

An Assessment of the Spatial Extent and Condition of Grasslands in the Apache Highlands Ecoregion

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Abstract—Grasslands in the Apache Highlands ecoregion have experienced dramatic changes. To assess and identify remaining native grasslands for conservation planning and management, we used a combination of expert consultation and field verification. Over two-thirds of native grasslands have experienced shrub encroachment. More than 30% of these may be restorable with prescribed fire. Private land accounts for more than half of open, non-shrub invaded native grasslands. Almost 95% of the private lands in this study have no legal protection. Over 25% of all native grasslands are contained in the Apache Highlands ecoregional analysis' top two priority conservation areas.

Introduction

Grasslands in the Apache Highlands ecoregion have experienced dramatic and spatially non-uniform vegetation changes over the last 130 years. Changes include decreased native perennial grass abundance and cover, conversion to shrubland, increased presence of non-native species, and fragmentation (Hastings and Turner 1965; Humphrey 1987; Bahre 1995). Explanations for the alteration of grasslands include: conversion to farmland, poorly managed cattle grazing, ground-water pumping, regional climate change, suppression of wildfire, and other activities related to human development (Humphrey 1958; Swetnam 1990; Archer et al. 1995; McPherson and Weltzin 2000).

Demographic projections and population movement patterns within the Southwestern United States suggest that grasslands will face particularly strong development pressures in the next decade (DES 2003; Theobald 2003). Suburban and exurban development results in the fragmentation of habitat and migration corridors linking adjacent mountain ranges. This prevents the restoration of important ecological processes, such as fire, that are critical to maintaining native perennial grasses by reducing shrub encroachment (McPherson 1995; Valone and Kelt 1999). Degradation of native grasslands threatens the viability of a diversity of grassland species such as pronghorn (*Antilocapra americana* Ord), the black-tailed prairie dog (*Cynomys ludovicianus* Ord), and numerous bird species. Moreover, vegetation change or loss in grasslands can negatively affect associated riparian systems (DeBano et al. 1984).

Numerous studies conducted on a variety of temporal scales have furthered the understanding of local vegetation dynamics in the borderlands (Bahre and Shelton 1993; Brown et al. 1997; Valone et al. 2002). Nevertheless, there have been few attempts to spatially characterize the spectrum of grassland changes at a landscape scale (Muldavin et al. 2001; Kepner et al. 2000).

Here we describe a field-based approach used to develop a landscape scale, rapid assessment of grasslands in the Apache Highlands ecoregion, a 12.1 million hectare planning area identified by The Nature Conservancy (TNC). Our specific objectives were to (1) map the ecoregion's extant and

historical grasslands, including those with restoration potential; (2) evaluate grassland condition by land manager and protection status; and (3) relate native grasslands with priority conservation areas selected in the Apache Highlands ecoregional analysis (Marshall et al. 2003; Turner et al., this proceedings).

Methods

Turner et al. (this proceedings) give a detailed description of the Apache Highlands ecoregion. Gori and Enquist (2003) provide a detailed account of this study's methodology. We first interviewed 24 range management specialists from 10 government institutions in the United States and Mexico. Experts were asked to delineate five grassland condition types on 1:250,000 scale maps (table 1). We then conducted 17 field trips in the United States portion of the study area to assess and modify the expert drawn maps. In total, we sampled 202 random points throughout the study area, estimating percent canopy cover of all shrubs, mesquite and juniper, and perennial grasses to the nearest 5%. The abundance of exotic perennial lovegrasses, Lehmann's (*E. lehmanniana* Nees.), and Boer's (*E. curvula* var. *conferta* Stapf.) was evaluated at each sample site. Additionally, we estimated the potential for using prescribed fire to reduce shrubs and restore open grassland (cf. Gori and Enquist 2003). All resulting field-verified grassland maps of the United States portion of the study area were digitized and merged using a geographical information system (GIS).

Delineation of the extent of different grassland types in Mexico was accomplished through a combination of expert mapping and analysis of Landsat Thematic Mapper satellite images using a mixed strategy of supervised and unsupervised classification (Aguirre et al. 2002). Field sampling and verification was conducted by staff from the Mexican State agency, the Instituto del Medio Ambiente y el Desarrollo Sustentable del Estado de Sonora (IMADES), utilizing a vegetation classification system developed for the State of Sonora (COTECOCA 1986). Two training sessions were conducted in the United States and Mexico to not only ensure that vegetation sampling techniques would be consistent across the border, but that the classification system was uniformly applied. The

Table 1—Classification of grassland condition. Experts were asked to base their opinion on their field-based experience, knowledge of local soil conditions and properties, and awareness of other data sources (historical accounts, survey points, photographs, etc.). In addition, experts were asked to identify grasslands with unknown condition types.

Grassland condition	Description
Open native	<10% shrub cover whose herbaceous component is entirely or predominantly native perennial grasses and herbs (D. Robinett, personal communication; modified from Anderson et al. 1998).
Riparian native	Riparian grassland dominated by giant sacaton (<i>Sporobolus wrightii</i> Munro ex Scribn.).
Restorable native	Native perennial grasses and herbs dominate with 10-35% total shrub cover and mesquite or juniper cover <15% (D. Robinett, NRCS, personal communication). A key characteristic of this type is its restoration potential back to open-native grassland by using prescribed burning to reduce shrub cover. In some cases, grazing rest may be required to accumulate sufficient fine fuels to carry a fire (Brunson et al. 2001).
Non-native	Non-native perennial grasses (primarily <i>Eragrostis lehmanniana</i> Nees and <i>Eragrostis curvula</i> var. <i>conferta</i> Stapf.) are common or dominant.
Historical	>15% canopy cover of mesquite and juniper combined and/or >35% total shrub cover; perennial grass canopy cover usually <1 %, always <3 %; soil condition and characteristics (D. Robinett, personal communication; McAuliffe 1995); type conversion to shrubland that is either permanent or will require 40+ years of livestock exclusion for partial recovery of perennial grasses (Valone et al. 2002). The historical time scale relates to vegetation accounts provided by vegetation inventories from the mid to late 1800s (Gelbach 1993).

final digital map developed by IMADES was subsequently appended to the United States grassland map to create a seamless cross-border GIS data set.

We conducted a spatial analysis of the final ecological condition map of grasslands using available spatial data layers of land management status and legally mandated land protection status (Weinstein 2002). We also related the network of conservation areas identified by the Apache Highlands ecoregional analysis (Marshall et al. 2003) to the best remaining native grassland patches identified in our assessment. Specifically, conservation areas ranked as most critical to grassland conservation encompassed the largest areas of open-native, restorable native, and riparian grasslands.

Results

With field verification, we estimated that the accuracy of the expert opinion-based maps ranged between 76% and 88%. With subsequent mapping modifications, the accuracy of our final grassland map for the Apache Highlands was likely improved.

Our study identified 4,928,448 ha (12.2 million acres) as either extant or historical grassland, accounting for 41% of the Apache Highlands ecoregion (figure 1). Over 1,782,280 ha (4.4 million acres) is historical grassland that is now dominated by shrubs (cf. table 1). Open-native grassland accounts for 816,624 ha (2 million acres) of all identified grasslands (includes extant and historical), or 26% of extant grassland. Giant sacaton (*Sporobolus wrightii*) riparian grassland covers 21,438 ha (52,973 acres) of all identified grassland, or 0.7% of extant grassland. Shrub encroachment has occurred on 3,341,184 ha (8.3 million acres) of all identified grassland. However, 1,558,904 ha (3.9 million acres) is potentially restorable, or 49.6% of all extant grassland. Nearly 150,000 ha (380,000 acres) of all identified grasslands are of an unknown condition.

Non-native lovegrass species (Lehmann's and Boer's) are now common or dominant on 594,163 ha (1.5 million acres) of all identified grassland, or 19% of extant grassland. The distribution of non-native grassland was restricted to

southeastern Arizona where the two lovegrass species were initially introduced in the 1930s to prevent soil erosion and provide forage for livestock (Cox and Ruyle 1986). We found no regional-scale exotic grass invasion on the Mexico side of the study area.

The majority of open-native and riparian grasslands are on private lands, while State lands were a distant second (table 2). Restorable native grasslands are almost evenly distributed among Federal, private, and State land management. This was also true of historical grasslands, while non-native grasslands occurred predominantly on private land. When considering specific Federal land managers, 59% of Bureau of Land Management (BLM) managed grasslands are historical, 29% are restorable, and 6% are open-native. In contrast, 61% of USDA Forest Service (USFS) managed grasslands are restorable, 14% are historical, and 11.2% are open-native.

Most grassland in the Apache Highlands has either a low level to no legal protection (table 3). More specifically, a majority of open-native and riparian grasslands on private (89%) and State (99%) land has no legal protection. One-third of restorable grassland occurs on Federally managed lands. Of this, 88% has a low level of legal protection. The remaining two-thirds of restorable grassland (in roughly equal proportions on private and State lands) has virtually no legal protection (91% on private and 99% on State).

Over 25% of all native grasslands identified in this study are found in the two top priority conservation areas selected in the Apache Highlands ecoregional analysis. The first is the Huachuca Mountains Grassland Valley Complex (HMGC), with 267,024 ha (659,816 acres) of native grassland (78% of which is open-native, 20% is restorable, and 3% is riparian). The second is the Sierra San Luis/Peloncillos Mountains (SLPM), with 390,558 ha (965,069 acres) of native grassland (42% is open-native, 56% is restorable, and 2% is riparian). Of total HMGC lands, 54% is private, 25% is State, and 18% is Federal. Of total SLPM lands, 66% is private, 12% is State, and 17% is Federal.

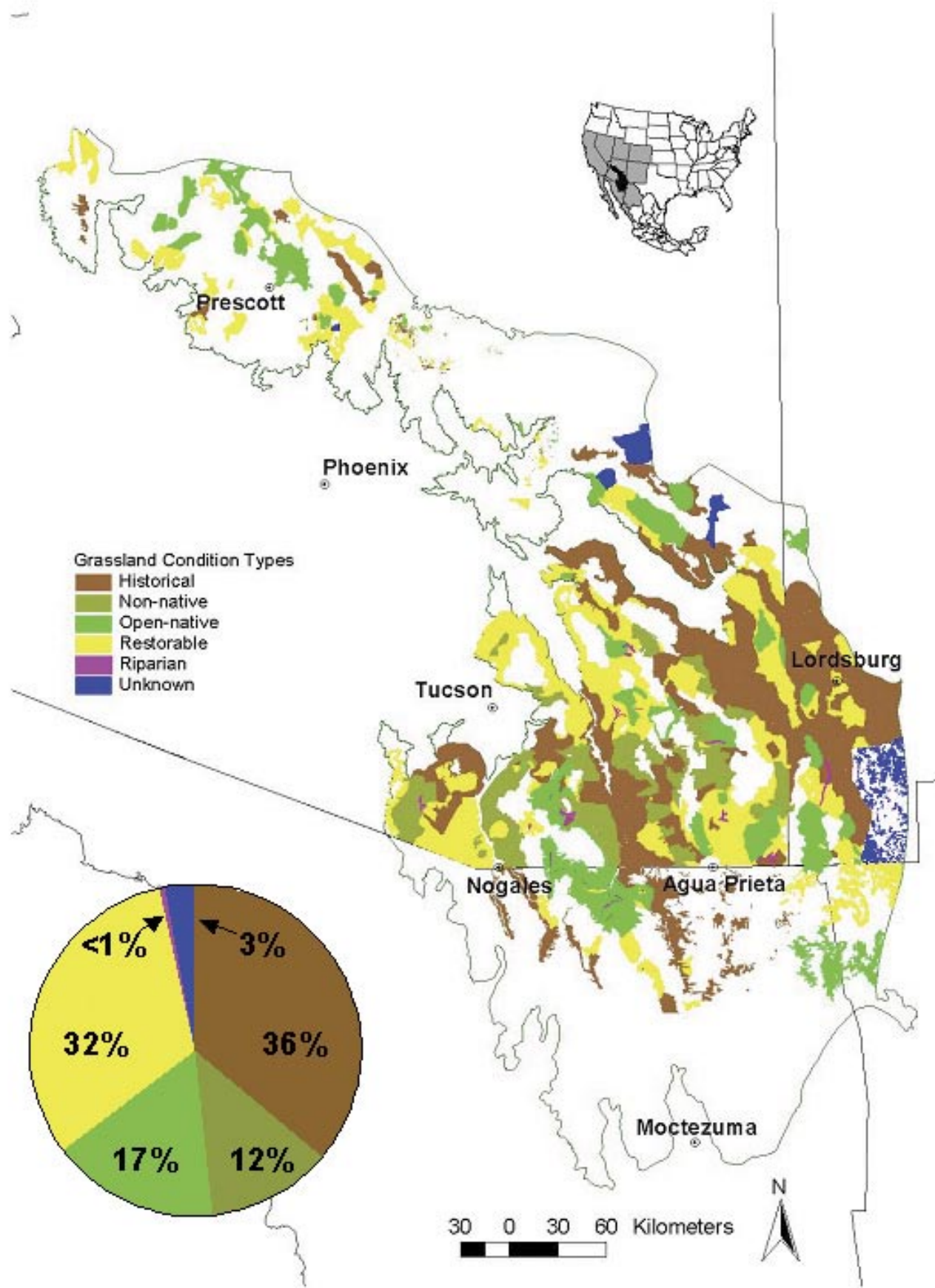


Figure 1—Ecological condition types of grasslands in the Apache Highlands ecoregion.

Table 2—Land manager by grassland condition type in area units of hectares. Percentages were calculated based on sum totals of each column.

Manager	Open native	Riparian	Restorable	Non-native	Historical	Unknown	Total
<i>Federal</i>	105,913 (13.0%)	1,808 (8.4%)	526,296 (33.8%)	131,294 (22.1%)	519,563 (29.2%)	49,490 (31.9%)	1,334,363 (27.1%)
Private	484,677 (59.4%)	15,368 (71.7%)	499,344 (32.0%)	259,649 (43.7%)	602,221 (33.8%)	42,039 (27.1%)	1,903,299 (38.6%)
State	140,019 (17.1%)	4,262 (19.9%)	480,151 (30.8%)	202,772 (34.1%)	526,055 (29.5%)	6,048 (3.9%)	1,359,308 (27.6%)
Tribal	85,968 (10.5%)	-- (0.0%)	49,891 (3.2%)	-- (0.0%)	125,914 (7.1%)	57,462 (37.1%)	319,235 (6.5%)
Other	47 (0.0%)	-- (0.0%)	3,222 (0.2%)	447 (0.1%)	8,528 (0.5%)	-- (0.0%)	12,244 (0.2%)
Total (ha)	816,624	21,438	1,558,904	594,163	1,782,280	155,039	4,928,448

Discussion

Over the course of a century, 36% of the grassland in the Apache Highlands ecoregion experienced a conversion to shrubland as a result of factors ranging from climate change to fire suppression. Open-native grassland constitutes less than 20% of the extant and historical grasslands identified in the Apache Highlands ecoregion. Although shrubs have invaded nearly 70% of these grasslands, nearly a third may be restorable with prescribed fire (cf. table 1). Together, open and restorable native grasslands comprise nearly 50% of identified grasslands.

Private land accounts for more than half of identified open-native grasslands. However, 94% of the private lands in the study area have no legal protection. One-third of restorable native grassland is Federally-managed, primarily

by the USFS, and has some legal protection. The remaining two-thirds are State or private lands with less protection. Our results suggest that private land owners need to be engaged in native grassland conservation. Federal conservation partners should specifically be engaged in the restoration of native, shrub-invaded grassland. Native grasslands on State lands could be addressed via legislative and policy-related initiatives. These recommendations also apply to the two top priority conservation areas identified in the Apache Highlands ecoregional analysis.

The results of this study demonstrated that a field-based landscape scale assessment of the condition and spatial extent of grasslands can be used to inform conservation planning and ecological land management decisions. Moreover, our 14-month long assessment produced results with high accuracy in a time and cost effective manner. We have set the stage for an enhanced

Table 3—Legal protection status by grassland condition type in area units of hectares. Percentages were calculated based on sum totals of each column. High = USGS Gap protection level 1 or the highest level of legally mandated permanent land protection; Moderate = USGS Gap protection level 2 or lands with permanent protection but which may receive uses or management practices that degrade the quality of existing natural communities; Low = USGS Gap protection level 3 or lands with some degree of protection but that are subject to extractive uses which may involve land cover clearing; No = USGS Gap protection level 4 or lands without legal protection (Weinstein 2002).

Protection status	Open native	Riparian	Restorable	Non-native	Historical	Unknown	Grand total
High	2,752 (0.3%)	1,701 (7.9%)	18,098 (1.2%)	42,846 (7.2%)	26,712 (1.5%)	-- (0.0%)	92,108 (1.9%)
Moderate	4,220 (0.5%)	202 (0.9%)	53,578 (3.4%)	3,808 (0.6%)	23,516 (1.3%)	3,181 (2.1%)	88,505 (1.8%)
Low	152,448 (18.7%)	4,158 (19.4%)	508,506 (32.6%)	107,597 (18.1%)	486,068 (27.3%)	50,865 (32.8%)	1,309,643 (26.6%)
No	571,185 (69.9%)	15,376 (71.7%)	928,518 (59.6%)	439,911 (74.0%)	1,114,167 (62.5%)	43,530 (28.1%)	3,112,687 (63.2%)
Unknown	86,020 (10.5%)	-- (0.0%)	50,205 (3.2%)	-- (0.0%)	131,818 (7.4%)	57,462 (37.1%)	325,504 (6.6%)
Total (ha)	816,624	21,438	1,558,904	594,163	1,782,280	155,039	4,928,448

approach currently being developed by TNC of New Mexico for the BLM that includes assessments of other habitats. In Arizona, an assessment of the remainder of the State's grasslands from the perspective of fire management has been conducted as a direct result of the original Apache Highlands grassland report (Gori and Enquist 2003; Schussman and Gori 2004).

The classic basin and range physiography of the Apache Highlands ecoregion is often described as being composed of mountain islands surrounded by desert seas (Gehlbach 1993). This analogy underestimates the importance of semi-arid grasslands, or seas, in comparison to the mountain "sky" islands. In a region experiencing substantial development pressure, grasslands are at risk of becoming increasingly fragmented and vulnerable to exotic species invasion. Now, with new reconnaissance of grassland condition, conservation practitioners and partners are better positioned to protect and restore the last remaining native grasslands in the Apache Highlands.

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