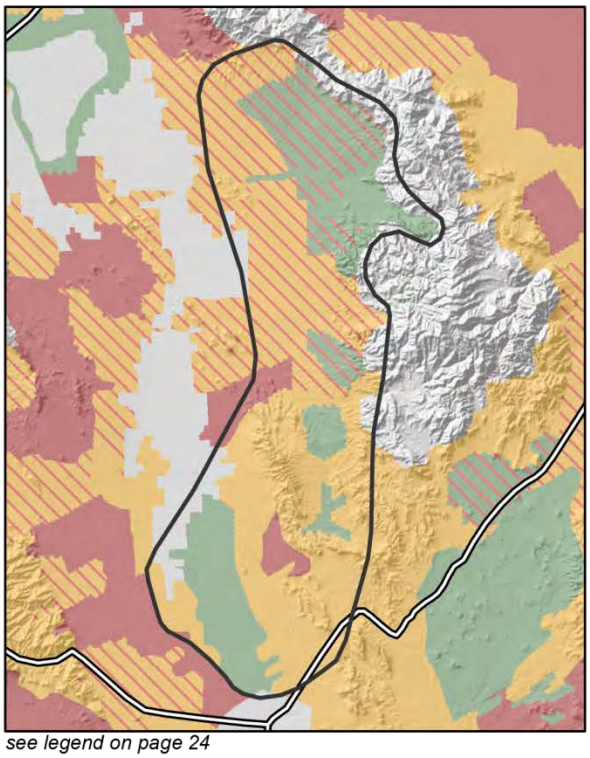
Southern Sulfur Springs Valley

The Southern Sulfur Springs Valley lies between the Chiricahua Mountains on the east and the Mule and Dragoon mountains on the west. The valley has a closed drainage to the north, ending at Willcox Playa, and drains to the south into Whitewater Draw which flows into Mexico (Yaqui River drainage). Grasslands are patchy and connectivity across the valley has been almost completely lost due to residential development and agricultural conversion (e.g., ranked low). The result of this fragmentation is that the priority landscape identified by experts is located on the east side of the valley described above. Connectivity with other grasslands landscapes and north-south across the international border are also low.

Grassland and Savanna Condition
High quality, open grassland occurs in patches along the western flanks of the Chiricahua Mountains and on the valley bottom southwest of the Swisshelm Mountains, e.g., southwest corner of the landscape (Figure 17, Table 5). Most of the remaining grassland in the landscape has experienced medium woody increase (267,500 acres, 62% or current and former grasslands),

Figure 17. Southern Sulphur Springs Valley

Current Grassland Condition



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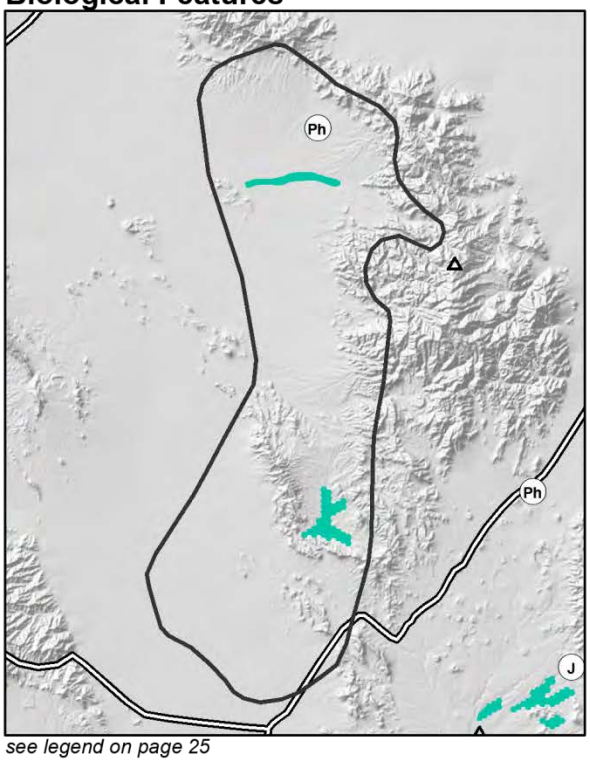
Biological Features



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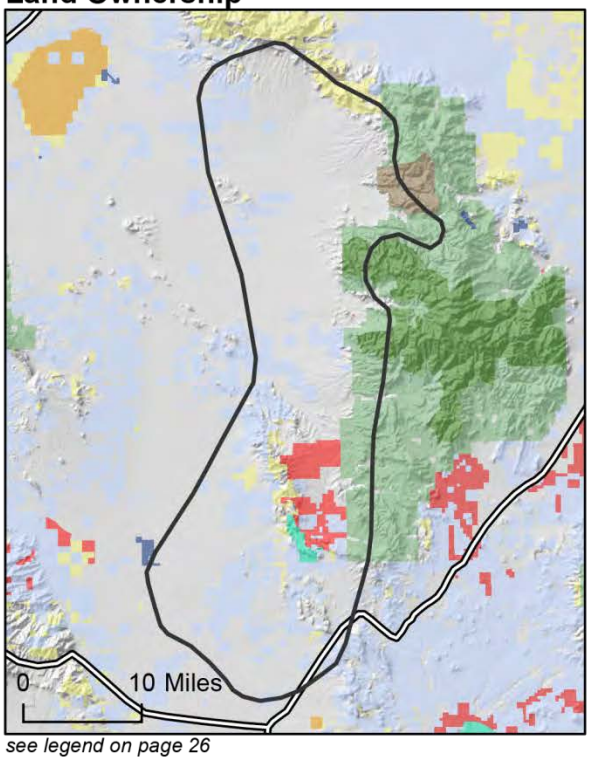
Land Ownership



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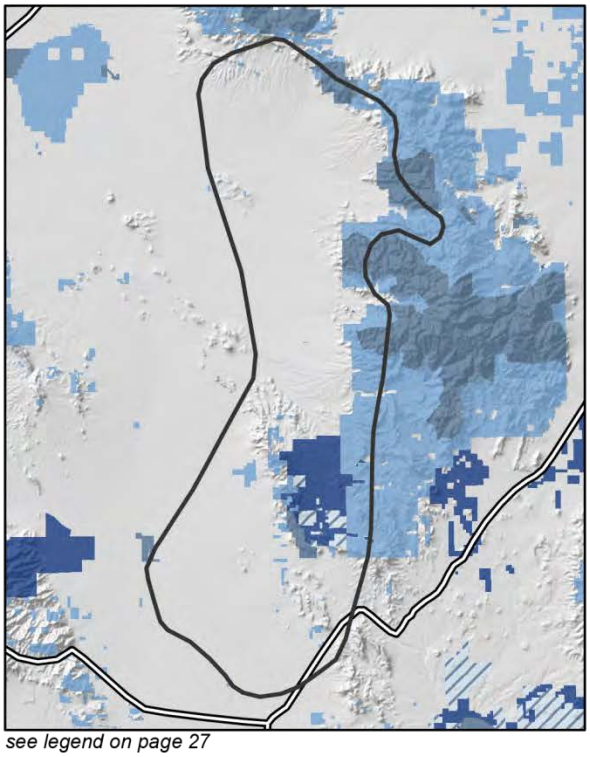
Protection Status



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and Lehmann's lovegrass is now common or dominant on nearly 181,000 acres (or 42%). Two sacaton riparian grasslands occur here.

At a finer-scale, current and former grasslands and savannas within this landscape occur on a variety of soils and in three different precipitation zones resulting in 35 dominant ecological sites, each with varying grass, herb, shrub and tree species compositions in reference and non-reference condition (Appendix 2).

Other Biological Features
The landscape supports a pronghorn herd and an isolated population of desert massasauga, a grassland dependent species (Figure 17, Table 7). Leslie Canyon, located on the Leslie Canyon National Wildlife Refuge (NWR), is the most significant perennial stream in the landscape, supporting 3 sensitive riparian plants, including Huachuca water umbel, Chiricahua leopard frog and four species of Yaqui drainage native fish: Yaqui chub, Yaqui longfin dace, Mexican stoneroller, and Yaqui topminnow. These native fish were transplanted into West Turkey Creek along with Yaqui catfish. A number of grassland birds have also been recorded in this landscape by the Rocky Mountain Bird Observatory including Baird's sparrow, Cassin's sparrow, grasshopper sparrow, eastern meadowlark and loggerhead shrike.

Threats
The entire central portion of the valley bottom has been largely converted to irrigated agriculture, with rural residential development spreading around several communities.

Partnerships, Restoration and Land Protection
The eastern edge of landscape is under federal ownership and managed by USFS, BLM, and National Park Service (Chirichahua National Monument) and there is additional BLM land in the valley bottom for a total of over 45,000 acres (Figure 17, Table 6). The USFWS manages Leslie Canyon NWR and holds conservation easements on two ranches there totaling over 21,000 acres, which it acquired with TNC assistance. The Whitewater Draw Wildlife Area, managed by the Arizona Game and Fish Department, lies just to the southwest of the landscape boundary. Unprotected private lands and State Trust Lands make up most of the landscape at 276,000 acres and 81,000 acres, respectively; approximately 4,500 acres of State Land have been identified to receive greater protection if the State Trust Land Reform ballot measure is approved by Arizona voters.

Wetland and aquatic habitat management is occurring at Leslie Canyon NWR and Whitewater Draw Wildlife Area. Experts ranked the landscape as medium-low for both land protection and ecological land management (Table 4). Only 70,000 acres of grassland are permanently protected on federal land and with conservation easements, representing only 16% of grasslands in the landscape (Figure 17, Table 6).

San Bernardino Valley

The San Bernardino Valley extends from the Chiricahua Mountains on the north and west to the Peloncillo Mountains on the east. Two continguous, low-elevation ranges, the Pedregosa and Perilla Mountains, extend from the southern end of the Chiricahuas to the international border and form the western edge of the landscape. Black Draw drains the watershed, flowing east into Mexico where it becomes the Rio San Bernardino (Yaqui River drainage). Perennial flow begins

close to the international border on the San Bernardino National Wildlife Refuge (NWR) and continues into Mexico. The refuge also contains an historic cienega as well as ponds that have developed cienega-like characteristics. Grassland connectivity between mountain ranges is high as is connectivity between this landscape and the Animas and Playas Valleys to the east (see below). However, shrub encroachment and conversion of grassland to shrubland in Mexico interrupts connectivity across the international border (Table 4).

Grassland and Savanna Condition
A large open grassland occurs in the valley bottom and adjacent to the Chiricahua Mountains, extending more than 136,000 acres (42% of current and former grasslands), and surrounded by nearly 165,000 acres of grassland with medium woody increase and high restoration potential (50% or historic grasslands; Figure 18, Table 5). Lehmann's lovegrass was seeded in the landscape and has passively spread such that it is now common or dominant on over 74,000 acres (23%) of these grasslands. Sacaton riparian grasslands and former grasslands that have converted to shrublands also occur here.

At a finer-scale, there are 28 dominant ecological sites representing the grasslands and savannas in this landscape; these ecological sites occur on different soils and in two precipitation zones (Appendix 2).

Other Biological Features
Pronghorn have recently been re-introduced to the valley and desert massasauga also occurs here (Figure 18). The landscape is rich in aquatic and riparian species as a result of ongoing protection and restoration efforts at San Bernardino NWR and along the mainstem Rio San Bernardino by Cuenca Los Ojos Foundation (Table 7; Appendix 1). Seven species of native Yaqui drainage fish occur on the refuge and downstream including Yaqui chub, Yaqui catfish, beautiful shiner, Yaqui sucker, Yaqui longfin dace, Mexican stoneroller, and Yaqui topminnow. The refuge also supports Chiricahua leopard Frog, San Bernardino springsnail, Mexican garter snake and three species of sensitive wetland plants. Rosen et al. (2001) reported the garter snake population was declining although its current status is unknown.

Threats
This region is relatively free from threats, but rural residential development is spreading into the area from the vicinity of Rodeo, NM, on the north and from Douglas, AZ, on the west. On-going pressure from smuggling along the international border has been the source of continuing tension between border security and community conservation goals.

Partnerships, Restoration and Land Protection
The Malpai Borderlands Group is a local, rancher-led land trust that has been working in this area and in the adjacent Animas-Sierra San Luis and Playas Valley-Janos Plain priority landscapes for almost 20 years (Figure 18, Table 6). The Malpai Group has been a leader in use of conservation easements, protecting over 38,500 acres in the San Bernardino Valley, and in the use of fire for grassland restoration and management, with an average of more than 20,000 acres burned per year over the last 20 years. The Group completed the first programmatic fire plan of its kind in Arizona for the Peloncillos Mountains, and has been conducting extensive erosion control and brush management projects with landowners. The NRCS has been a key partner in planning and funding these range improvement projects (e.g. erosion control, prescribed fire, and water development). The USFWS has also been an important cooperator in promoting watershed

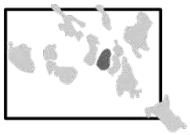
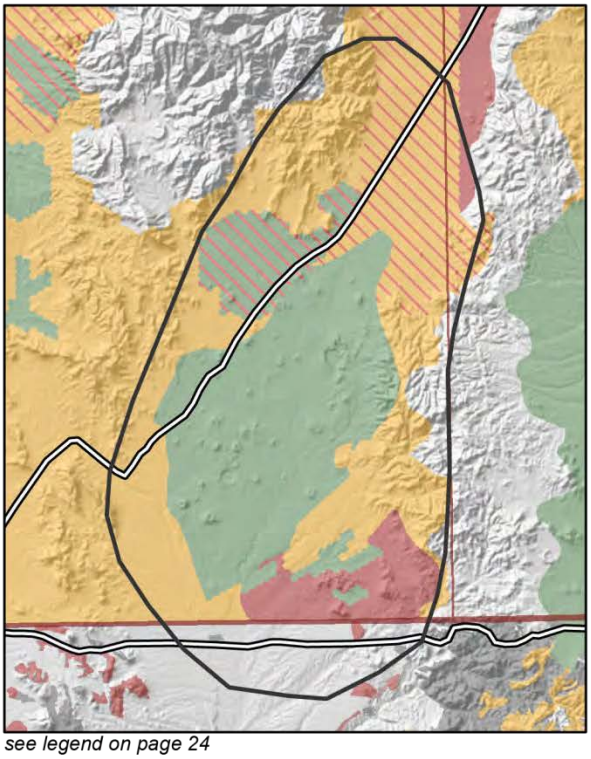


Figure 18. San Bernardino Valley

Current Grassland Condition



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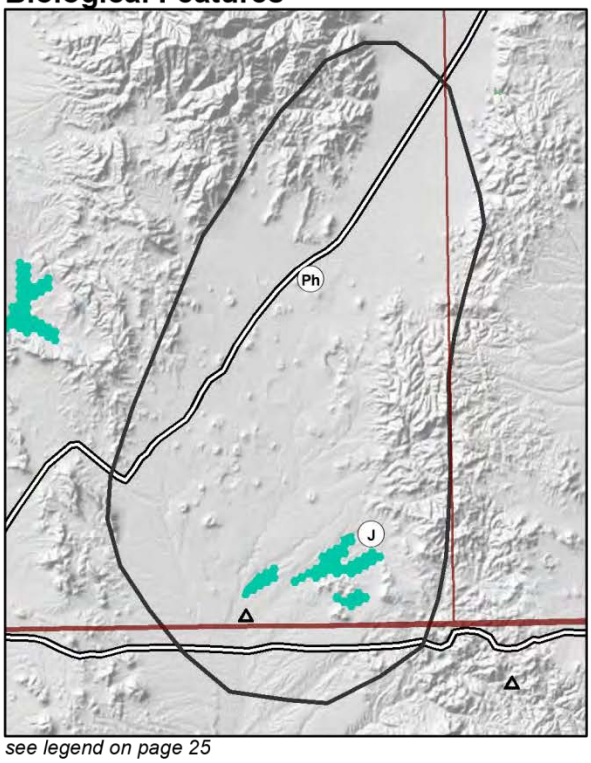
Biological Features



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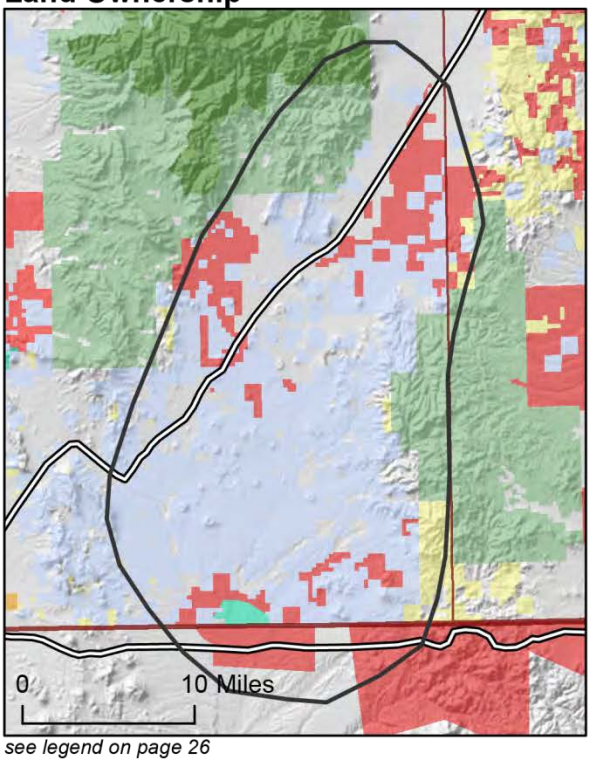
Land Ownership



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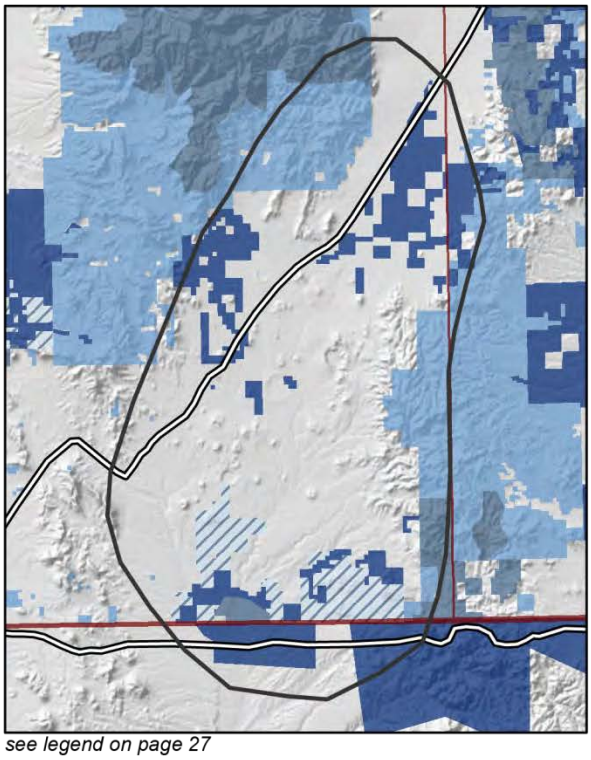
Protection Status



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restoration above the San Bernardino NWR and in securing funding for grassland (watershed) restoration.

TNC has assisted the Malpai Group with conservation easements and fundraising, and is continuing to explore innovative new funding sources for land protection such as working with Arizona Department of Transportation to protect habitat through the scenic easement program. Finally, Cuenca Los Ojos Foundation, a bi-national non-profit organization, has protected a number of large ranches in Mexico that are part of this landscape (16,500 acres) and the adjacent Animas Valley-Sierra San Luis Grassland. The Foundation has been conducting prescribed burns, brush treatments, and extensive erosion control work in the watershed and riparian restoration along the Rio San Bernardino. Altogether, over 99,000 acres of grassland in the landscape, roughly 30%, are permanently protected on federal land and by conservation easements.

Animas Valley-Sierra San Luis Grassland

This expansive 427,000 acre grassland landscape extends from the Peloncillos Mountains on the west, across the Animas Valley to the Animas Mountains on the east, and south to the Sierra San Luis. The landscape is completely unfragmented between mountain ranges and habitat connectivity is continuous to the south and east into the Playas Valley, Janos Plains and the Sierra Madre in Mexico (Table 4). Thus, experts ranked landscape connectivity as high across all categories. The landscape contains a number of important streams and wetlands including Cloverdale Creek and Cienega and Headquarters Cienega in the Animas Valley, and Cajón Bonito in the Sierra San Luis (Rio Yaqui drainage)

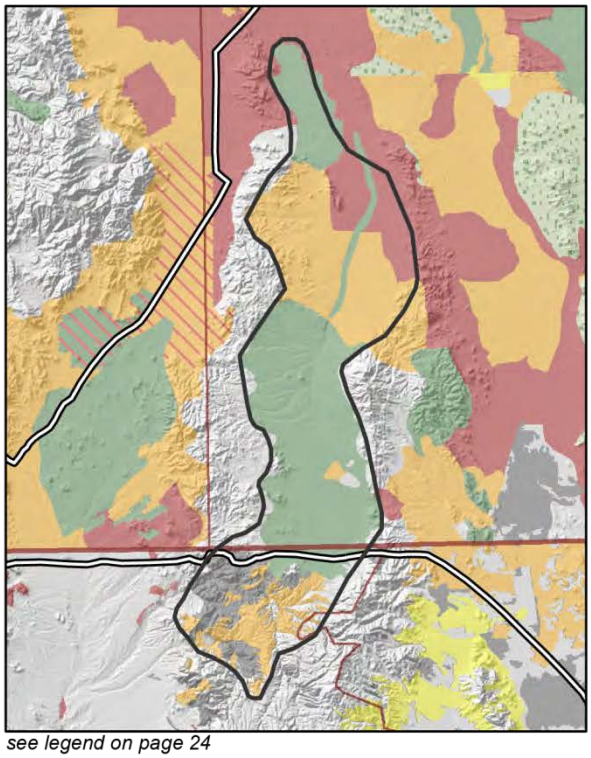
Grassland and Savanna Condition
Two large patches of high-quality open grassland (> 185,000 acres) and the most extensive sacaton riparian grassland mapped in the Sky Islands region occur in this landscape (Figure 19, Table 5). These grasslands are surrounded by over 126,000 acres of grassland with medium woody increase and high restoration potential. At the north end of the Animas Valley, and lower in elevation, shrub encroachment and loss of perennial grass cover has been more severe, resulting in the conversion of former grassland to shrubland (38,000 acres).

At a finer-scale, current and former grasslands and savannas occur on a variety of soils representing 18 dominant ecological sites (Appendix 2).

Other Biological Features
The extensive grasslands in this landscape support a large pronghorn herd as well as a number of other grassland-dependent species: mountain plover, western burrowing owl, white-sided jackrabbit, black-tailed prairie dog and a free-ranging bison herd that moves across the international border and through the adjacent Playas Valley-Janos Plains landscape (Figure 19, Table 7). Aplomado falcons are also periodically sighted in the landscape, but there are no records of the species breeding here. Chiricahua leopard frog occurs in Cloverdale Creek and Cienega and the population appears to be the only one tested to date that is free of chytrid fungus. In addition, the Cajón Bonito in Mexico supports the most intact assemblage of Rio Yaqui fish species in the US and Mexico (and the most diverse native fish assemblage in the Borderlands); fish species includes Yaqui beautiful shiner, Mexican stoneroller, ornate shiner,

Figure 19. Animas Valley-Sierra San Luis Grassland

Current Grassland Condition



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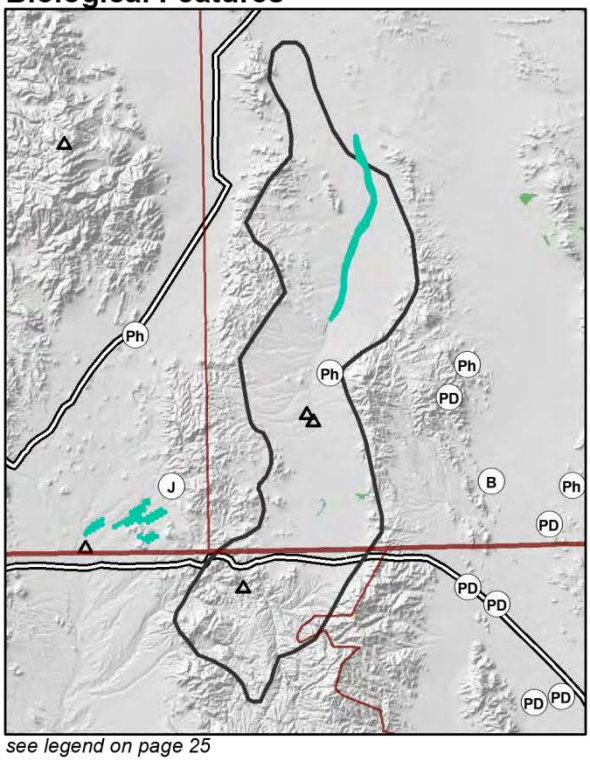
Biological Features



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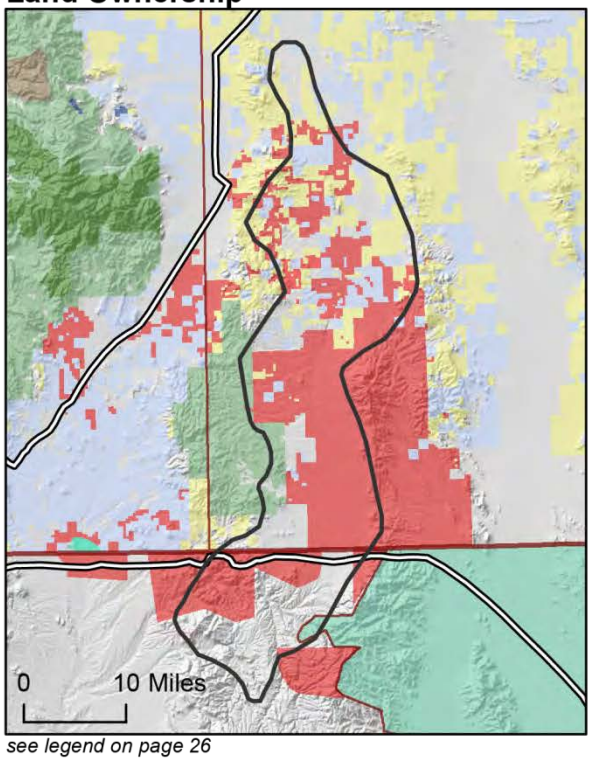
Land Ownership



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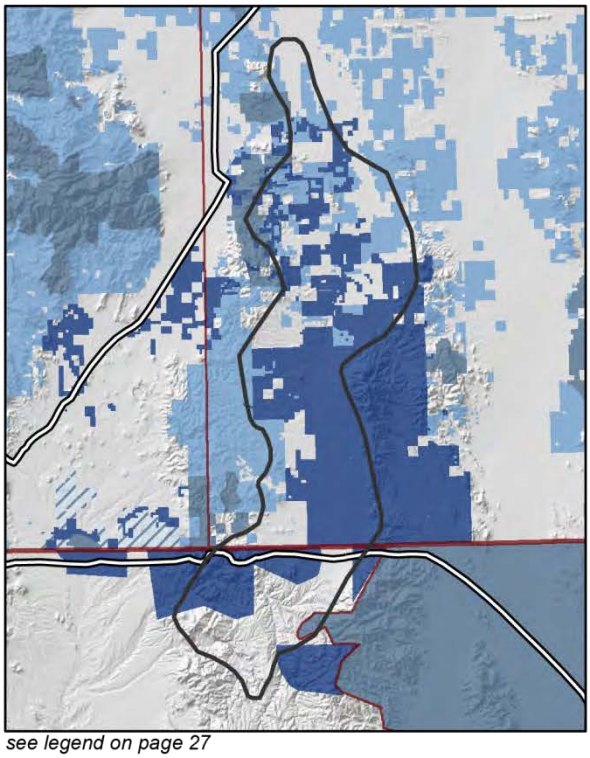
Protection Status



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Yaqui longfin dace, Mexican roundtail chub, Yaqui sucker, Yaqui topminnow, Yaqui catfish, and Yaqui chub. The expansive grasslands also support a diverse assemblage of grassland birds.

Threats
This landscape is relatively free from threats, including rural residential development. On-going pressure from smuggling along the international border has been the source of continuing tension between border security and community conservation goals.

Partnerships, Restoration and Land Protection
The Malpai Borderlands Group has been working in this area for almost 20 years (for more details on the Malpai Group, see the San Bernardino description). The Malpai Group has protected nearly 22,000 acres in conservation easements in this landscape with technical and fundraising assistance from TNC (Figure 19, Table 6). The Conservancy working with the Animas Foundation has protected an additional 133,500 acres of private land with conservation easements, while Cuenca Los Ojos Foundation has protected over 38,000 private acres in Mexico. The Malpai Group, Animas Foundation, and the Cuenca Los Ojos Foundation (CLOF) have been conducting erosion control and brush management projects to improve grassland and watershed condition, including prescribed burning, mechanical shrub treatments and extensive use of wildland fire to meet resource objectives. The NRCS has been a key partner in planning and funding these range improvement projects in the US. In addition, CLOF has been working to restore riparian and aquatic habitat in Cajón Bonito.

Together, over two-thirds of the grasslands in this landscape (258,000 acres) are permanently protected through conservation easements and on federal land (Figure 19, Table 6).

Playas Valley-Janos Plain

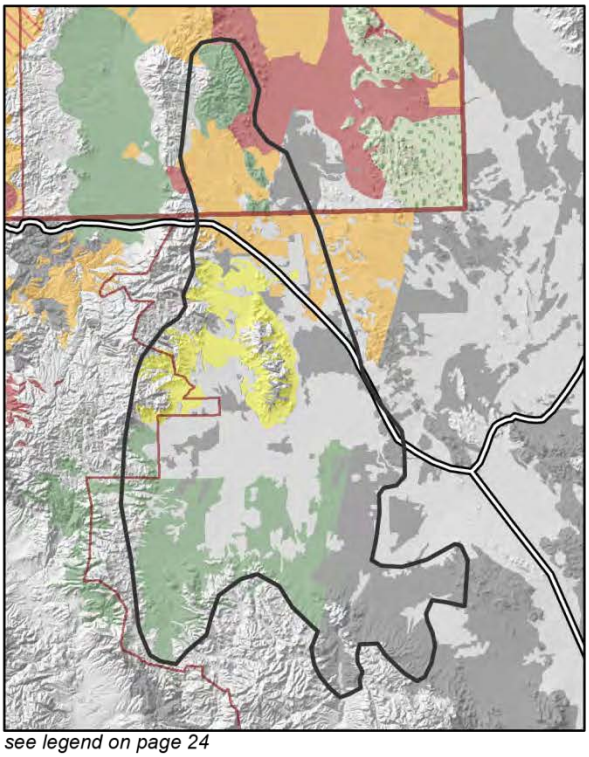
This 922,000 acre landscape encompasses a portion of the southern Playas Valley and the grasslands of the Janos Plains south of the international border. The Playas Valley extends from the Animas Mountains on the west to the Big Hatchet and Alamo Hueco mountains on the east. Shrub encroachment has compromised grassland connectivity across the valley to such an extent that experts delineated only the western side of the valley as part of the landscape. Separated from the Playas Valley by a low divide, the Janos Plain extends from the Sierra San Luis on the Sonora-Chihuahua state line south and east from the international border to the town of Janos, Chihuahua, and south to the Sierra Madre at the Mesa Guacamaya. This broad plain is gently sloping with internal drainage, and so is relatively free from gully erosion, however, its deep soils have almost no perennial surface water.

Grassland and Savanna Condition
Open native grasslands cover nearly 191,000 acres or 32% of current and former grasslands in this landscape (Figure 20, Table 5). Grasslands with varying degrees of shrub encroachment but with high restoration potential cover 176,000 acres (14%). Finally, undetermined grasslands occur on over 216,000 acres (36%). Additional reconnaissance and survey work in this landscape would assist in clarifying their status, condition and restoration potential.

Other Biological Features
Pronghorn occur in the Playas Valley and a small herd still persists in Janos Plains in Mexico. In addition, a free-ranging bison herd moves periodically into the western portion of the Playas

Figure 20. Playas Valley-Janos Plain

Current Grassland Condition



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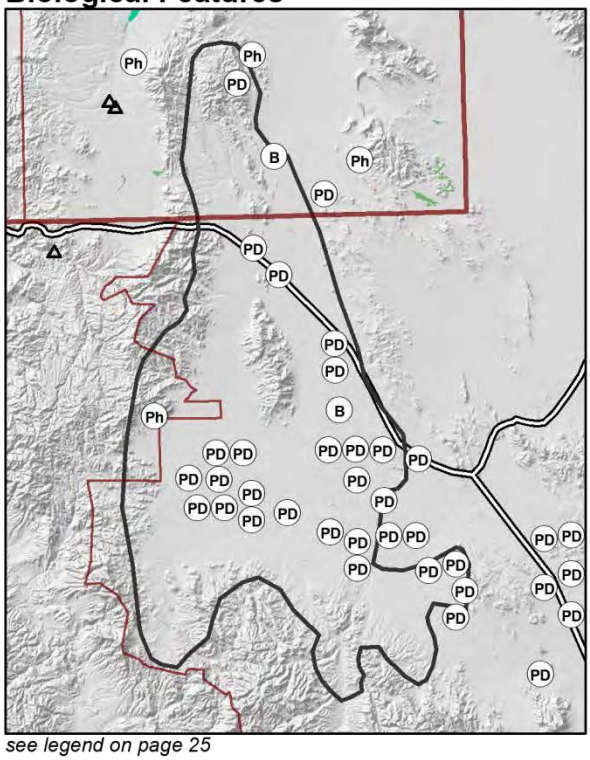
Biological Features



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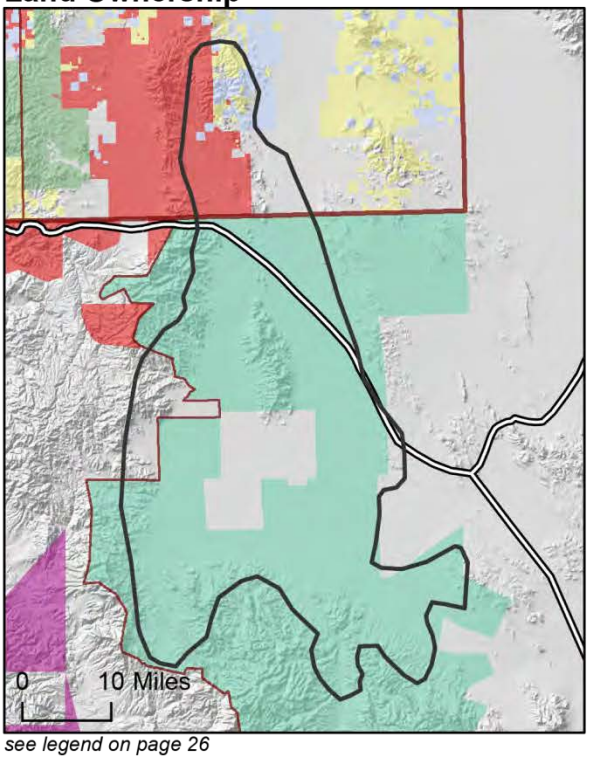
Land Ownership



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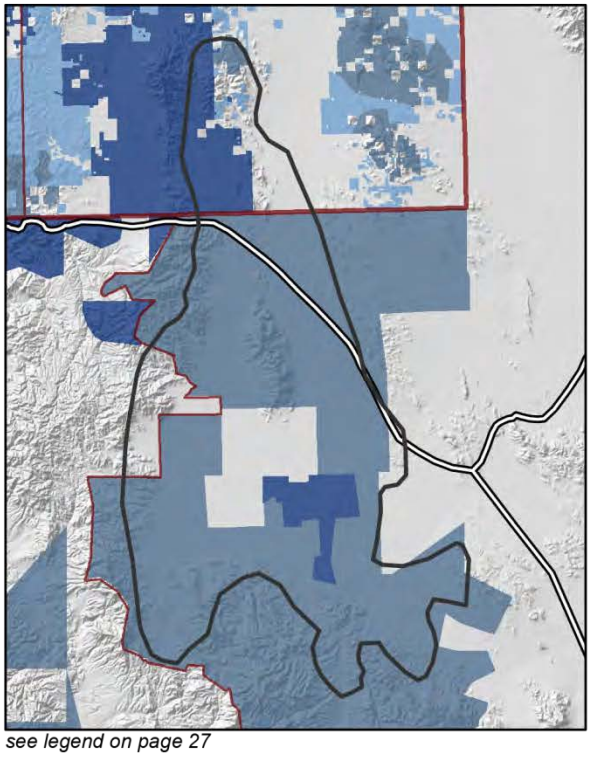
Protection Status



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Valley from Chihuahua, Mexico, continuing into the adjacent Animas Valley-Sierra San Luis landscape (Figure 20, Table 7). A second bison herd has been introduced to Rancho El Uno as part of a project to repopulate bison to their historic range. Black-tail prairie dogs are abundant and widely distributed in the Mexico portion of the landscape to such an extent that the USFWS and the Universidad Autónoma de México in Mexico City (UNAM) released black-footed ferrets near the town of Janos in 2001. In addition, the grasslands support white-sided jackrabbit and a suite of grassland birds including aplomado falcon, grasshopper sparrow, Baird's sparrow, Cassin's sparrow, loggerhead shrike, eastern meadowlark and western burrowing owl. Chiricahua leopard frog is also reported to occur in the landscape.

Threats

Center pivot irrigation has been spreading rapidly across the Janos plains, fragmenting grassland and displacing prairie dog colonies. The irrigation wells are going in without permitting and with no regulatory oversight, so are largely unmanageable.

Partnerships, Restoration and Land Protection

In the US, most of the current and former grasslands in this landscape are privately owned, although BLM owns and manages 10,500 acres of grassland (18%) and NM State Land Office owns/manages slightly over 13,000 acres (13%; Figure 20, Table 6). In Mexico, the land is privately owned by individuals, ejidos, and non-governmental organizations. In the US, TNC, working with the Animas Foundation, has protected over 58,500 acres of private land in conservation easements, and in Mexico, the Conservancy purchased the 46,500 acre Rancho El Uno in 2005. In 2009, the Mexican federal government designated the Janos Biosphere Reserve which extends across approximately 1.26 million acres of the landscape in Mexico. Although the designation explicitly prohibits the conversion of natural vegetation to agriculture, the level of protection that the decree conveys in practice is uncertain.

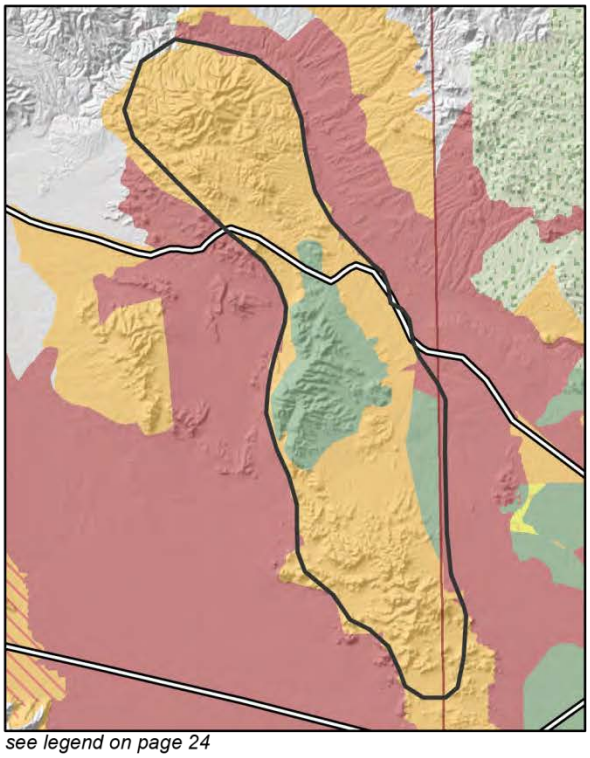
Researchers from UNAM are studying the grassland ecosystem and are active in promoting conservation in the landscape. The lead federal agency for establishing the Janos Biosphere Reserve, SEMARNAT, is also involved in management of grassland wildlife. These partners, along with Pronatura Noreste have collaborated with TNC in the grassland restoration work at El Uno Ecological Preserve (Rancho El Uno). In 2009, the US National Park Service contributed a small herd of genetically pure bison to help restore the Janos ecosystem. The bison were released at the Preserve where the herd is growing within the confines of its boundaries and will be the seed herd to restore bison to its historical range in the landscape. The local municipio of Janos is hoping to use natural resource values of the landscape, such as prairie dogs and bison, to promote tourism.

North Peloncillos Mountains

This 277,000 acre landscape encompasses the north end of the Peloncillos Mountains and the alluvial fans that emerge from the range on its east and west sides. The Gila River is just north of the landscape, while the Lordsburg Playa lies to the southeast. Extensive shrub encroachment and conversion of historic grassland to shrubland outside the landscape boundary may reduce connectivity with adjacent grassland landscapes. However, we do not understand, for example, to what extent the pronghorn herd that occurs in the North Peloncillos uses the open grassland around the Lordsburg Playa or other high-quality grassland patches to the east and north of I-10. For this reason, experts: (1) restricted the landscape boundary to the Peloncillos range in the

Figure 21. North Peloncillos Mountains

Current Grassland Condition



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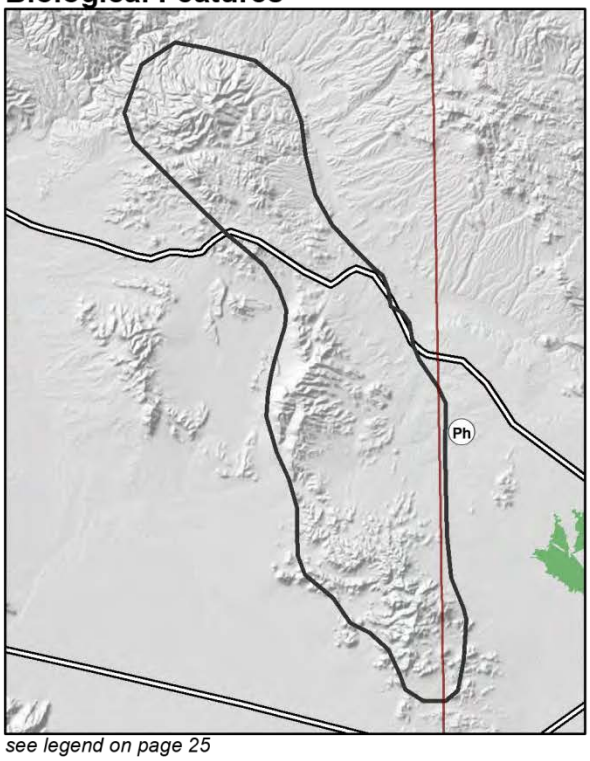
Biological Features



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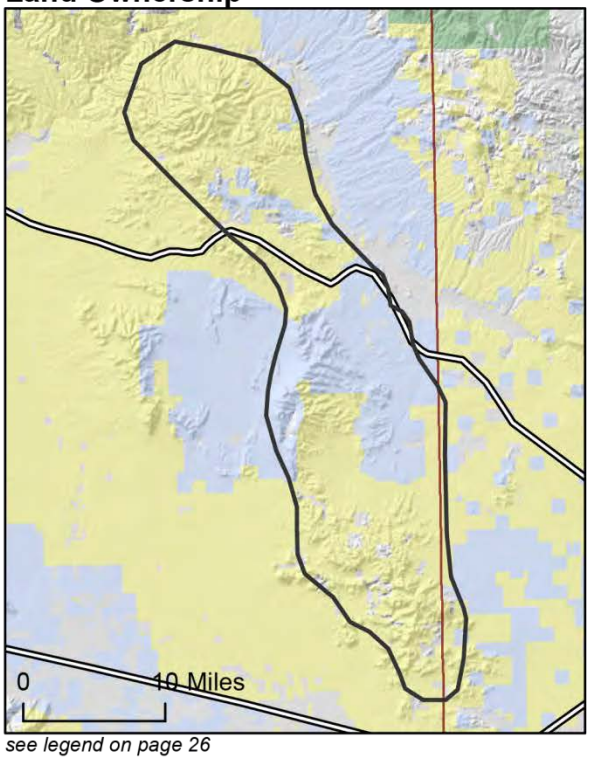
Land Ownership



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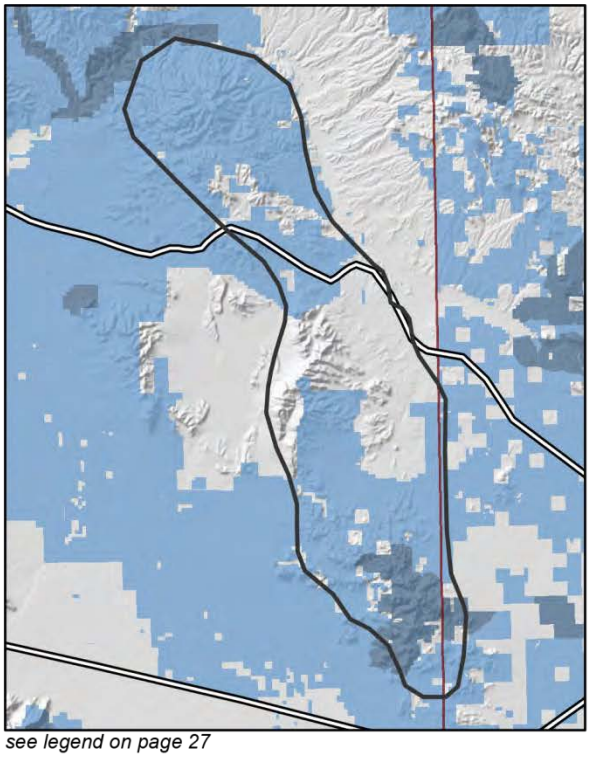
Protection Status



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hopes of encouraging further investigation; and (2) ranked both connectivity with other grassland landscapes and north-south connectivity across the international border as low.

Grassland and Savanna Condition
Grasslands and savannas with medium woody increase dominate this foothill and piedmont grassland landscape, comprising nearly 209,000 acres or 76% of current and former grasslands here (Figure 21, Table 5). Open native grasslands occur in two large patches, comprising nearly 58,000 acres (21%). Grasslands with high woody increase are restricted to the edges of the landscape and are probably an artifact of how experts mapped the boundaries of the landscape.

At a finer-scale, current and former grasslands and savannas within this landscape are represented by 29 dominant ecological sites which occur on a variety of soils and in three different precipitation zones. The diversity of soils and variation in rainfall results in considerable variation in grassland composition, structure and productivity across the landscape (Appendix 2).

Other Biological Features
Except for pronghorn, there are there are no records of grassland dependent species, nor did experts identify significant wetlands or perennial streams in the landscape (Figure 21, Table 7).

Threats
As a result of its isolation, generally rocky soils and scarcity of surface water, there are currently no threats to the landscape.

Partnerships, Restoration and Land Protection
Over two-thirds of the grasslands in this landscape are managed by the BLM (187,000 acres) while State Lands in Arizona and New Mexico comprise over a quarter of the grasslands (74,500 acres). A small amount of private land also occurs here (Figure 21, Table 6). At the south end of the landscape is BLM's Peloncillos Mountain Wilderness at over 19,000 acres. Over two-thirds of the grasslands in this landscape are permanently protected on federal land.

Burro Cienega-Hachita Grasslands

This expansive 1,206,000 acre grassland landscape extends from the foothills of the Big Burro, Little Burro and Pinos Altos mountains on the north, south across the Continental Divide to the international border, and from the Pyramid, Little Hatchet and Big Hatchet mountains on the west across three valleys to the Cedar Mountains on the east. These valleys are: the Lordsburg and Hatchita Valleys and an unnamed valley east of the Hachita Valley that is drained by Wamels Draw. The Lordsburg Valley lies to the north of the Continental Divide, draining to the north in an internal basin (bolson), while the Hachita Valley and the adjacent valley (east) drain to south, ending in bolsons in Chihuahua Mexico. These internal basins hold water seasonally depending on the amount and timing of winter and summer precipitation. Experts ranked connectivity across valleys within the site and north-south connectivity across the international border both as high. Connectivity with other priority grassland landscapes was ranked as medium due to the extent of shrub encroachment (shrub conversion) to the southwest, separating this landscape from the Playas Valley-Janos Plains and Animas Valley-Sierra San Luis landscapes.

Grassland and Savanna Condition
Two large atches of open grassland and savanna comprise over two-thirds of grasslands in the landscape (673,000 acres; Figure 22, Table 5). To the west and south, shrub-invaded but restorable grasslands and savannas occur on more than 221,000 acres (23%). Former grassland and savanna represent a relatively minor component of the landscape, covering only 78,000 acres (8%). A large area in the northern part of the landscape was not mapped in the REA, although we now know that much of it is grassland. Additional assessment of grassland extent and condition in this area is needed.

At a finer-scale, current and former grasslands and savannas within this landscape are represented by 21 dominant ecological sites that occur on different soils and landforms (Appendix 2).

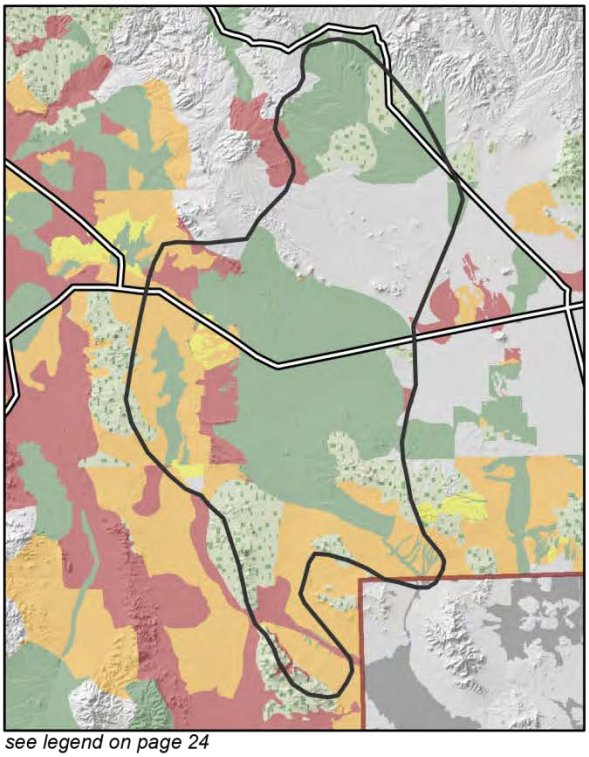
Other Biological Features
According to workshop experts, three pronghorn herds occur in this landscape: one south of Silver City, another in the vicinity of Burro Cienega, and a third in the Hachita Valley (Figure 22, Table 7). Re-introduction of Aplomado falcon is occurring on a ranch in the northern portion of the landscape and, although birds are periodically sighted over a much larger area, there have been no records of successful breeding. However, restoration of grasslands with medium woody increase would improve the site for falcon re-introduction (A. Montoya, pers. comm.). The landscape also supports Chihuahua scurfpea, a rare grassland plant known from only 3 sites in the US, and a suite of grassland birds (Appendix 1). Wetlands and streams are rare due to the lack of high-elevation mountain ranges in the landscape. Burro Cienega (stream and wetland) and scattered playa lakes on both sides of the international border, including a complex of playa lakes around Laguna Las Moscas in Chihuahua, are the landscape's most significant wetland features. These playas are important for migratory birds, including sandhill cranes, waterfowl, long-billed curlew and other shorebirds. Burro Cienega supports Chiricahua leopard frog and Gila topminnow.

Threats
Land cover conversion for vineyards has occurred around Deming and Hachita, New Mexico, and the potential for the establishment of additional vineyards is high. In addition, the proposed SunZia Transmission Corridor crosses the landscape, parallel to I-10, increasing the potential for energy development in the vicinity of transmission lines. A large wind farm was recently completed in the Nutt grassland northeast of Deming.

Partnerships, Restoration and Land Protection
Grasslands, including former ones, occur on a mix of BLM land (38%), NM State land (25%) and private land (36%; Figure 22, Table 6). The BLM Las Cruces District is conducting brush control treatments on thousands of acres of degraded grassland in this landscape under its Restore New Mexico Initiative. TNC is working with BLM to develop a habitat model for a rare plant, Chihuahua scurfpea, in order to increase the efficiency of BLM's pre-treatment surveys which are expensive, time-consuming and slow the rate of shrub control treatments. In addition, TNC is working with a private rancher along Burro Cienega (Pithfork Ranch) on erosion control and brush treatments and has initiated discussions with neighboring ranchers interested in grassland restoration projects. The Pitchfork Ranch has also been involved in extensive riparian restoration work with the assistance of USFWS and NRCS.

Figure 22. Burro Cienega-Hachita Grasslands

Current Grassland Condition



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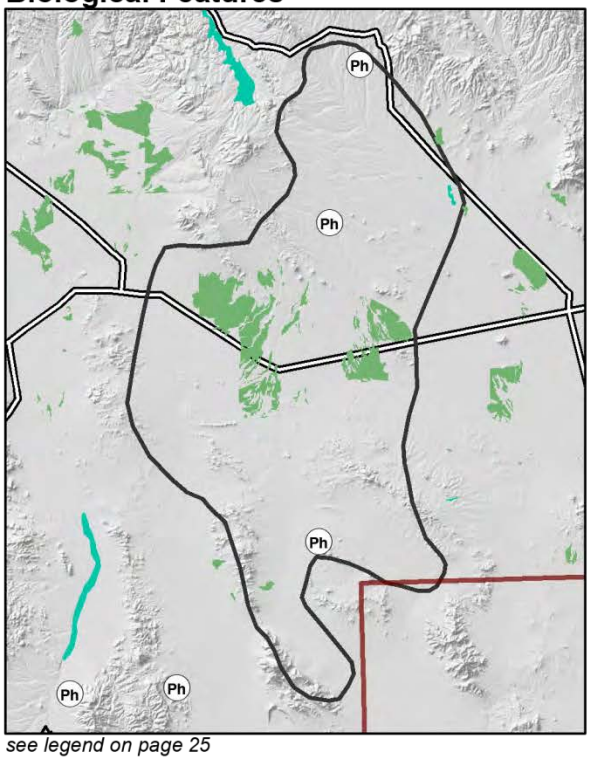
Biological Features



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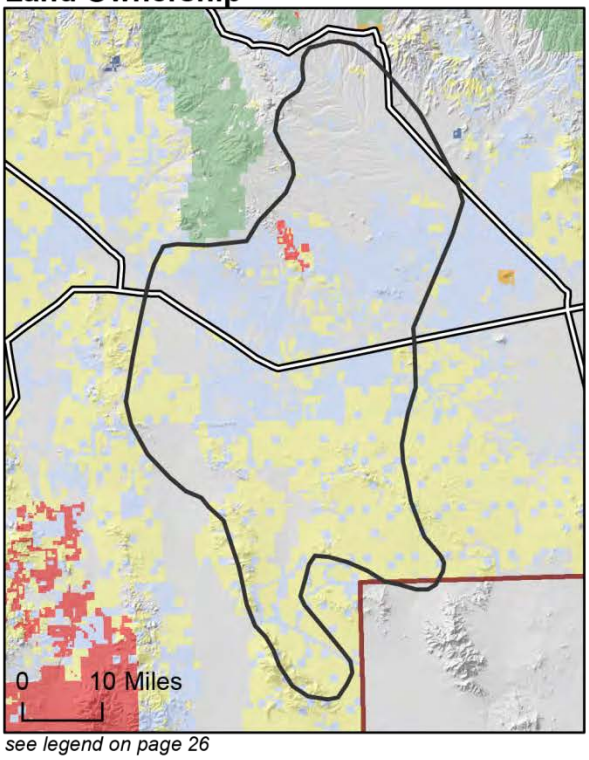
Land Ownership



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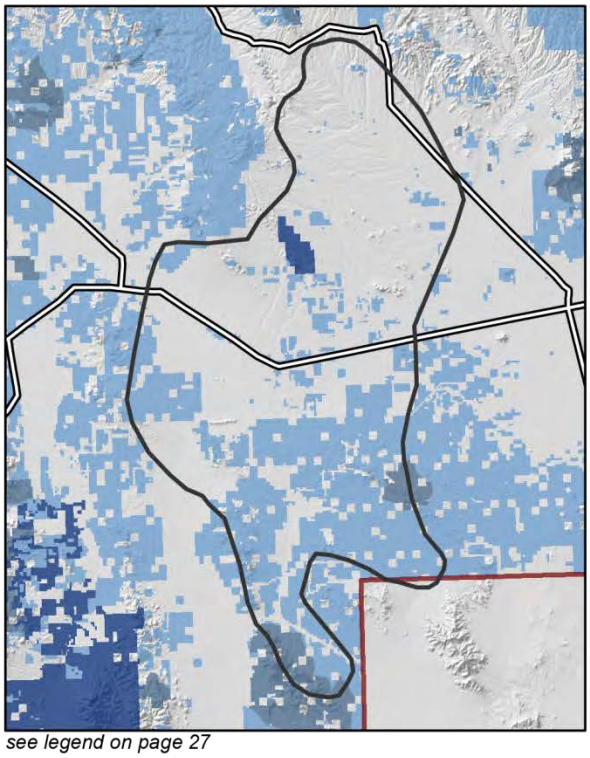
Protection Status



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Very little private land protection has been done in this landscape to date, although the Pitchfork Ranch has protected over 5,000 acres of grassland and wetlands with a conservation easement. Altogether, nearly 383,000 acres of grassland is permanently protected (39%), mostly on federal land (Figure 22, Table 6).

Buenaventura Grasslands

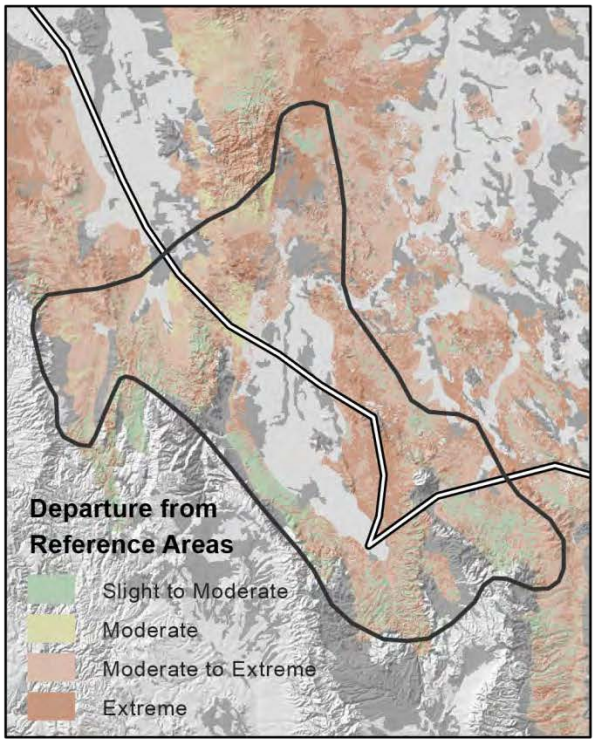
This 1,078,000 acre grassland landscape, which lies to the south and southeast of Nuevo Casas Grande, Chihuahua, is comprised of contiguous valley-bottom and piedmont-hill grasslands bounded by the Sierra Occidental to the west, the Sierra de las Tunas and Sierra del Nido to the south, and isolated "sky island" mountain ranges, the Sierra del Capulin and Cerro Grande, to the north. Experts ranked landscape connectivity as high in all categories, except for connectivity across the international border which was ranked as medium. Approximately 666,000 acres of grassland (of undetermined condition) was mapped by INEGI within this landscape (Figure 23, Table 6).

Grassland and Savanna Condition
Valerio et al. (2005) spatially mapped grassland type and condition across the state of Chihuahua, Mexico, using Landsat 7 imagery and ground-based plots; the resulting maps were field verified. Their condition assessment estimated the degree of departure from reference conditions or areas using the Indicators of Rangeland Health methodology (Pellant et al. 2005); the classification included four categories: slight to moderate, moderate, moderate to extreme, and extreme departure from reference areas. Using these data, 17% of the grasslands showed slight to moderate departure, 8% showed moderate departure, 39% showed moderate to extreme departure, and 37% was extremely departed from reference areas (Figure 23). Since the method evaluates degree of departure for 17 indicators representing different attributes of biotic integrity, hydrologic function and soil/site stability factors, comparison or cross-walking these results with our condition assessment classes is not possible. However, the results suggest that over three quarters of the grasslands in this landscape are at risk due to excessive soil erosion, altered grass composition and/or shrub encroachment. Further, it is likely that conditions have worsened in this landscape since 2005 due to recent climatic events, including unusually cold (freezing) weather in early February, 2011, and a severe drought which occurred between summer 2010 and fall 2011 (J. Esquer, pers. comm.). Shrub encroachment, especially by mesquite, has reduced the extent of high-quality grassland in this landscape especially in the Santa Maria and Santa Clara watersheds (Valerio et al. 2005). Poorly-managed cattle grazing continues to promote mesquite expansion, loss of perennial grass cover and increased soil erosion.

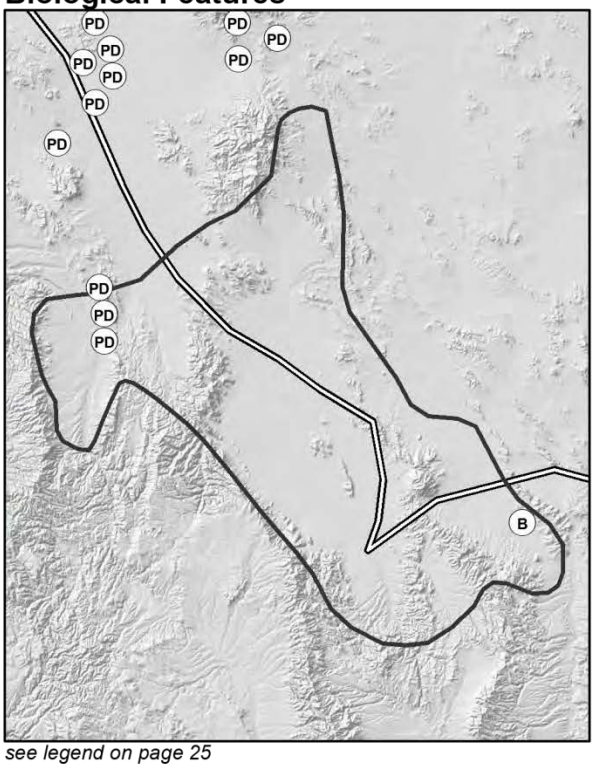
Other Biological Features
Correon and Lafon (2012) present spatial information on pronghorn occurrence in Chihuahua, Mexico, showing pronghorn locations just north and east of the Buenaventura landscape polygon and not inside of it. Other sources list ranch names for known pronghorn localities, however, we were unable confirm pronghorn presence within this landscape, lacking a map of ranch boundaries and names. Several sources indicate the greatest numbers and highest densities of pronghorn in Chihuahua are to the east of the Buenaventura landscape and well outside of the NFWF Area of Interest (SEMARNAT 2009, Correon and Lafon 2012).

Figure 23. Buenaventura Grassland

Current Grassland Condition



Biological Features



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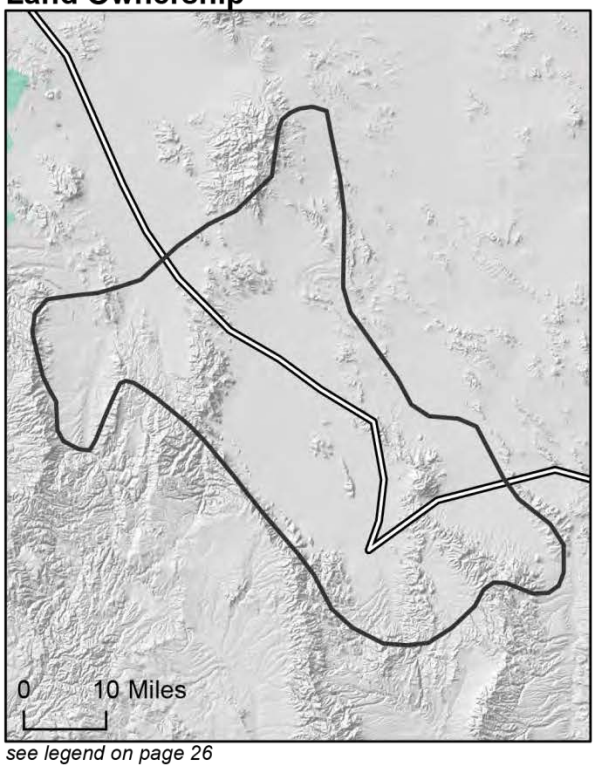
Land Ownership



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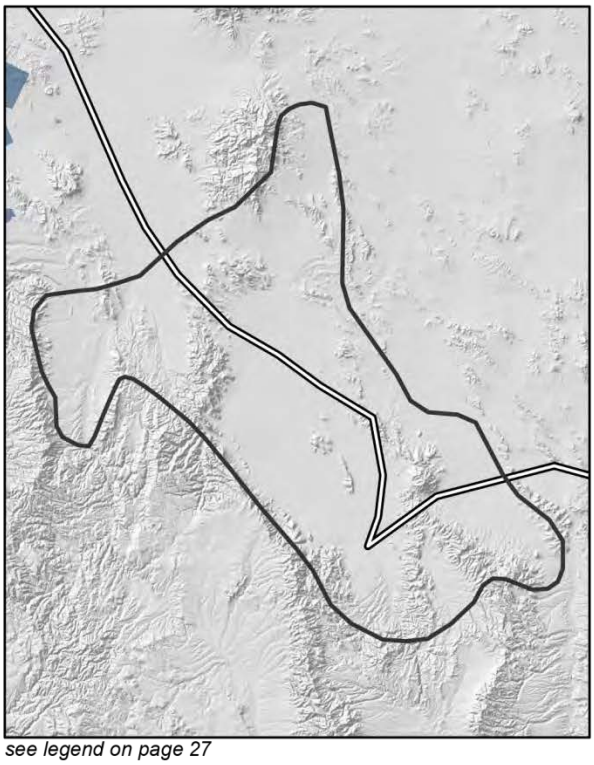
Protection Status



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The distribution of Chiricahua leopard frogs in this landscape is also unclear. The distribution map in USFWS (2012) shows a few widely-spaced records in the area, but map resolution is not fine enough to determine whether any of these records fall within the Buenaventura grassland polygon. However, the landscape contains at least three playa wetlands that are regionally important for waterfowl and other migratory birds (J. Esquer, pers. comm.). Bison are also present, but these animals are contained on private ranches and are not free-ranging (Figure23). Beyond this, there is little published information on the occurrence of grassland-dependent species within the landscape, however, several experts have confirmed the presence of black-tailed prairie dog, white-sided jackrabbit, as well as a number of grassland birds including grasshopper sparrow, Baird's sparrow, Cassin's sparrow, rufous-winged sparrow, chestnut-collared longspur, lark bunting, loggerhead shrike, Sprague's pipit, McGown's longspur, mountain plover and western burrowing owl (Table 7).

Threats

Land cover conversion to center-pivot irrigated agriculture is the primary threat in this landscape. This conversion is fragmenting habitat for grassland birds, modifying raptor and carnivore population dynamics by changing the availability of their small mammal prey base, and affecting the movement patterns of large ungulates. In addition, there are reports linking the intensive groundwater pumping to reductions in the size and inundation period in the Victorio and Chacate wetlands. The development of new highways and roads further fragments grassland habitat and may be a significant source of mortality for grassland birds, including raptors, reptiles ungulates, and small mammals. Finally, poorly-managed livestock grazing, especially year-round continuous grazing which occurs on ejido lands and other ranches in the landscape reduces the quality of unfragmented grassland patches.

Partnerships, Restoration and Land Protection

Grasslands in this landscape are all privately owned and there is currently no permanent protection on any of these grassland acres (Figure 23, Table 6). Several ranches and ejidos are receiving funds from the Secretaria de Ganadería, Agricultura and Pesca (SAGARPA) and Comisión Nacionál Forestal (CONAFOR) for shrub and erosion control.

Management to benefit wildlife in this landscape occurs primarily through the Unidades de Conservación, Manejo y Aprovechamiento de Vida Silvestre (UMAs). Private lands participating in this program are required to adopt management plans designed to improve wildlife habitat while allowing for sustainable use of the land, including hunting which can have significant economic benefits for participating landowners. There is some debate over how effective they are to date, although several UMAs in this landscape, notably Rancho Ojo Caliente and Rancho Campo Blanco, are strong collaborators in conservation and research programs with partners.

The Universidad Autónoma de Chihuahua (UACH) and Protección de la Fauna Mexicana (PROFAUNA) and UACH are the two primary institutions involved in research projects and conservation activities in the Buenaventura grasslands. Ongoing projects include: (1) an evaluation of rangeland health across Chihuahua by PROFAUNA working with The Nature Conservancy; (2) an evaluation of the harvest potential for mule deer and white-tailed deer by PROFAUNA and Fundación Produce; (3) research on the nesting ecology of golden eagle by PROFAUNA, CONABIO and Virginia Tech University; (4) development of a GIS system to assess forage production and rangeland health by UACH and partners; (5) wetland evaluations and migratory waterfowl monitoring by PROFAUNA and Ducks Unlimited de México; and (6)

wintering grassland bird surveys coordinated by Rocky Mountain Bird Observatory and Universidad Autónoma de Nuevo León since 2007.

IV. Literature Cited

Albrecht, E.W., E.L. Geiger, A.R. Litt, G.R. McPherson, and R.J. Steidl. 2008. Fire as a tool to restore biodiversity in ecosystems dominated by invasive grasses. Unpublished report on file at: U.S. Department of Defense, Legacy Resource Management Program.

Archer, S. 1989. Have southern Texas savannas been converted to woodlands in recent history? American Naturalist 134:545-561.

Archer, S., D.S. Schimel, and E.A. Holland. 1995. Mechanisms of shrubland expansion: land use, climate, or CO2? Climatic Change 29:91-99.

AZGFD (Arizona Game and Fish Department). 2011. Arizona statewide pronghorn management plan. 101 p. Report available online: http://www.azgfd.gov/h_f/documents/2011%20Pronghorn%20Management%20Plan%20-%20December%203%202011.pdf [August 15, 2012]

Bahre, C.J. 1985. Wildfire in southeastern Arizona between 1859 and 1890. Desert Plants 7:190-194.

Bahre, C.J. 1991. A legacy of change: historic human impact on vegetation of the Arizona borderlands. Tucson: University of Arizona Press. 231 p.

Bahre, C.J., 1995. Human impacts on the grasslands of southeastern Arizona. In: M.P. McClaran; T.R. Van Devender, eds. The Desert Grassland. Tucson: University of Arizona Press, Tucson, AZ. 230-226.

Bahre, C.J., and M.L. Shelton. 1993. Historic vegetation change, mesquite increases, and climate in southeastern Arizona. Journal of Biogeography 20:489-504.

Bailey, R.G. 1995. Descriptions of the ecoregions of the United States. 2nd edition. U.S.D.A. Forest Service Miscellaneous Publication No. 1391. Washington, D.C.

Bailey, R.G. 1998. Ecoregions map of North America: explanatory note. Prepared in Cooperation with The Nature Conservancy and the U.S. Geological Survey. U.S.D.A. Forest Service Miscellaneous Publication No. 1548. Washington, D.C.

Bestlemeyer, B.T., J.E. Herrick, J.R. Brown, D.A. Trujillo, and K.M. Havstad. 2004. Land management in the American Southwest: a state-and-transition approach to ecosystem complexity. Environmental Management 34:38-51.

Bestelmeyer, B.T., A.J. Tugel, G.L. Peacock, D.G. Robinett, P.L. Shaver, J.R. Brown, J.E. Herrick, H. Sanchez, and K.M. Havstad. 2009. State-and-Transition models for heterogeneous landscapes: A strategy for development and application. Rangeland Ecology and Management 62(1):1-15.

Bestelmeyer, B. T., D. P. Goolsby, and S. R. Archer. 2011. Spatial perspectives in state-and-transition models: a missing link to land management? Journal of Applied Ecology 48(3):746–757.

Betancourt, J.L., Van Devender, T.R., Martin, P.S., 1990. Packrat Middens: The Last 40,000 years of Biotic Change. Univ. Arizona Press, Tucson, AZ, 467 pp.

Bock, C.E., J.H. Bock, K.L. Jepson, and J.C. Ortega. 1986. Ecological effects of planting African lovegrasses in Arizona. National Geographic Research 2(1986):456-463.

Brown, D.E. and R.A. Ockenfels. 2007. Arizona's pronghorn antelope: a conservation legacy. Phoenix: Arizona Antelope Foundation. 190 p.

Brown, J.H., T.J. Valone, and C.G. Curtin, C.G. 1997. Reorganization of an arid ecosystem in response to recent climate change. Proceedings of the National Academy Sciences 94:9729-9733.

Buffington, L.C., and C.H. Herbel. 1965. Vegetational changes on a semidesert grassland Range from 1858 to 1963. Ecological Monographs 35:139-164.

Cable, D.R. 1967. Fire effects on semidesert grasses and shrubs. Journal of Range Management 20:170-176.

Carreón H., E., and A. Lafón T. 2012. Áreas de distribución de berrendo (*Antilocapra americana mexicana*) en el Estado de Chihuahua; Sistema de Información Geográfica Berrendo. Protección de la Fauna Mexicana, A.C.

Ceballos, G., A. Davidson, R. List, R., J. Pachecho, P. Manzano-Fischer, G. Santos-Barrera, and J. Cruzado, J. 2010. Rapid decline of a grassland system and its ecological and conservation implications. PLoS One 5:1-12.

Cox, J.R., and G.B. Ruyle. 1986. Influence of climatic and edaphic factors on the distribution of Eragrostis lehmanniana Nees in Arizona, USA. Journal Grassland Society of South Africa 3:25-29.

Emmerich, W.E., and J.R. Cox. 1992. Hydrology characteristics immediately after seasonal burning on introduced and native grasslands. Journal Range Management 45.5 (1992):476-479.

Enquist, C.A.F., and D.F. Gori. 2008. Application of an expert system approach for assessing grassland status in the U.S.-Mexico borderlands: implications for conservation and management. Natural Areas Journal 28(4):414-428.

Flesch, A. D. 2008. Status and population size of breeding grassland birds on Rancho Los Fresnos, northern Sonora, Mexico. Unpublished report. School of Natural Resources and the Environment, University of Arizona, Tucson, AZ.

Gibbens, R.P., R. P. McNeely, K.M. Havstad, R.F. Beck, and B. Nolen. 2005. Vegetation changes in the Jornada Basin from 1858 to 1998. Journal of Arid Environments 61:651–668.

Glinski, R. L., and D. E. Brown. 1982. Mesquite (Prosopis juliflora) response to severe freezing in southeastern Arizona. Journal of the Arizona-Nevada Academy of Science 17:15-18.

Gori, D.F., and C.A.F. Enquist. 2003. An assessment of the spatial extent and condition of grasslands in central and southern Arizona, Southwestern New Mexico and Northern Mexico. The Nature Conservancy of Arizona. 28 p. Report available online: http://azconservation.org/dl/TNCAZ_Grasslands_Assessment_Report.pdf [August 15, 2012]

Gori, D., and H. Schussman. 2005. State of the Las Cienegas National Conservation Area. Part I. Condition and Trend of the Desert Grassland and Watershed. Prepared by The Nature Conservancy of Arizona. 63 pp.

Halvorson, W.L., K. Thomas, L. Graham, M.R. Kunzmann, P.S. Bennett, C. Van Riper, and C. Drost. 2002. The Arizona GAP analysis project final report. U.S. Geological Survey, Biological Resources Division, Western Ecological Research Center, University of Arizona. Tucson, AZ. 166 p.

Hastings, J.R., and R.M. Turner. 1965. The Changing Mile. Tucson: University of Arizona Press. 317 p.

Hendrickson, D.A., and W.L. Minckley. 1984. Ciénegas-vanishing climax communities of the American Southwest. Desert Plants 6(3):130-175

Hennessey, J.T., R.P. Gibbens, J.M. Tromble, and M. Cardenas. 1983. Vegetation changes from 1935 to 1980 in mesquite dunelands and former grasslands of southern New Mexico. Journal of Range Management 36:370-374.

Humphrey, R.R. 1958. The desert grassland: a history of vegetational change and an analysis of causes. Botanical Review 24:193-253.

Humphrey, R.R. 1960. Forage production on Arizona ranges. V. Pima, Pinal and Santa Cruz Counties. University of Arizona Agricultural Experiment Station Bulletin 302:1-138.

Humphrey, R.R. 1987. 90 years and 535 miles: vegetation changes along the Mexican border. Albuquerque: University of New Mexico Press. 448 p.

Jornada Experimental Range. No date. Introduction, methods, and uses of state mapping, including example from 2011-2012 Pitchfork Ranch work, available at http://jornada.nmsu.edu/esd/state-mapping6 [August 24, 2012]

Kepner, W.G., C.J. Watts, C.M. Edmonds, J.K. Maingi, S.E. Marsh, and G. Luna. 2000. A landscape approach for detecting and evaluating change in a semi-arid environment. Environmental Monitoring and Assessment 64:179-195.

LANDFIRE. 2009. Homepage of the LANDFIRE Project, U.S. Department of Agriculture, Forest Service; U.S. Department of Interior. Available online: http://www.landfire.gov/index.php [August 15, 2012].

Lauver, C.L., and J.L. Whistler. 1993. A hierarchical classification of Landsat TM imagery to identify natural grassland areas and rare species habitat. Photogrammetric Engineering and Remote Sensing 59(5):627-634.

Lincoln Institute. No date. Overview of Conserving Arizona's Future, Prop 106, Arizona ballot initiative from 2006. Initiative language and overview available at http://www.lincolninst.edu/subcenters/managing-state-trust-lands/challenges/az_trustland_reform.asp. [August 2012

List, R. and M. Valdez. 2009. Diagnóstico de la población del berrendo (*Antilocapra americana)* el la zona colindante entre México y Estados Unidos y sus potenciales afectaciones por el muro fronterizo. Report for the Instituto Nacional de Ecologia. 49 p. Report available online: http://www.ine.gob.mx/descargas/con_eco/2009_inf_final_berrendo.pdf [August 15, 2012]

Mackinnon, W., J.E. Herrick, G.R. Toevs, J.W. Karl, M.S. Karl, C.S. Spurrier, and J.J. Taylor. 2011. BLM Core Terrestrial Indicators and Methods. Technical Note 440. U.S. Department of the Interior, Bureau of Land Management, National Operations Center, Denver, CO. BLM/OC/ST-11/003+1735. 13 p

Malpai Borderlands Group. No date. Explanation of this area's conservation easements and their terms, available at http://www.malpaiborderlandsgroup.org/Conservation_Easements.pdf [August 15, 2012]

Marshall, R.M., D. Turner, A. Gondor, D. Gori, C. Enquist, G. Luna, R. Paredes Aguilar, S. Andersnon, S. Schwatrtz, C. Watts, E. Lopez and P. Comer. 2004. An ecological analysis of conservation priorities in the Apahe Highlands ecoregion. Prepared by the nature Conservancy in Arizona, Institiuto del Medio Ambient y el Desarrollo Sustentable de Estado de Sonora, agency and institutional partners. 152 p.

McClaran, M.P., and T.R. Van Devender, T.R., eds. 1995. The Desert Grassland. Tucson: University of Arizona Press. 346 p.

McPherson, G.R. 1995. The role of fire in desert grasslands. In: McClaran, M.P., and T.R. Van Devender, eds. The Desert Grassland. Tucson: University of Arizona Press. 130-151 p.

McPherson, G.R., and J.F. Weltzin. 2000. Disturbance and climate change in the United States/Mexico borderland plant communities: a state-of-the-knowledge review. Gen. Tech. Rep. RMRS-GTR-50. CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research and Experiment Station. 24 p.

Minckley, T.A., D. Turner, and S.R. Weinstein. *In press.* The relevance of wetland conservation in arid regions: A re-examination of vanishing climax communities in the American Southwest. Journal of Arid Environments.

Mueller, J.E. 1988. Climate of southwestern New Mexico. In: Mack, G.H., T.F. Lawton, and S.G. Lucas, eds. Cretaceous and Laramide tectonic evolution of southwestern New Mexico. New Mexico Geological Society 39th Annual Field Conference, Deming: 28–29.

NFWF (National Fish and Wildlife Foundation). 2009. Sky Island grassland business plan. 34 p. Report available online: http://www.nfwf.org/AM/Template.cfm?Section=Wildlife_and_Habitat12&TEMPLATE=/CM/ContentDisplay.cfm&CONTENTID=14106 [August 15, 2012].

NRCS (U.S. Natural Resources Conservation Service). 2009. Homepage of the Ecological Site Information System, U.S. Department of Agriculture, U.S. Natural Resources Conservation Service, http://esis.sc.egov.usda.gov/ [August 15, 2012].

Pellant, M., P. Shaver, D.A. Pyke, and J.E. Herrick. 2005. Interpreting indicators of rangeland health, version 4. Technical Reference 1734-6. U.S Department of the Interior, Bureau of Land Management, National Science and Technology Center, Denver, CO. BLM/WO/ST-00/001+1734/REV05. 122 p. Available online: http://www.blm.gov/nstc/library/pdf/1734-6.pdf [August 15, 2012].

Ringrose, S., S. Mussisi-Nkambwe, T. Colemen, D. Nellis, and C. Bussing. 1999. Environmental auditing: use of Landsat Thematic Mapper data to assess rangeland changes in the southeast Kalahari, Botswana. Environmental Management 23(1):125-138.

Rosen, P.C., E.J. Wallace, and C.R. Schwalbe, C. R. 2001. Resurvey of the Mexican Garter Snake (*Thamnophis eques*) in Southeastern Arizona. Unpublished report on file at: Arizona Game and Fish Department and U.S. Fish and Wildlife Service, Phoenix, Arizona. 64 p.

Ruth, J.M. 2008. Distribution of breeding Arizona grasshopper sparrow (*Ammodramus savannarum ammolegus*) in the southwestern United States: Past, present, and future. Studies in Avian Biology No. 37:113-124.

Sartor, K. and D. Gori. 2012. Arid-grassland mapping as a decision support tool for restoration planning and rare plant survey. Conference presentation. Biodiversity and Management of the Madrean Archipelago III: Merging Science and Management in a Rapidly Changing World, Tucson AZ. 2012, May 1-5.

Sonoran Institute. No Date. Map images of lands proposed for conservation under 2008 initiative process. http://www.sonoraninstitute.org/state-trust-land-conservation-profiles/southern-arizona-trust-lands-considered-for-conservation.html [August 2012]

Sundt, P. 2009. Rangeland monitoring of the Diamond A Ranch: Western, Central, and Eastern Divisions, 1993-2008. Unpublished report on file at: The Nature Conservancy in New Mexico, Santa Fe, NM.

Schussman, H., E. Geiger, T. Mau-Crimmins, and J. Ward, J. 2006. Spread and current potential distribution of an alien grass *Eragrostis lehmanniana* Nees., in the southwestern USA: comparing historical data and ecological niche models. Diversity and Distributions 12:582-592.

SEMARNAT (Secretaría de Medio Ambiente y Recursos Naturales). 2009. Programa de acción para la conservación de la especie: berrendo (*Antilocapra americana*). Official conservation action plan of the government of Mexico. 86 p. Report available on line: http://www.biodiversidad.gob.mx/especies/especies_priori/fichas/pdf/pace_berrendo.pdf [August 15, 2012].

Steele, C.M., B.T. Bestelmeyer, L.M. Burkett, P.L. Smith, and S. Yanoff. 2012. Spatially explicit representation of state-and-transition models. Rangeland Ecological Management 66:213-222.

Swetnam, T.W., 1990. Fire history and climate in the southwestern United States. In: Krammes, J.S., tech. coord. Effects of fire management of southwestern natural resources. Gen. Tech. Rep. RM-191. CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 6-16 p.

Tiller, R., M. Hughes, and G. Bodner. 2012. Sacaton Riparian Grasslands: Mapping Distribution and Ecological Condition using State-and-Transition Models in the Upper Cienega Creek Watershed. The Nature Conservancy, Tucson, Arizona. 47 pp + appendices.

Toevs, G. R., J. W. Karl, J. J. Taylor, C. S. Spurrier, M. Karl, M. R. Bobo, and J. E. Herrick. 2011. Consistent indicators and methods and a scalable sample design to meet assessment, inventory, and monitoring information needs across scales. Rangelands 33(4):14–20.

USFWS (U.S. Fish and Wildlife Service). 2012. Listing and Designation of Critical Habitat for the Chiricahua Leopard Frog (*Lithobates chiricahuensis*); Final Rule. Federal Register 77(54):16324-16423. Available online: http://www.gpo.gov/fdsys/pkg/FR-2012-03-20/pdf/2012-5953.pdf [August 15, 2012].

Valerio V. A, E. Carreón H., A. Lafón T., J.M. Ochoa B., P. Calderón D., D. M. Soto V., C. Chacón Z., and E. Favela T. 2005. Distribución, extensión espacial y condición de los pastizales en el Estado de Chihuahua. Protección de la Fauna Mexicana, A.C., en colaboración con The Nature Conservancy. Chihuahua, México. 54 p.

Valone, T.J., M. Meyer, J.H. Brown, and R.M. Chew. 2002. Timescale of perennial grass recovery in desertified arid grasslands following livestock removal. Conservation Biology 16(4):995-1002.

Warshall, P.W. 2005. Earth Forces and Living Systems in the Peloncillo Region. In: *Natural heritage of the Peloncillo Mountain Region: a synthesis of science*. Bodner, G., J.A. Montoya, R. Hanson, and W. Anderson, eds. World Wildlife Fund and Sky Island Alliance. Tucson, Arizona, USA

Wright, H.A. 1980. The role and use of fire in the semidesert grass-shrub type. Gen. Tech. Rep. INT-85. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 24 p.

Yanoff, S., P. McCarthy, J. Bate, L.W. Miller, A. Bradley, and D. Gori. 2008. New Mexico rangeland ecological assessment. 73 p. The Nature Conservancy in New Mexico. Report available online: http://nmconservation.org/projects/rangeland_ecological_assessment/ [August 15, 2012].

Appendix 1. The number of occurrences of sensitive species and subspecies in priority grassland landscapes and outside of these landscapes in the Sky Islands region. Occurrence records were obtained from the Natural Heritage Programs in New Mexico and Arizona and were screened to identify species that are grassland-dependent (G) or that occur in riparian and aquatic habitats embedded in grasslands (RA). The latter species may not be *restricted* to grasslands per se but may also occur in streams, wetlands or riparian habitats at lower and higher elevations. An "X" indicates that the species is a NFWF target or high-priority species. See text for further explanation.

Category [1.]	Type	Scientific Name	Common Name	Global Rank [2.]	NFWF Target or High Priority Species	No. of priority grasslands	No. of records, priority grasslands	No. of records, outside priority grasslands	% of records in priority landscapes
I	G	Amblyscirtes elissa	Elissa roadside skipper	G3G4		1	4	0	100.0
I	RA?	Calephelis arizonensis	Arizona metalmark	G3G4		2	10	17	37.0
I	RA	Cicindela oregona maricopa	Maricopa tiger beetle	G5T3		1	1	1	50.0
I	RA	Limenitis archippus obsoleta	Obsolete viceroy butterfly	G5T3T4		1	1	8	11.1
I	RA	Pyrgulopsis bernardina	San Bernardino springsnail	G1		1	4	0	100.0
I	RA	Pyrgulopsis sp. 2	Mimbres spring snail	G1		0	0	1	0.0
I	RA	Pygulopsis thompsoni	Huachuca springsnail	G2		2	6	9	40.0
I	G	Sphingicampa raspa	A royal moth	G1G2		1	4	3	57.1
I	RA	Sympetrum signiferum	Spot-winged meadowhawk	G2G3		3	5	2	71.4
P	RA	Agastache rupestris	Baboquivari giant hyssop	G3?		2	19	5	79.2
P	G	Agave parviflora var. parviflora	Santa Cruz striped agave	G3T3		1	49	4	92.5
P	G	Agave toumeyana var. bella	Toumey agave	G3T3		1	10	0	100
P	G	Amoreuxia gonzalezii	Saiya	G1		1	4	4	50.0
P	RA	Carex chihuahuensis	Chihuahua sedge	G3G4		3	30	40	42.9
P	RA	Carex ultra	Arizona giant sedge	G3?		4	49	23	68.1
P	RA	Cleome multicaulis	Playa spider plant	G2G3		2	13	0	100
P	G	Coryphantha recurvata	Santa Cruz beehive cactus	G3		1	98	6	94.2
P	G	Coryphantha scheeri var. robustispina	Pima pineapple cactus	G4T2		1	115	338	25.4
P	RA	Erigeron piscaticus	Fish Creek fleabane	G1		1	2	0	100

Category [1.]	Type	Scientific Name	Common Name	Global Rank [2.]	NFWF Target or High Priority Species	No. of priority grasslands	No. of records, priority grasslands	No. of records, outside priority grasslands	% of records in priority landscapes
P	G	Heterotheca rutteri	Huachuca golden aster	G2		4	24	14	63.2
P	G	Laennecia eriophylla	Wooly fleabane	G3		4	26	3	89.7
P	RA	Lilaeopsis schaffneriana var. recurva	Huachuca water umbel	G4T2		4	29	39	42.6
P	G	Muhlenbergia dubioides	Box canyon muhly	G1Q		2	8	36	18.2
P	G	Muhlenbergia xerophila	Weeping muhly	G3		2	24	38	38.7
P	G	Paspalum virletii	Virlet paspalus	G3?		1	3	0	100
P	RA	Passiflora arizonica	Arizona passionflower	G5T3T5		1	84	0	100
P	RA	Passiflora bryonioides	Mossy passionflower	G3G5		1	12	0	100
P	G	Pectis imberbis	Beardless chinch weed	G3		4	37	11	77.1
P	G	Pediomelum pentaphyllum	Chihuahua scurfpea	G1		1	11	1	91.7
P	RA	Puccinellia parishii	Parish’s alkali grass	G2		1	1	1	50.0
P	RA	Salvia amissa	Aravaipa sage	G2		1	20	12	62.5
P	RA	Solanum lumholtzianum	Lumholtz nightshade	G3G4		2	61	24	71.8
P	RA	Spiranthes delitescens	Madrean ladies’ tresses orchid	G1		2	5	0	100
P	RA	Thelypteris puberula var. sonorensis	Aravaipa wood fern	G5T3		1	1	2	33.3
F	RA	Agosia chrysogaster chrysogaster	Gila longfin dace	G4T3T4	X	6	79	91	46.5
F	RA	Agosia chrysogaster ssp 1.	Yaqui longfin dace	G4T1	X	2	15	1	93.8
F	RA	Campostoma ornatum	Mexican stoneroller	G3	X	2	5	1	83.3
F	RA	Catostomus clarki	Desert sucker	G3G4	X	4	36	49	42.4
F	RA	Catostomus insignis	Sonora sucker	G3	X	5	40	12	76.9
F	RA	Cyprinella formosa	Beautiful shiner	G2	X	1	3	0	100
F	RA	Cyprinodon macularius	Desert pupfish	G1	X	1	1	5	16.7

Category [1.]	Type	Scientific Name	Common Name	Global Rank [2.]	NFWF Target or High Priority Species	No. of priority grasslands	No. of records, priority grasslands	No. of records, outside priority grasslands	% of records in priority landscapes
F	RA	Gila ditaenia	Sonora chub	G2	X	1	13	0	100
F	RA	Gila intermedia	Gila chub	G2	X	3	30	9	76.9
F	RA	Gila purpurea	Yaqui chub	G1	X	2	15	0	100
F	RA	Gila robusta	Roundtail chub	G3	X	1	20	3	87.0
F	RA	Ictalurus pricei	Yaqui catfish	G2	X	1	4	0	100
F	RA	Meda fulgida	Spikedace	G2	X	1	14	4	77.8
F	RA	Poeciliopsis occidentalis occidentalis	Gila topminnow	G3T3	X	3	41	43	48.8
F	RA	Poeciliopsis occidentalis sonoriensis	Yaqui topminnow	G3T3	X	2	11	0	100
F	RA	Rhinichthys osculus	Speckled dace	G5	X	2	29	19	60.4
F	RA	Tiaroga cobitis	Loach minnow	G2	X	1	13	3	81.3
A	RA	Ambystoma tigrinum stebbinsi	Sonora tiger salamander	G5T1T2	X	2	62	4	93.9
A	RA	Hyla wrightorum (Huachucas-Canelo Hills population)	Huachucas/Canelo Hills treefrog	G4T2		2	6	9	40.0
A	RA	Lithobates (Rana) chiricahuensis	Chiricahua leopard rrog	G3	X	7	159	75	67.9
A	RA	Rana yavapaiensis	Lowland leopard frog	G4	X	7	104	187	35.7
R	G	Sistrurus catenatus edwardsii	Desert massasauga	G3G4T3T4Q	X	3	44	9	83.0
R	RA	Thanmophis eques megalops	Mexican gartersnake	G5T5	X	4	40	44	47.6
B	G	Ammodramus bairdii	Baird’s sparrow	G4	X	6	43	26	62.3
B	G	Athene cunicularia hypugaea	Western burrowing owl	G4T4	X	3	14	80	14.9
B	RA	Buteo nitidus maxima	Northern gray hawk	G5T4Q		3	42	84	33.3
B	G	Charadius montanus	Mountain plover	G2		1	1	0	100

Category [1.]	Type	Scientific Name	Common Name	Global Rank [2.]	NFWF Target or High Priority Species	No. of priority grasslands	No. of records, priority grasslands	No. of records, outside priority grasslands	% of records in priority landscapes
B	RA	Coccyzus americanus occidentalis	Western yellow-billed cuckoo	G5T2Q		7	59	123	32.4
B	G	Colinus virginianus ridgwayi	Masked bobwhite	G5T1	X	1	34	0	100
B	RA	Empidonax traillii extimus	Southwestern willow glycatcher	G5T1T2		2	2	57	3.4
B	G	Falco femoralis septentrionalis	Northern aplomado galcon	G4T2	X	2	7	2	77.8
M	G	Lepus callotis	White-sided jackrabbit	G3	X	2	10	0	100
M	G	Sigmodon ochrognathus	Yellow-nosed cotton rat	G4G5		8	125	76	62.2

1. Taxonomic category abbreviations: I = Invertebrate; P = P; F = Fish; A = Amphibian; R = Reptile; B = Bird; and M = Mammal.
2. NaturServe global ranks are: G1= Critically imperiled globally because of extreme rarity or because of some factor(s) making it especially vulnerable to extinction. Typically 5 or fewer occurrences globally or very few remaining individuals (<1,000), or acres (<2,000) or linear miles (<10); G2 = Imperiled globally because of rarity or because of some factor(s) making it vulnerable to extinction or elimination. Typically 6 to 20 occurrences globally or few remaining individuals (1,000-3,000) or acres (2,000-10,000) or linear miles (10-50); G3 = Vulnerable globally either because very rare and local throughout its range, found only in a restricted range (even if abundant at some locations), or because of other factors making vulnerable to extinction or elimination. Typically 21 to 100 occurrences globally or between 3,000 and 10,000 individuals; G4 = Apparently secure, uncommon but not rare, some cause for long-term concern due to declines or other factors; and G5 = Secure, common and widespread. T ranks (T1-T5) refer to subspecies and their definitions correspond to those for global ranks.

Appendix 2. Dominant Ecological Sites within Priority Grassland Landscapes

Methods

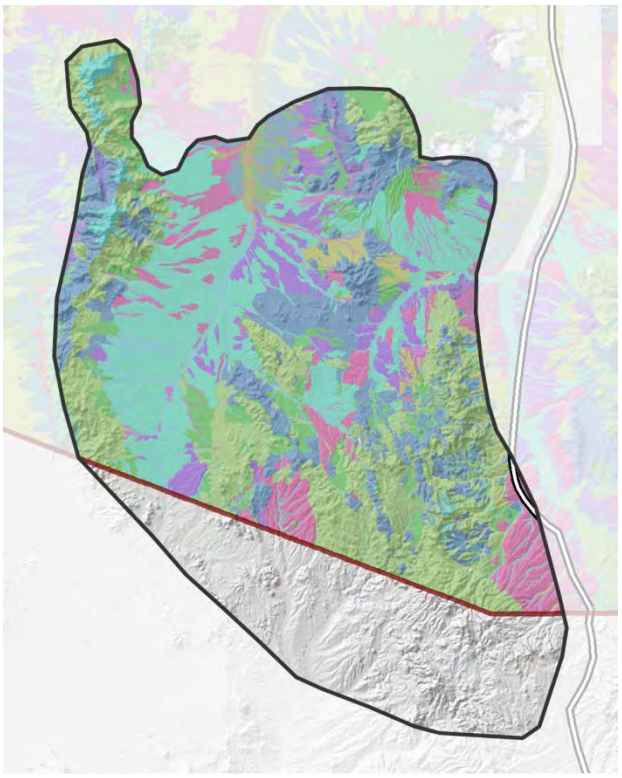
We used the NRCS Soil Data Viewer (SDV) to identify the dominant ecological sites for the Sky Island region (NRCS 2009). The 'one to many' structure of SSURGO soils databases presents a challenge for analyzing ecological site data, which is contained within a relational database, distributed as 'tabular' data by the NRCS Soil Data Mart http://soildatamart.nrcs.usda.gov/. Each soil map unit polygon can represent several distinct soil series, or 'soil map unit components', mapped in the soil survey, so there can be several ecological sites associated with each soil map unit polygon. For most soil map units, the tabular data (or database) for each soil map unit contains information on the relative proportion of each soil component within a soil map unit polygon. The SDV Arcmap plug-in (available for free download at http://soils.usda.gov/sdv/) is useful for computing a single value, that is the ecological site associated with the most dominant soil component, to symbolize each soil map unit polygon (see below).

To use the SDV, we downloaded both spatial and tabular soil survey data (SSURGO data) for the area of interest http://soildatamart.nrcs.usda.gov/. We then used the SDV to connect the tabular and spatial data, using the SDV "Dominant Condition" aggregation method which queries the tabular data and selects the ecological site represented by the most soil components within a polygon. From the resulting shape file, we calculated the area of each soil map unit polygon, and exported the entire attribute table to Microsoft Access, where we summarized the data according to the most common (greatest area) ecological sites for each landscape. For more detailed methods, please contact the authors. Note that the procedure described here results in a simplified, higher level map of ecological sites, which is subject to errors associated with soil mapping. The SSURGO soil layer, Ecological Site Descriptions and the tools described above are available only for the US. Methods for finer-scale mapping of ecological sites and states have been developed and the resulting products are appropriate for restoration planning at the site and landscape levels (Steele et al. 2012).

Results

The dominant ecological sites for 11 priority landscapes that are located entirely or in part in the US are listed below. Dominant ecological sites that comprised $\geq$ 8% of grasslands by area within a landscape are indicated in bold.

Altar-Tumacacori Grassland



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Clayey Upland 12-16" p.z. (R041XC304AZ)
Basalt Hills 12-16" p.z. (R041XC301AZ)
Granitic Hills 16-20" p.z. (R041XA102AZ)
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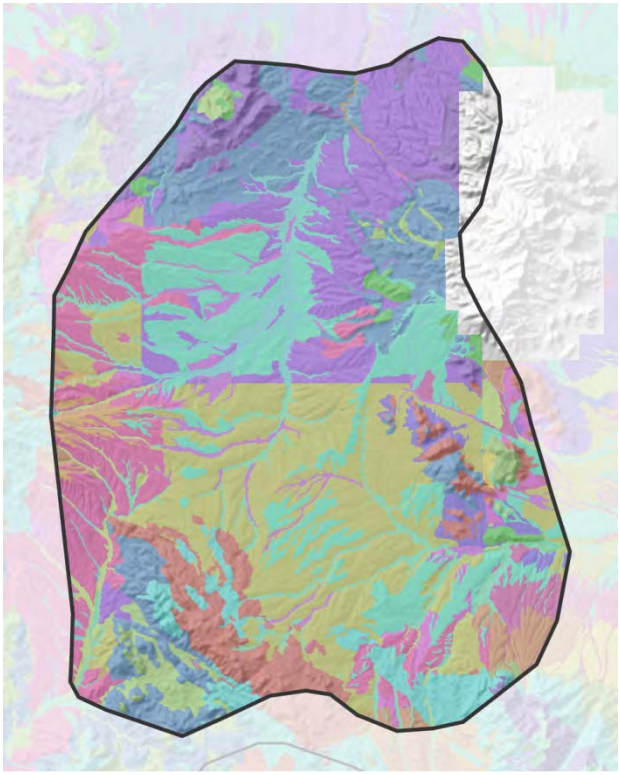
Empire-Cienega-Sonoita Grassland



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San Rafael Valley

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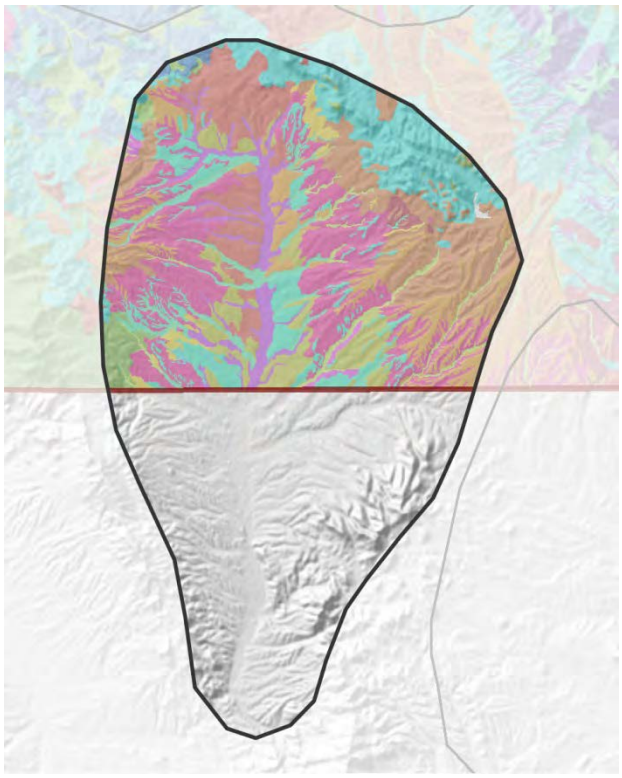

Upper San Pedro in Mexico

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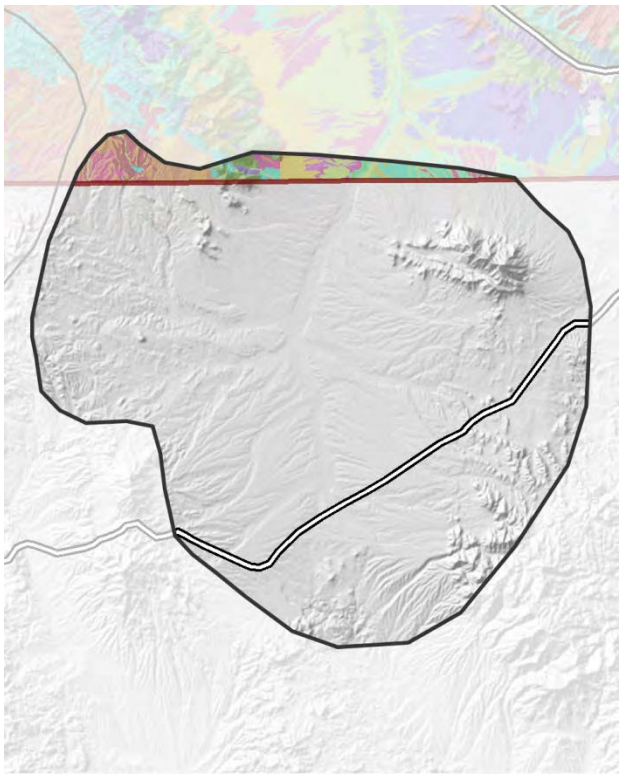
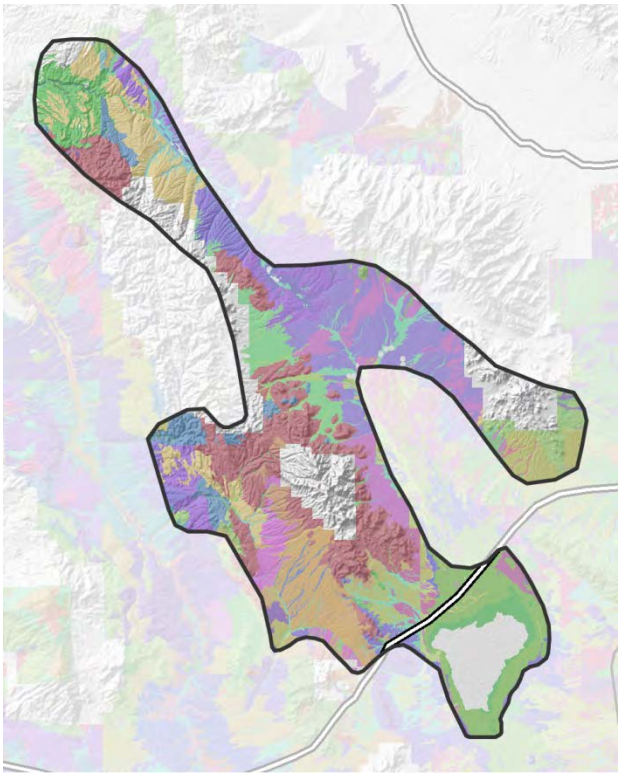


Aravaipa-Muleshoe-Willcox Grasslands



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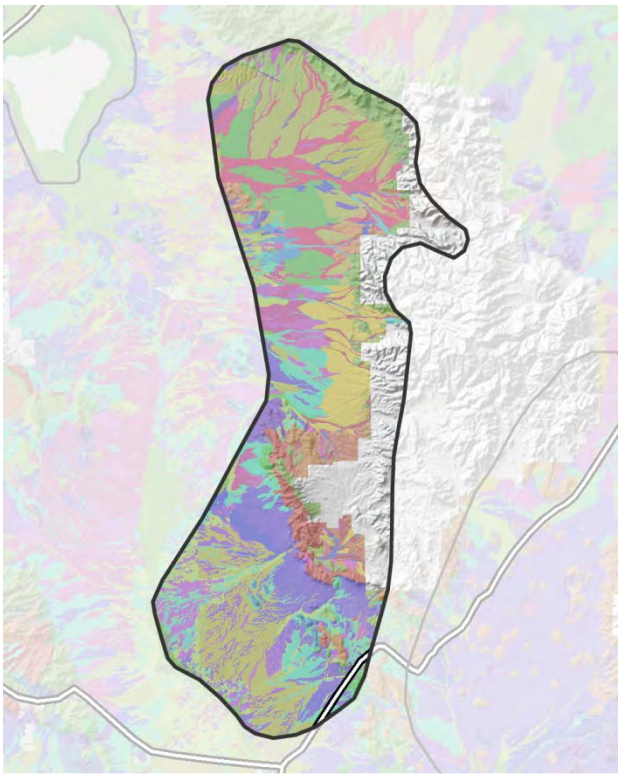
Southern Sulphur Springs Valley



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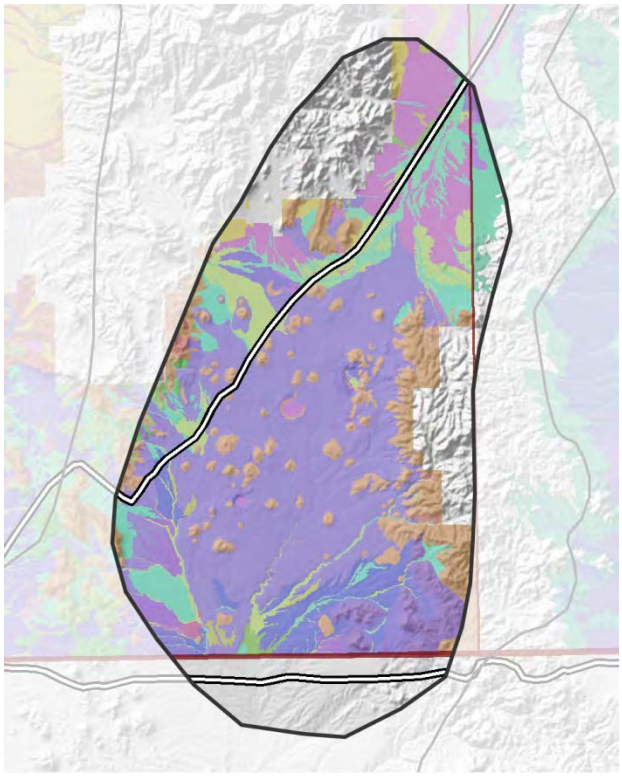
Clay Loam Upland 16-20" p.z. (R041XA109AZ)
Volcanic Hills 16-20" p.z. (R041XA111AZ)
Sandy Upland 12-16" p.z. (R041XC325AZ)

San Bernardino Valley



Clayey Upland 12-16" p.z. (R041XC304AZ)
Limy Upland 12-16" p.z. (R041XC309AZ)
Sandy Loam 12-16" p.z. Deep (R041XC318AZ)
Clay Loam Upland 12-16" p.z. (R041XC305AZ)
Basalt Hills 12-16" p.z. (R041XC301AZ)
Clayey Slopes 16-20" p.z. (R041XA118AZ)
Clayey Swale 12-16" p.z. (R041XC302AZ)
Loamy Upland 12-16" p.z. (R041XC313AZ)
Sandy Loam Upland 12-16" p.z. (R041XC319AZ)
Limestone Hills 12-16" p.z. (R041XC307AZ)
Loamy Swale 12-16" p.z. (R041XC311AZ)
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Sandy (R042XB012NM)
Sandy Loam Upland 16-20" p.z. (R041XA110AZ)
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Granitic Hills 12-16" p.z. (R041XC306AZ)
Loamy (R042XB014NM)
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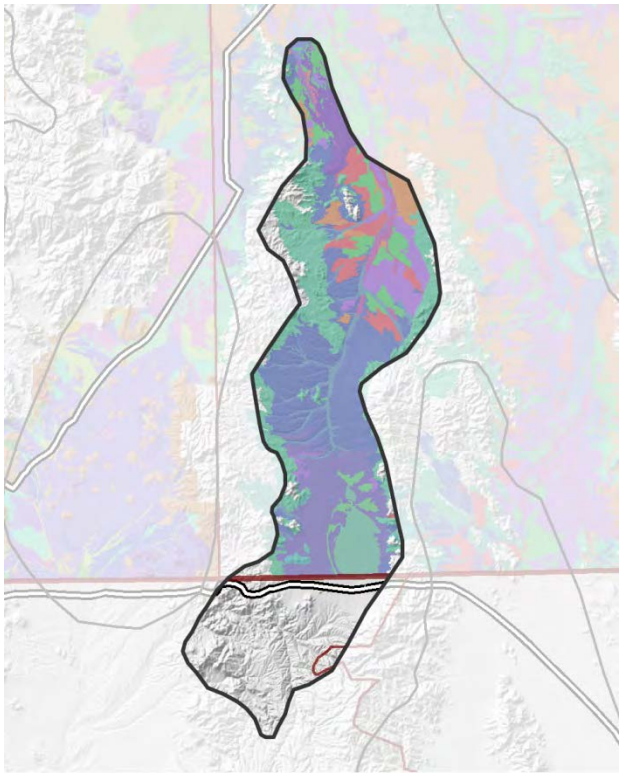
Clay Loam Upland 16-20" p.z. (R041XA109AZ)
Granitic Hills 16-20" p.z. (R041XA102AZ)
Malpais (R042XB037NM)
Draw (R042XB016NM)
Loamy Upland 16-20" p.z. (R041XA108AZ)
Loamy Bottom 12-16" p.z. (R041XC312AZ)
Gravelly Slopes (R041XA004NM)
Granitic Upland 12-16" p.z. (R041XC322AZ)
Loamy Cienega 12-16" p.z. (R041XC327AZ)
Bottomland (R042XB018NM)

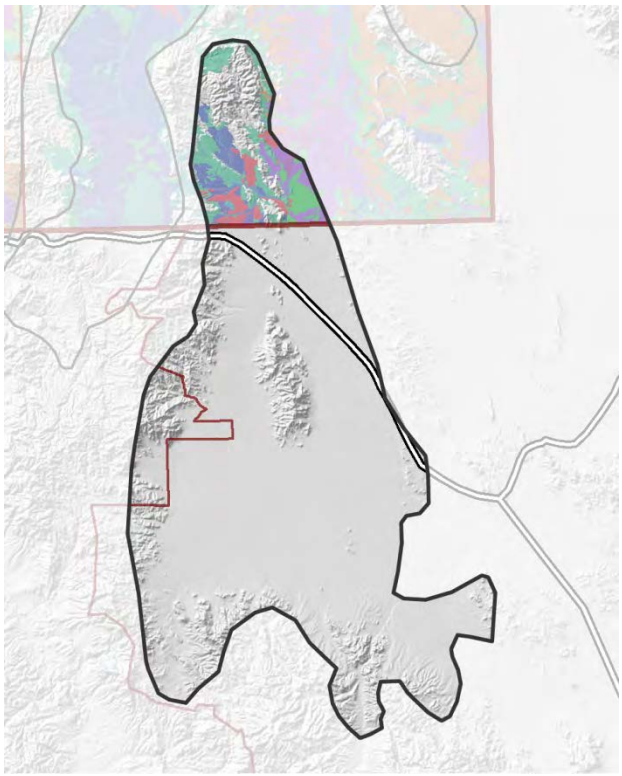
Animas Valley-Sierra San Luis Grassland

Gravelly Slopes (R041XA004NM)
Clay Loam Upland (R041XA002NM)
Hills (R042XB027NM)
Loamy (R042XB014NM)
Clayey (R042XB023NM)
Loamy Upland (R041XA001NM)
Clay Upland (R041XA007NM)
Loamy Bottom (R041XA006NM)
Malpais (R042XB037NM)
Gravelly (R042XB010NM)
Bottomland (R042XB018NM)
Deep Sand (R042XB011NM)
Clay Hills (R041XA003NM)
Draw (R042XB016NM)
Salt Flats (R042XC036NM)
Limy (R042XB019NM)
Sandy (R042XB012NM)
Salty Bottomland (R042XC033NM)

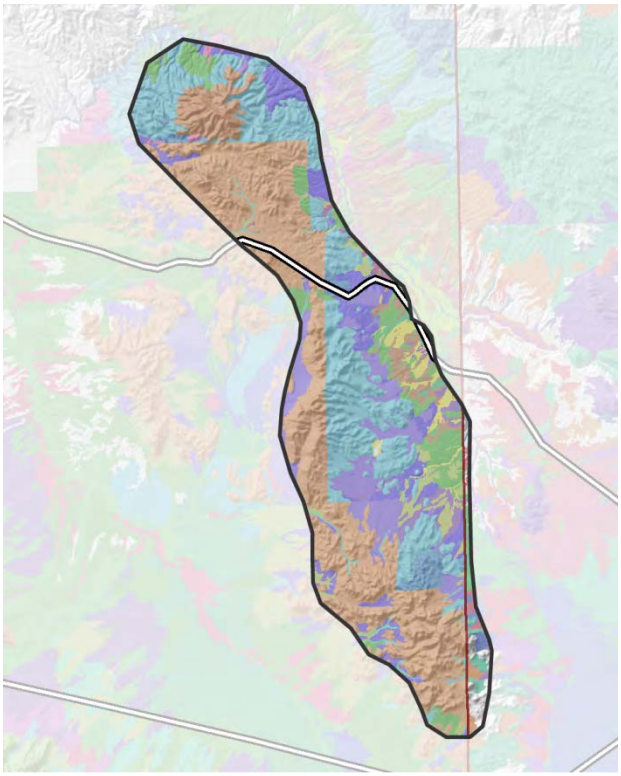


Playas Valley-Janos Plains

Gravelly Slopes (R041XA004NM)
Loamy Upland (R041XA001NM)
Loamy (R042XB014NM)
Clayey (R042XB023NM)
Hills (R042XB027NM)
Loamy Bottom (R041XA006NM)
Clay Loam Upland (R041XA002NM)
Draw (R042XB016NM)
Clay Hills (R041XA003NM)
Bottomland (R042XB018NM)
Deep Sand (R042XB011NM)



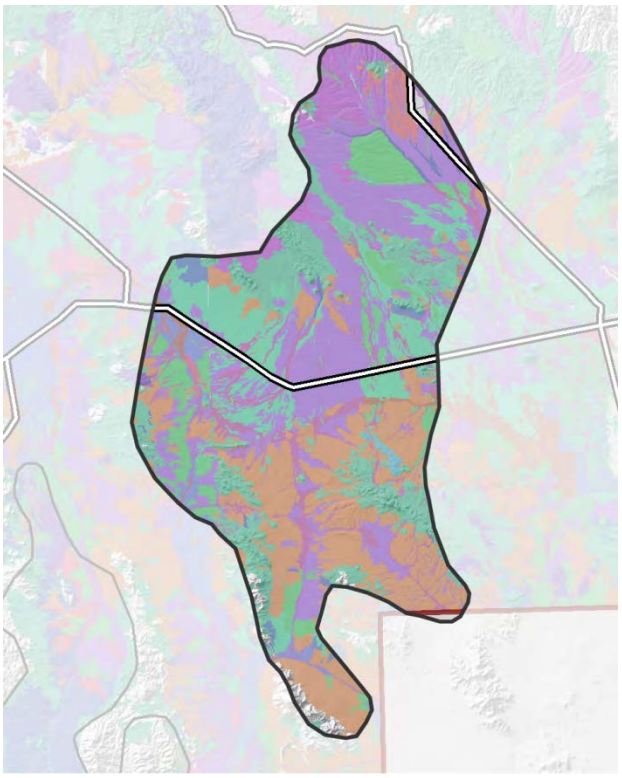
North Peloncillos Mountains



Volcanic Hills 12-16" p.z. Loamy (R041XC323AZ)
Clayey Slopes 12-16" p.z. (R041XC303AZ)
Basalt Hills 12-16" p.z.(R041XC301AZ)
Clay Loam Upland 8-12" p.z. (R041XB204AZ)
Clayey Upland 12-16" p.z. (R041XC304AZ)
Limy Fan 8-12" p.z. (R041XB206AZ)
Loamy Slopes 16-20" p.z. (R038XB208AZ)
Breaks 8-12" p.z. (R041XB201AZ)
Limy Upland 12-16" p.z. (R041XC309AZ)
Clayey Fan 8-12" p.z. Saline (R041XB228AZ)
Sandy Loam Upland 8-12" p.z. (R041XB215AZ)
Hills (R042XB027NM)
Sandy Wash 8-12" p.z. (R041XB213AZ)
Clayey (R042XB023NM)
Sandy Wash 12-16" p.z. (R041XC316AZ)
Limy Upland 8-12" p.z. Deep (R041XB229AZ)
Loamy Upland (R041XA001NM)
Limy Slopes 8-12" p.z. (R041XB207AZ)
Gravelly Slopes (R041XA004NM)
Gravelly Loam (R042XB035NM)
Limy Upland 8-12" p.z. (R041XB208AZ)
Loamy (R042XB014NM)
Basalt Hills 8-12" p.z. (R041XB223AZ)
Limy (R042XB019NM)
Loamy Bottom (R041XA006NM)
Gravelly (R042XB010NM)
Sandy (R042XB012NM)
Draw (R042XB016NM)
Clayey Swale 8-12" p.z. (R041XB202AZ)

Burro Cienega-Hachita Grasslands

Loamy (R042XB014NM)
Gravelly (R042XB010NM)
Hills (R042XB027NM)
Sandy (R042XB012NM)
Clayey (R042XB023NM)
Loamy (R038XB104NM)
Hills (R038XB103NM)
Salt Flats (R042XC036NM)
Deep Sand (R042XB011NM)
Bottomland (R042XB018NM)
Breaks (R038XB105NM)
Clayey (R038XB107NM)
Shallow (R038XB101NM)
Limy (R042XB019NM)
Gravelly Loam (R042XB035NM)
Draw (R042XB016NM)
Salty Bottomland (R042XC033NM)
Limestone Hills (R042XB021NM)
Malpais (R042XB037NM)
Gravelly (R038XB102NM)
Gravelly Slopes (R041XA004NM)



Appendix 3. Density of grassland bird species sampled in each landscape.

Species reported here occur on "concern" lists from US Fish and Wildlife Service, Partners in Flight, Mexico's Instituto Nacional de Ecologia, and/or The Nature Conservancy. Data are from RMBO winter bird surveys on 773 one-km transects within these polygons. Transects have been sampled as many as six different winters (2007-2012), once per winter. US transects have data from 2011 and 2012 only. Survey methods are described in Panjabi, Arvind, Gregory Levandoski and Rob Sparks. 2010. Wintering Bird Density and Habitat Use in Chihuahuan Desert Grasslands. Rocky Mountain Bird Observatory, Technical Report I-MXPLAT-08-02.

Grassland bird species	Empire-Cienega-Sonoita	San Raphael	Upper San Pedro Mexico	Aravaipa - Muleshoe - Wilcox	Southern Sulphur Springs	San Bernardino	Animas - San Luis	Janos-Playas	Burro Cienega - Hachita	Buenaventura	average
Aplomado Falcon			0.02								0.02
Baird's Sparrow	0.23		0.10	0.05	0.02	0.03		0.03	0.01	0.07	0.07
Botteri's Sparrow		0.08									0.08
Brewer's Sparrow	1.68		0.77	12.58	2.81	6.84	16.36	2.65	6.99	9.01	6.63
Burrowing Owl								0.02			0.02
Cassin's Sparrow	0.15	0.08	0.02	0.07	0.05		0.07	0.02	0.03	0.04	0.06
Chestnut-collared Longspur	13.18	29.52	2.26		0.35	3.45	0.60	7.44	19.31	5.70	9.09
Clay-colored Sparrow			0.06			0.03	0.07	0.20		0.06	0.08
Eastern Meadowlark	0.98	1.42	0.90	0.21	1.84	0.42	0.40	0.61	0.10	0.36	0.72
Ferruginous Hawk			>0.01	0.02				0.03			0.02
Golden Eagle			0.01				0.07	0.01	0.04	0.01	0.03
Grasshopper Sparrow	0.68	0.94	0.16	0.57	0.32	0.03		0.16	0.11	0.10	0.34
Lark Bunting	0.15		0.68	15.43	7.00	5.27	24.70	3.93	7.30	8.65	8.12
Lark Sparrow			0.03					>0.01			0.02
Loggerhead Shrike	0.09	0.24	0.09	0.19	0.14	0.15	0.33	0.18	0.22	0.18	0.18
Long-billed Curlew								0.25			0.25
McCown's Longspur			0.01					0.38			0.19
Mountain Plover								0.04			0.04
Northern Harrier	0.32	0.63	0.16	0.14	0.09	0.24	0.07	0.14	0.08	0.05	0.19
Prairie Falcon			0.01		0.02	0.03	0.07	0.01		0.01	0.02
Sandhill Crane			0.02	3.11				0.50		0.86	1.13
Scaled Quail			0.08		0.11	0.73	0.07	0.44		0.66	0.35
Short-eared Owl		0.08						>0.01		0.02	0.03
Sprague's Pipit	0.06		0.04					0.06	0.01	0.01	0.04
Vesper Sparrow	3.57	1.50	3.06	4.52	4.62	4.30	2.47	2.21	1.06	4.00	3.13
Total	21	34	8	37	17	22	45	19	35	30	27.0

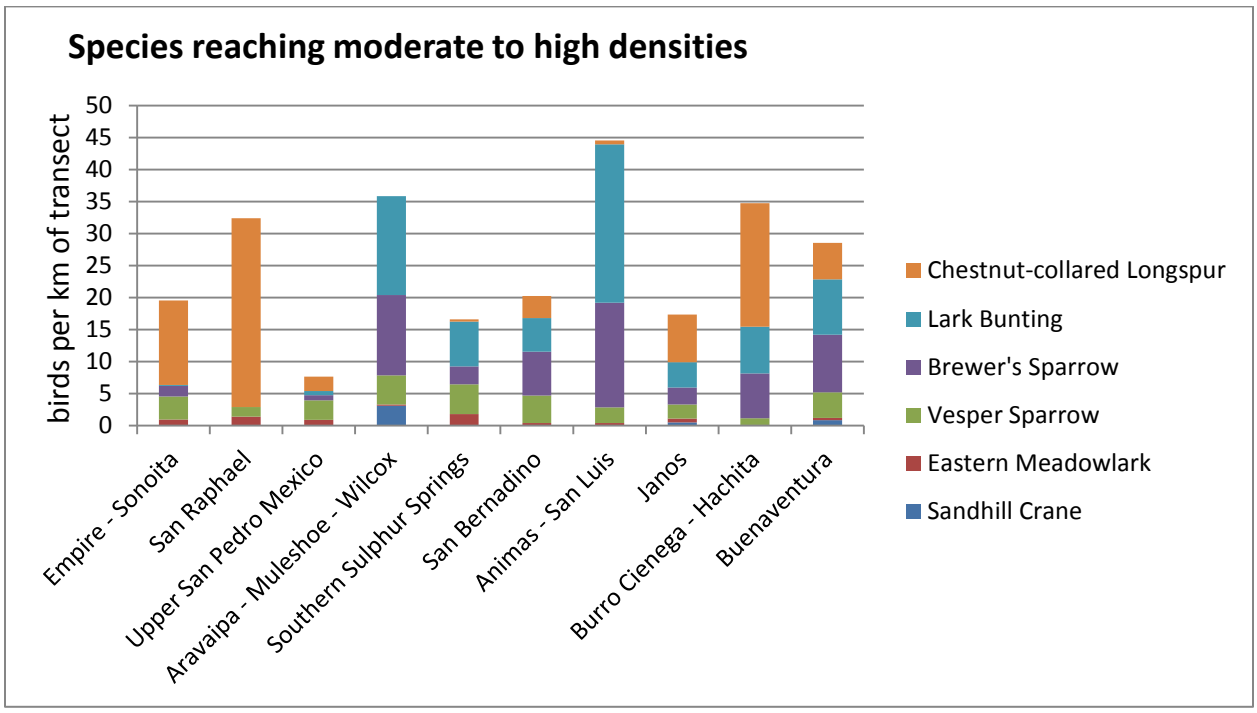


Figure 3.1. Densities of birds found per kilometer of transect sampled in each landscape. This figure shows species found at densities exceeding three birds/km for at least one landscape.

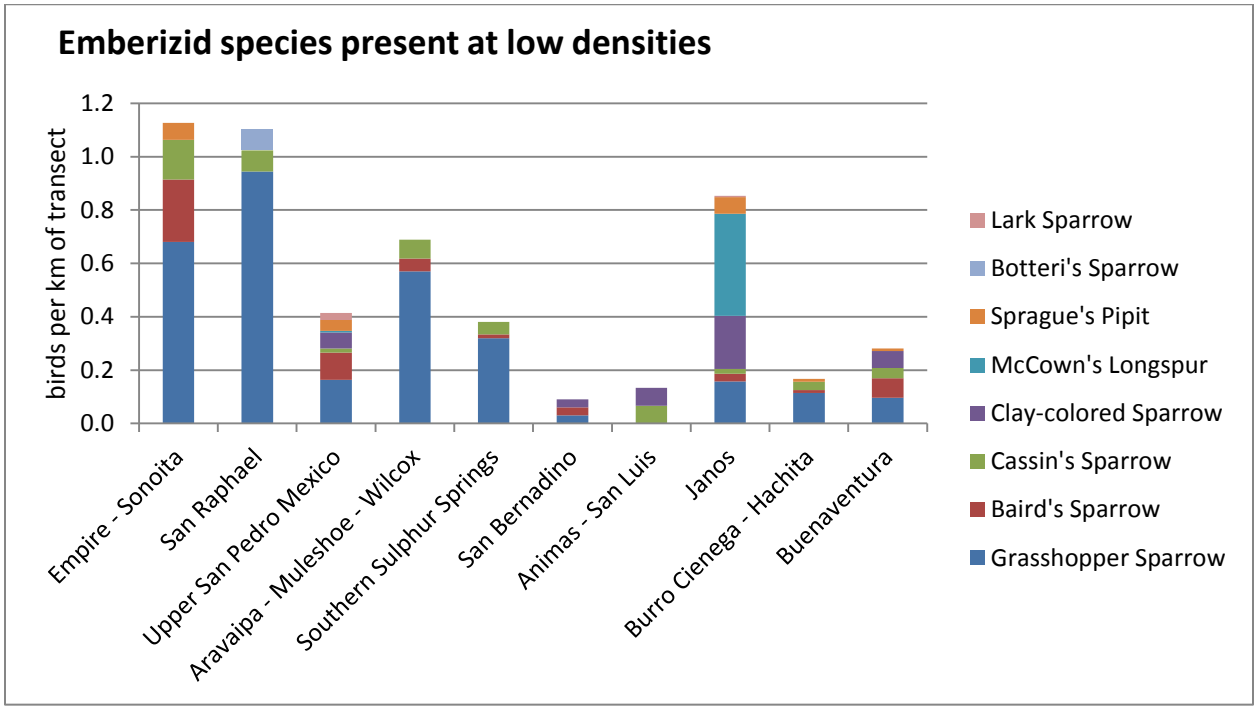


Figure 3.2. Densities of birds sampled in each landscape. This figure shows Emberizidae species (sparrows and their kin) found at densities below one bird/km in any given landscape. Note that more intensive and/or longer surveys in some landscapes (e.g. Janos, Upper San Pedro Mexico) increase the chances of rare species having been detected in these areas.

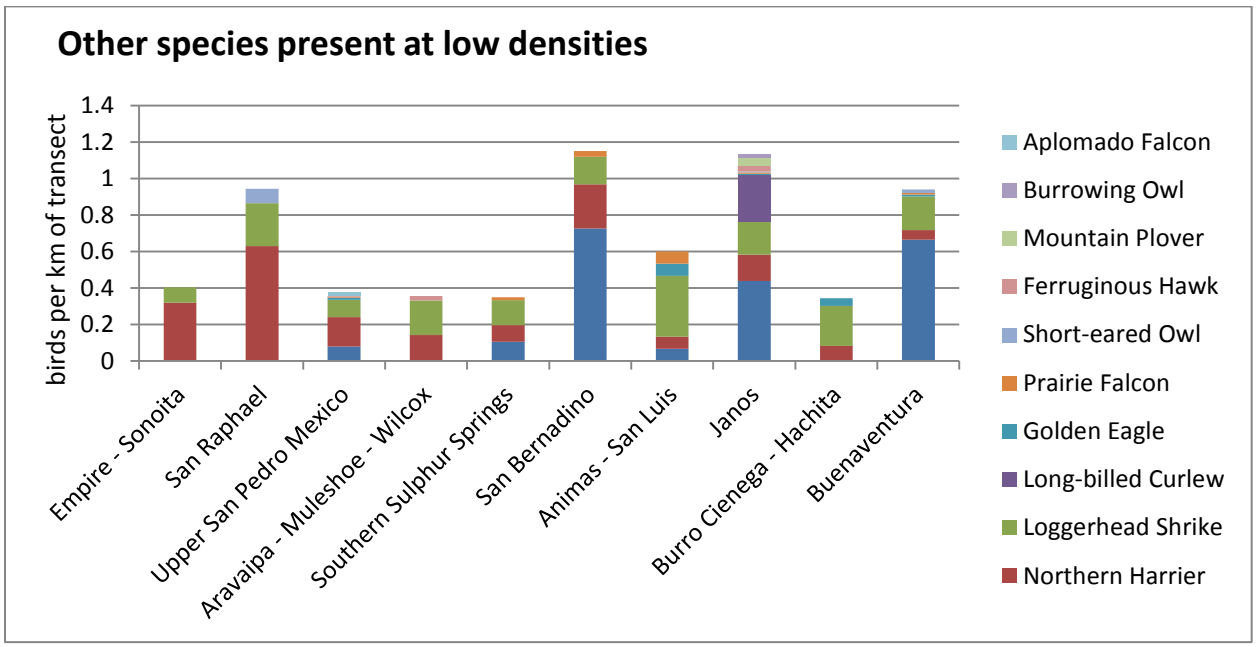


Figure 3.3. Densities of birds sampled in each landscape. This figure shows non-Emberizid species found at densities below one bird/km in any given landscape.

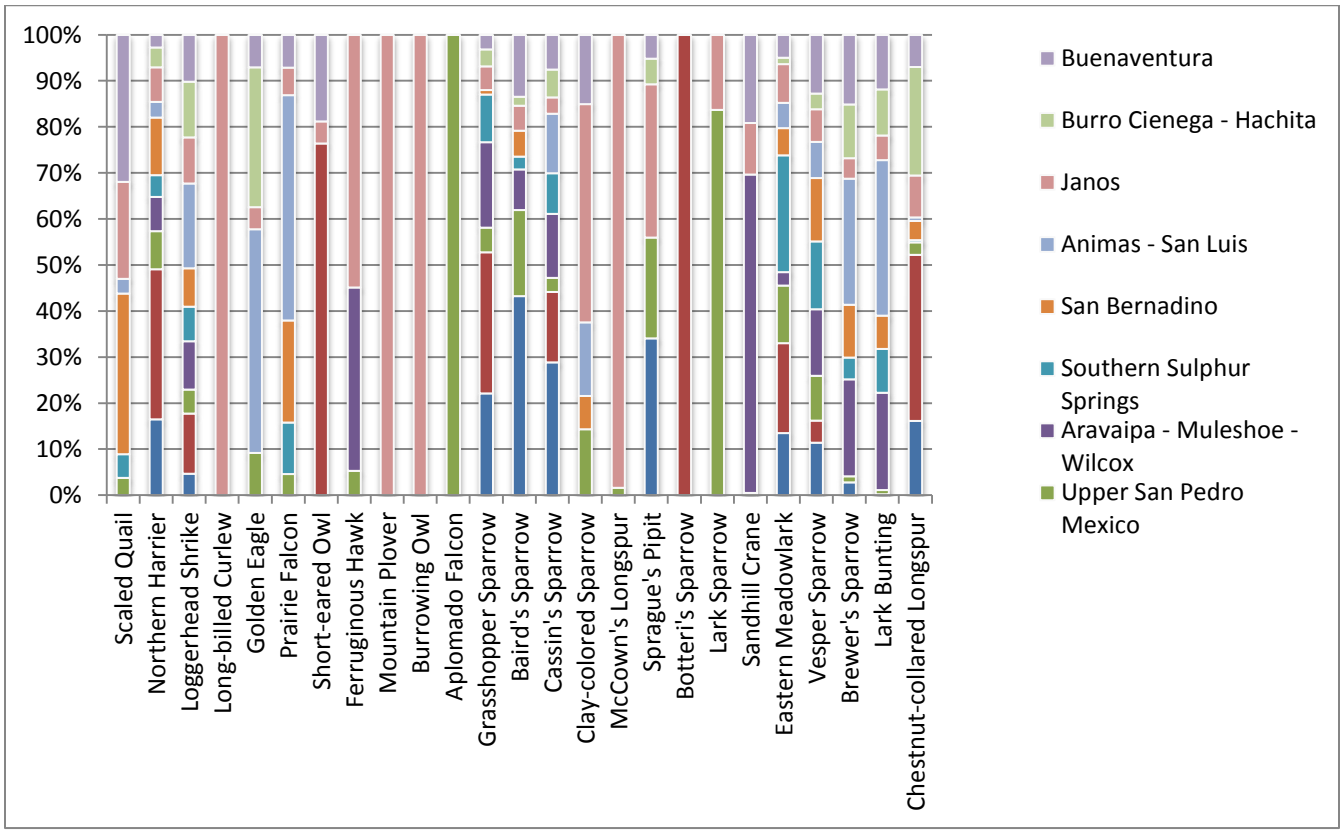


Figure 3.4. For each species, proportion of survey observations made in specific landscapes. Some species, e.g. Loggerhead Shrike, were found in all landscapes surveyed. Others, e.g. Aplomado Falcon and Mountain Plover, were sampled in just one landscape during this study. Many of these species have been recorded for other landscapes in other studies; greater sampling in some landscapes may bias representation of rare species.