Vegetation Map of Lesser Prairie-chicken Habitat on the Caprock Wildlife Habitat Management Area, New Mexico

Draft
Final Report

Submitted to:

Bureau of Land Management
Roswell, NM Field Office

By

Kristine Johnson
Teri Neville
Phil Tonne
New Mexico Natural Heritage Program
Biology Department, University of New Mexico

And

Paul Neville
Emily Clary
Earth Data Analysis Center
University of New Mexico

October 2001

NMNHP Publication No.: 01-GTR-218

Table of Contents

List of Tables and Figures

Introduction

The Lesser Prairie-chicken (LPCH, *Tympanuchus pallidicinctus)* has the most restricted distribution and smallest population size of any native North American grouse species. Distribution has declined approximately 92% since the 1800s. Significant reductions in population and distribution during that time have been attributed to drought, excessive grazing of rangelands, conversion of native rangelands to croplands, and chemical control of sand sagebrush (*Artemesia filifolia*) and shin-oak (*Quercus havardii*, Giesen 1998). As a consequence, populations in all states are now fragmented and isolated (Giesen 1998, Mote et al. 1999), and the species is a candidate for listing as threatened under the Endangered Species Act.

The LPCH occurs in habitats dominated by shin-oak or sand sagebrush grasslands, in five states within the Southern Shortgrass Ecoregion (Bailey 1998). In Colorado and Kansas, the LPCH is restricted to sand sagebrush communities dominated by sand dropseed (*Sporobolus cryptandrus*), side-oats grama (*Bouteloua curtipendula*), three-awn (*Aristida* spp.), and blue grama (*B. gracilis*) grasses. In New Mexico, Texas, and Oklahoma, it occurs in shinnery oak-bluestem habitats dominated by sand bluestem (*Andropogon halli*), little bluestem (*Schizachyrium scoparium*), sand dropseed, three-awn, and blue grama grasses (Giesen 1998).

The LPCH nests on the ground under sand sagebrush or shin-oak shrubs, or in tall bunchgrasses (e.g., *Aristida* spp., *Schizachyrium* spp., *Andropogon* spp.; Davis et al. 1979; Giesen 1994; Johnson and Smith 1998, 1999). Predation is the primary cause of nest failure (Davis et al. 1979; Riley et al. 1992; Johnson and Smith 1998, 1999, Johnson 2000), and nest depredation and abandonment rates are lower when vegetation height and tallgrass cover near nests are higher (Riley et al. 1992). Although tall grass appears important for nesting cover, LPCH hens prefer to nest in pastures containing a mixture of grass and shin-oak over pastures in which shrubs have been eliminated (Haukos and Smith 1989, Johnson 2000). LPCH in New Mexico need shin-oak for brood rearing (Riley and Davis 1993). The spring and summer diets of young birds are dominated by insects, particularly grasshoppers, which are found in shinnery oak tallgrass community types (Davis et al. 1979). In southeast New Mexico, acorns, galls, catkins, and new leaves of shin-oak were the most important year-round items in the diets of adult birds (Riley et al. 1993a).

LPCH habitat is apparently impacted by several agricultural practices. Conversion of native rangeland to croplands destroys and fragments the shinnery oak dune habitats crucial to nesting and winter survival of the species (Taylor and Guthery 1980). Grazing results in reduced vegetation height and reduced tallgrass cover, which in turn increases levels of depredation, the primary cause of nest failure (Davis et al. 1979; Merchant 1982; Riley et al. 1992; Johnson and Smith 1998, 1999). Shin-oak competes with more desirable livestock forage plants, and its early-spring buds and leaves are toxic to livestock. Shrub removal, a common range management practice, degrades and fragments nesting, brood rearing, and wintering habitat (Peterson and Boyd 1998 and references therein). A landscape-level analysis showed that greater loss of shrub-dominated habitats was associated with a greater tendency for a LPCH population to be classified as declining (Woodward et al. 2001).

Shinnery oak communities are some of the least understood and most poorly described communities in the southwestern United States (Dhillion and Mills 1999). Much of the research on shinnery oak communities has occurred in Texas, and little is known about the extent of these communities in New Mexico. Most research has emphasized control of shin-oak using herbicides such as tebuthiuron to manage for increased grass cover favorable to livestock grazing (Scifres 1972, Pettit 1979, Sears et al. 1986). Other studies have concentrated on characterizing the shinnery oak plant community and structure (Sullivan 1980, Holland 1994).

These highly threatened communities (Dhillion et al. 1994) not only provide important habitat for the LPCH, but also harbor the sand dune lizard (*Sceloporus arenicolus*), which is listed as threatened in the state of New Mexico (New Mexico Department of Game and Fish 1996). The shinnery oak community supports a high diversity of raptors (up to 22 species, Bednarz et al. 1990). The geographic range of shinnery oak communities extends from eastern New Mexico, principally Chavez, Roosevelt, and Lea counties, across the Texas plains and Texas Panhandle, northward into western Oklahoma (Muller 1951, Everitt et al. 1993, Dhillion and Mills 1999). Shin-oak grows on deep, well-drained, nutrient-poor, Pleistocene-derived soils (Wiedman and Penfound 1960, Lenfesty 1980), which form dunes (Dhillion and Mills 1999) and sand sheets. The shin-oak of eastern New Mexico hydridizes with Mohr's oak (*Q. mohriana*) (Muller 1951; Correll and Johnson 1979; Vines 1982) and possibly with *Q. undulata* and *Q. gambelii* (Muller 1951). The height and density of plants increase going east in the species' range, due to the deeper sandy horizon and higher precipitation (Sullivan 1980).

LPCH habitat contains four main components: mating areas, nesting areas, brood-rearing areas, and wintering areas. LPCH mate at traditional display grounds, where males assemble and perform courtship displays to females. Lek sites are typically characterized by sparse vegetation (Davison 1940, Giesen 1998, Ahlborn 1980). Lek sites may occur in naturally bare areas or disturbed areas such as abandoned oil drilling pads, bare dunes, herbicide-treated areas, or even old roads (Davis et al. 1979, Ahlborn 1980, Giesen 1998, Mote et al. 1999). The primary habitat requirement for lek sites appears to be visibility (Davis et al. 1979). Thus, habitat preferences for lek sites seem to be the least restrictive of the four main habitat types.

A study conducted in the CWHMA before widespread application of tebuthiuron defined four habitat types used by LPCH, three subtypes of “Shinnery Oak Tallgrass” and one of ‘Mesquite-Shortgrass” (Davis et al. 1979). Davis et al.’s Shinnery Oak Tallgrass subtype I had basal composition of 57.8% grasses, 30.8% shrubs, and 11.4% forbs. Grasses were dominated by sand bluestem (26.8%), three-awn (7.7%), and hairy grama (*Bouteloua hirsuta*, 7.3%). Shrubs comprised mainly shin-oak (29.1%). Subtype II contained 58.1% grasses (three-awn, 16.7%; little bluestem, 12.1%; and sand bluestem, 8.5%), 30.9% shrubs (29.1% shin-oak), and 11.0% forbs. Subtype III was covered in 42.4% grasses (three-awn, 13.3%; little bluestem, 5.8%; dropseed [*Sporobolus* spp.], 5.5%; and sand bluestem, 5%), 45.8% shrubs (43.8% shin-oak), and 12% forbs. Mesquite-Shortgrass habitat contained 89.1% grasses, 6.1% shrubs (5.5% broom snakeweed, *Gutierrezia sarothrae*), and 4.8% forbs.

In spring-early summer, and fall-winter, radio collared hens spent more time in subtype I, followed in order by subtype III, subtype II, and Mesquite-Shortgrass. In late spring-summer, subtypes were used in the following order: I, II, and III, with no use of Mesquite-Shortgrass (Davis et al. 1979).

Nests are typically found in plant communities dominated by shin-oak and having residual tall bunchgrasses from the previous growing seasons (Haukos and Smith 1989, Mote et al. 1999). Ahlborn (1980) considered the Shinnery Oak-Bluestem community the preferred nesting vegetation type for the LPCH in eastern New Mexico. Shinnery Oak-Midgrass was considered to be a more degraded type of the Shinnery Oak-Bluestem, resulting from heavier grazing pressures (Ahlborn 1980). In a recent study on the CWHMA, hens nested in pastures having from 35.5-58.3% shrubs, 39.3-60% grasses, and 2.4-4.4% forbs (Johnson 2000). Plant height is typically greater within 3 m (3.28 ft) of nests than in the pasture as a whole (Johnson 2000).

In the Davis et al. (1979) study, hens nested preferentially in subtype I, followed by II and III, and no nests were found in Mesquite-Shortgrass habitat. Nesting success was more than three times higher in subtype I than in subtype II and was slightly lower in subtype III than II. These differences corresponded to differences in the percent composition of sand bluestem. This relationship presumably occurred because sand bluestem near nests concealed nests more thoroughly than other species (Davis et al. 1979).

Brood-rearing habitat must provide sufficient protection from climatic extremes and predators and provide an ample supply of food for broods. Young chicks and juveniles eat almost exclusively insects, primarily grasshoppers (Davis et al. 1979). In comparison to surrounding areas, brood-rearing habitat has greater canopy cover, with taller shrubs and greater basal area of grasses and forbs (Ahlborn 1980, Mote et al. 1999 and references therein). Brood foraging sites within the three Shinnery Oak-Tallgrass subtypes at the CWHMA generally had more shrubs and less grass than the subtypes on average, and grasshopper abundance is presumed to be high in these habitats (Davis et al. 1979).

Autumn and winter habitat is similar to breeding habitat, but LPCH make greater use of small-grain agricultural fields in areas close to agriculture (Giesen 1998). In a study on the CWHMA, which contains no agricultural fields, LPCH foraged almost exclusively in the Shinnery-Oak-Tallgrass vegetation type in the fall and winter (Davis et al. 1979). Fall and winter foraging habitat tended to be more grassy than the subtypes overall, and resting/roosting habitat was slightly more grassy than foraging habitat, apparently because grasses were used for cover (Davis et al. 1979). In the same study, LPCH used habitat containing 37% shrubs (32% shin-oak) and 63% grasses (*Aristida* spp., 23%; *Sporobolus* spp., 10%; *Andropogon scoparius*, 8%; *A. halli*, 7%) in autumn. LPCH wintered in habitat containing 41% shrubs (38% shin-oak) and 59% grasses, with the same four dominant species as in autumn (Riley et al. 1993b).

The purpose of this study was to create a map depicting the major LPCH habitat types in the CWHMA, with emphasis on breeding, as opposed to wintering, habitats. The map is intended for uses such as analysis of LPCH habitat preference and use; habitat management for LPCH, sand dune lizard, and other wildlife species; and monitoring of wildlife habitat condition. Therefore, it is not a traditional vegetation map, but instead it emphasizes plant communities known to be important to LPCH.

A possible result of this approach is that some mapping units appear “lumped” and others “split,” relative to more standard vegetation classifications. For example, MU 1, Shinnery Oak-Mixed Mid-Grass and Tall-Grass Duneland, and MU 3, Shinnery Oak-Mixed Mid-Grass and Tall-Grass Shrubland, have similar species composition, but MU 3 has a somewhat higher cover percent and shorter shrubs than MU 1. The primary difference in these two MUs is in fact more topographical than vegetative, and we distinguish them because LPCH use dunes differently from inter-dune areas. In contrast, MU 11, Tall-Grass Grassland, and MU 12, Short-Grass Grassland, each contain several grassland communities that might be distinguished using a more traditional vegetation mapping methodology. Because none of the communities contained in MU 11 or MU 12 constitutes preferred habitat for LPCH, our map combines these structurally similar but compositionally different grassland community types. As a result, this LPCH habitat map is different from other vegetation maps, but it is potentially more useful for addressing wildlife management and conservation concerns.

Study Area and Methods

The study area is located approximately 60 km (36 mi.) east of Roswell, New Mexico in Chavez County. It encompasses approximately 169,386 ha (587,948 ac; acreages derived from GIS). The region receives on average 342.39 mm (13.48 in) of annual rainfall, most of it from convective thundershowers during the summer. Snow can occur from October to April with usually not more than 83.82 mm (3.3 in) of accumulation at any time. Temperatures can range from as low as –22.8°C (-9°F) in winter to a high of 45.6°C (114°F) in summer. July is typically the warmest month, with an average temperature of 27.2°C (80.9°F), and January is the coldest with an average temperature of -3.4°C (25.9°F). Climate summaries are based on records from 1/1/1920 to 7/31/2000 (Roswell FAA Airport, New Mexico, Summer = Jun., Jul., and Aug; Winter = Dec., Jan., and Feb. http://wrcc.sage.dri.edu/summary/climsmnm.html).

Much of the study area is dominated by the Faskin-Roswell-Jalmar soil map unit (Lenfesty 1980). The Faskin and Jalmar soils are nearly level on high terraces formed in alluvial and eolian deposits (Lenfesty 1980). They are well drained, moderately permeable soils found in depressional and interdunal areas on high plains. The Roswell Series are gently undulating to hilly areas consisting of deep, excessively drained, rapidly permeable soils on coppice dunes formed in eolian deposits (Lenfesty 1980). Overgrazing of Faskin-Roswell-Jalmar soils is a management concern because it makes them susceptible to wind erosion (Pettit 1978, Lenfesty 1980). Blowouts are caused by grazing or other disturbances that remove stabilizing vegetation cover (Dhillion and Mills 1999). They typically form on the southwest sides of dunes (Wilhite 1960), in the prevailing wind direction on the eastern plains of New Mexico (Bennett 1986).

The amount of clay and calcium carbonate accumulated within the subsoil affect the vertical height and density of shin-oak (Wiedeman and Penfound 1960, Pettit 1986). If the sand layer is shallow, underlying clays can prevent movement of water to the roots (Sullivan 1980), although this has not been studied on the soils of the shinnery oak communities (Dhillion and Mills 1999). In addition, shin-oak cover decreases as clay content of soil increases (Sullivan 1980, Pettit 1986). Similarly, the relative depth to a calcic horizon is a limiting factor for shin-oak (Wiedeman and Penfound 1960, Sullivan 1980, Peterson and Boyd 1998). Sullivan (1980) found that oak decreased dramatically when the accumulation of calcium carbonate was shallower than 101 cm (40 in). Mesquite may replace shin-oak in areas where the calcic horizon is within a meter (3.28 ft) of the soil surface (Sullivan 1980), and sand sagebrush may dominate where the subsoil is rich in carbonates or clay (Pettit 1978).

Data Sources

Satellite Imagery

Landsat ETM$^+$ satellite imagery was the primary data set used to map the natural vegetation for the study area. We used an ETM$^+$ scene acquired on May 27, 2000, by the Landsat 7 platform. The ETM$^+$ scene was of good quality with no clouds, cirrus, or scan line defects. The image was imported into ERDAS Imagine (Version 8.4), where all raster processing and analyses were accomplished.

The satellite imagery, with its stable sensor platform, is relatively easy to geometrically correct to the known coordinate system of a base map. The height of the sensor above the earth (705 km. for Landsat) negates most parallax problems, commonly found in aerial photography. (Parallax is the apparent change in positions of stationary objects affected by the viewing angle – creating greater distortions at greater distances from the center of an aerial photo.) Also, satellite data do not have the radiometric problems of air photos, such as hot spots, dark edges, or different contrasts for each photo due to sun-angle changes during the overflight.

The quantitative spectral and spatial aspects of ETM$^+$ imagery add particularly important dimensions to the mapping process. Multi-spectral satellite imagery records the variable reflection of natural radiation of surface materials such as rocks, plants, soils, and water, differently. Variations in plant reflection and absorption due to biochemical composition will register distinct spectral “signatures” (Wickland 1991, Lillesand and Kiefer 1987). These signatures provide a quantitative measure of reflectance at specific wavelengths, which can then be statistically analyzed to develop a vegetation map of spectrally similar plant communities.

Landsat ETM$^+$ has six spectral bands and one thermal band, which provides the highest spectral discrimination of all commercially available space-based sensors. Each band represents a specific range of light wavelength (Table 1). Bands 2, 3, 4, and 5 are particularly useful for vegetation mapping. ETM$^+$ bands 3, 5, and 7 are useful for detecting variations in surface geology. Surface geology and soil discrimination are important in developing mapping units of the vegetation communities in sparsely vegetated areas that occur within the study area. ETM$^+$ band 6 records at a coarser spatial resolution, but the thermal response, which directly measures surface temperature and indirectly indicates the moisture content, is important for discriminating between different plant and soil types.

ETM$^+$ integrates the spectral characteristics of each band over the Instantaneous Field of View (IFOV), an area 28.5 m. x 28.5 m (93.5 ft x 93.5 ft). This is the smallest area resolvable by the sensor, which is represented on the computer screen by individual “pixels” (picture elements). Individual occurrences of plants are not resolved by the sensor; therefore, ETM$^+$ is particularly suited for evaluating and quantitatively identifying more generalized vegetation “community” occurrence patterns and their associated surface substrate characteristics.

Table 1. Spatial and spectral ranges of Landsat ETM$^+$ bands (from http://landsat7.usgs.gov/).

Band	Spatial Resolution	Wavelength (microns)	Spectral Location
1	30m (98 ft)	0.45-0.52	Blue visible
2	30m (98 ft)	0.52-0.60	Green visible
3	30m (98 ft)	0.63-0.69	Red visible
4	30m (98 ft)	0.76-0.90	Near-infrared
5	30m (98 ft)	1.55-1.75	Mid-infrared
6	60m (197 ft)	10.4-12.5	Thermal Infrared
7	30m (98 ft)	2.08-2.35	Mid-infrared

Aerial Photography

We acquired forty black and white aerial photographs of the area at a 1:40,0000 scale, taken in October 1996 and November 1997 as part of the USGS National Air Photo Program (NAPP). These photographs provide a limited spectral profile, one band representing an overall surface response in the visible wavelengths. We used the photography to provide spatial detail not evident in the ETM$^+$ data. These photographs were scanned at 1,000 dots per inch (dpi), resulting in individual cells with a resolution of 1 m (3.28 ft).

Ancillary Map Geographic Information System (GIS) Layers

Several additional data sets were used to develop the map. These include GIS layers for roads, land status, treatment areas, nest sites, and lek sites. The road and land status layers were created from the 2000 USGS TIGER dataset and the BLM 1:100,000 series of ownership maps, respectively. Both were available from the New Mexico Resource Geographic Information System (RGIS) website (http://rgis/). Raster data sets such as the USGS 1:24,000 Digital Raster Graphics (DRG, scanned topographic map sheets) and the National Elevation Dataset (NED) Digital Elevation Model (DEM, spatial resolution of 30 m or 96 ft) were also clipped to the area and used for the study.

Software and Hardware Used

We used primarily ERDAS Imagine, Version 8.4, software throughout the mapping process. All digital imagery and GIS layers were processed, manipulated, and used as overlays for analysis within the Imagine environment. The ERDAS Imagine software was loaded on a PC using a Windows2000 operating system. We used Arc/Info, Version

8.0, and ArcView 3.2 to create, import, and manipulate vector layers. We stored and manipulated all field data using Microsoft Excel 2000.

Image Processing

Geometric Correction

The ETM$^+$ scene was rectified to a map-based coordinate system using a nearest-neighbor interpolation. This process makes the image planimetric, to allow measurement of area, direction, and distance. The image-to-map rectification involves selecting a point on the corresponding topographic map and the same point on the image and then pairing the coordinates. The root mean square error (RMS_{error}) is computed to determine how well the map and image coordinates fit in a least-squares regression equation. The RMS_{error} for these images was 0.976 cell error (or approximately 28 m [92 ft]). The images were projected into the New Mexico Universal Transverse Mercator, Zone 13, using the 1927 North American Datum and the Clarke 1866 Spheroid.

The aerial photographs were geometrically corrected using an ortho-rectification process as a base. This method models the geometry of the camera frame, the film and the relief on the ground and results in an image free of geometric distortion in the x, y, and z plane. The DRGs were used as a reference for ground control. The DEM was used as the topographic reference. Each of the aerial photographs was projected into the same coordinate system as the ETM+ image.

Normalized Difference Vegetation Index

A Normalized Difference Vegetation Index (NDVI) was created from the ETM$^+$ data. The NDVI enhances the spectral response of vigorous vegetation relative to the response from other major surface features. This approach emphasizes vegetation response patterns in the classification. The NDVI also allows for a quick assessment of class signatures; for example, the shrubbier oak areas should have a higher NDVI response than the senescent grasslands.

The Normalized Difference Vegetation Index (NDVI) was created using Equation 1 (Eq. 1) and added to the file.

$$\mathrm{NDVI} = (\mathrm{ETM}^{+}4 - \mathrm{ETM}^{+}3) / (\mathrm{ETM}^{+}4 + \mathrm{ETM}^{+}3) \quad (\textbf{\textit{Eq. 1}})$$

Where **ETM$^+$4** is the near infrared ETM+ band and **ETM$^+$3** is the visible red ETM+ band.

Texture Filter

As previously mentioned, the spectral detail of aerial photos is minimal, but the overall brightness response with a high spatial detail still provides useful information. For example, a shinnery oak shrubland community will have an overall dark response in the photo, whereas a shinnery oak duneland will have a brighter response due to the barren patches in the plant community. This overall brightness response was modeled using an averaging filter (Eq. 2) to minimize the effects of individual cell noise in the image.

$$\mu = (\sum DN) / k \quad (\textbf{\textit{Eq. 2}})$$

where **μ** is the resulting mean, **DN** is the individual cell brightness response, and **k** is the number of cells sampled.

Photos also provide an indication of differential response from one cell (pixel) to another, especially given that with such high spatial resolution a cell is close to the size of a single sand sagebrush or honey mesquite (*Prosopis glandulosa*) shrub. Taking the example described above, the shinnery oak shrubland may have a dark brightness response, but it will have a high spatial variation response due to changes in the image representing the shrub/grass/barren patchiness of this landscape. In contrast, a short-grass community that may also have a similar dark brightness response, will probably have a low spatial variation response due to a more homogenous cover type. The variance in the photo was modeled in the aerial photographs using Eq. 3, below, for every 3x3, 5x5, and 7x7 cell window in the image:

$$V = \sum(DN - \mu)^2 / 9 \quad (\textbf{\textit{Eq. 3}}),$$

where **V** is the resulting variance. The resulting three different images were then added together to create an overall variance filtered image. The average brightness image was divided by the variance image (Eq. 4) to create a combined texture image, **T**, which shows on a cell-by-cell basis the corresponding changes of brightness with variance.

$$T = \mu/V \quad (\textbf{\textit{Eq. 4}})$$

This image was then combined with the ETM^+ data for the classification.

Field Data Survey

The mapping process used here depends on ground vegetation survey data. The goal of the field sampling was to capture the variation in vegetation type present on the study area. In an attempt to gather data from all potential communities in the study area, on May 22-24, 2001 we collected data from 15 vegetation plots, supplemented by an additional 28 ‘quick’ plots. Rand French from the Roswell BLM Field Office assisted in choosing sampling areas representative of both vegetation and landform variation present on the study area. For example, shinnery oak-dominated communities can be found both on dunes and within the flat, inter-dune plain.

Plots were chosen based on homogeneity of floristics, physiognomy or physical structure, and known LPCH habitat needs. Plot data included the major vegetation community, percent cover of dominant plants, bare ground, litter, basal cover, and canopy cover. General comments included occurrence size, landform characterization, potential habitat use by the LPCH, and nearby historical LPCH nest sites. Plots were placed in the center of stands of more or less uniform vegetation representing the dominant vegetation type. Stands were a minimum of 1 ha (2.5 acres) in size.

A Global Positioning System (GPS) was used to record the plot locations. GPS positions were collected using Garmin GPS 12 units. The 12- channel receiver has an average accuracy of 7 to15m (21 to 45 ft, Garmin Corporation 2001). The units were preset to obtain averages for each position, thereby increasing percent accuracy of the units.

Image Classification

Supervised Strategy and Seeding

The image classification procedure synthesizes satellite image data, field plot data, and ancillary data derived principally from GIS layers. A supervised classification strategy was adopted to create the vegetation map based on vegetation community types. This strategy develops spectral classes based on ground locations with known characteristics such as vegetation composition and landscape context.

In a supervised classification strategy, the field data are applied to the image data through an interactive process called “seeding.” In the seeding process, a pixel at the field plot location was selected in the image and its spectral characteristics were used to gather other similar contiguous pixels to create a statistical model or “seed” of the field plot. The seeding algorithm (Eq. 5) searches around that point within user-defined parameters that contain a seed within: 1) a certain distance, 2) a certain area, and 3) a certain spectral distance defined as:

$$SD = \sqrt{}\sum(\mu - X)^2 \quad (\textbf{\textit{Eq. 5}}),$$

where **SD** is the spectral distance between a new pixel and the mean of the current seed group pixels across all bands, μ is the mean of the seed pixel group for each image band, and **X** is the spectral value of the new pixel for each band.

In an iterative process, we constructed the best seed models by adjusting the parameters and comparing the resulting pixel distributions against the terrain models and the original imagery. A seed was developed for each field plot using the plot GPS location and associated field information. The seed’s maximum area was initially defined by the size of the vegetation community occurrence as determined in the field. The actual seed was then defined by increasing the spectral distance iteratively until the spectral signature collected within the seed generated a covariance matrix that could be inverted, a requirement for the maximum likelihood decision rule used later in the actual classification.

The seed shape and location were checked against field notes and maps, and by direct interpretation of the seed in the image on the screen, in conjunction with the terrain models. Each seed was saved in a signature file with its field plot number, mean values for each image band, variance, number of pixels that were used to create the seed, and minimum and maximum values.

Supervised Classification

Statistics gathered in the seeding process were used to perform a supervised classification. Supervised classifications are based on a maximum likelihood decision rule containing a Bayesian classifier that uses probabilities to weight the classification towards particular classes. In this study the probabilities were unknown, so the maximum likelihood equation (Eq. 6) for each of the classes is given as:

$$D = [0.5\ln(\mathrm{cov}_c)]-[0.5(X-M_c)^T * (\mathrm{cov}_c^{-1})*(X-M_c)] \quad (\textbf{\textit{Eq. 6}}),$$

where **D** is the weighted distance, $\mathbf{cov_c}$ is the covariance matrix for a particular class, **X** is the measurement vector of the pixel, $\mathbf{M_c}$ is the mean vector of the class and $^{\mathbf{T}}$ is the matrix transpose function (ERDAS 1997). Each pixel is then assigned to the class with the lowest weighted distance. This technique assumes the statistical signatures have a normal distribution.

This decision rule is considered the most accurate, because it not only uses a spectral distance (as the minimum distance decision rule), but it also takes into account the variance of each of the signatures. The variance is important when comparing a pixel to a signature representing, for example, a blue grama/hairy grama grass community, which might be fairly heterogeneous, to a water class, which is more homogeneous.

To locate problems, informal accuracy checking was used based on field data, air photos, personal knowledge of a site and other ancillary data. If a distribution problem with a seed was detected, the seed was rechecked to insure it was properly modeling the vegetation type and landscape. This preliminary map had as many map classes as seeds used to develop it.

Draft Final Map

To create the draft final map, a filtering process was applied to create a minimum map unit polygon size of 400 square meters (4,306 square feet). The procedure eliminates the “speckle” created by spatially solitary map units that have less than 100 contiguous pixels. The eliminated areas were then filled with the majority MU found in the surrounding cells.

No attempt was made to classify buildings, pavement, concrete, or lawns due to the heterogeneity of reflecting surfaces. A few seeded classes did map features such as roadside trees very well and were used in the classification. Roads in vector format were placed directly onto the map to provide for their classification.

The 15 MUs in the draft final map were grouped together based on floristic composition, landscape position, spatial contiguity and spectral similarity; i.e., floristically similar seed classes, which had similar landscape positions and were spatially close were grouped into a map unit. This iterative process was based on informal accuracy checking continued until all seed classes were grouped into the most consistent and accurate map units

Final Map Field Data Survey

We made a second field trip (October 11-12, 2001) to refine the vegetation map units and perform a qualitative check of the draft map accuracy. We developed a set of field maps using the draft LPCH habitat maps, using USGS 7.5' digital quadrangle maps and previous plot sites as overlays. Of particular interest were areas within BLM lands that had not been previously visited. We also visited a set of predetermined locations where the accuracy of the map units was in question. Map unit descriptions and a representative photograph of all the draft map units were used as a key for determining the map unit designation of each site visited.

Large areas of relatively homogeneous map units were selected to visit in the field. Using a GPS unit to accurately locate each site, a quick, qualitative assessment of the map unit was determined by keying the site to the map unit descriptions and pictures. If the site visited did not exactly match the map unit descriptions, either (a) an adjustment to the map unit description was made to accommodate elements missed in the previous field trip, or (b) in the case of an inaccurate map unit, notes were taken to create a new 'seed' to reclassify the map. In either case, a GPS point was recorded, the map was annotated, and notes were taken.

Final Map Classification

Based on the second field trip, we made changes to the map unit descriptions, the designations of their aggregate community types, and spatial distributions. For example, we recognized a more significant mesquite component to a particular short-grass grassland class that contained honey mesquite. Another change involved differentiating the tall grass map units dominated by sand bluestem from the mid-grasses dominated by little bluestem and other mid-grasses. Previously, some of the mid-grasses (e.g., little bluestem) had been grouped with the tall-grass dominated units. We determined that two of the original field plots used in the classification did not result in an accurate spatial distribution; therefore, these were deleted from the statistics used to classify the imagery.

In place of one of these field plots, a new seed was generated based on the findings of the second field trip. The entire supervised classification procedure was again repeated, creating the final map.

Results

Fifteen map units (Figure 1, Table 2) represent vegetation assemblages or community types repeated across the study area. The plant communities are relatively homogeneous with respect to vegetation and landscape features such as dunes. The community concept encompasses both the dominant species (those that cover the greatest area) and diagnostic species (those found consistently in some vegetation types but not others). These community types correspond roughly to the U.S. National Vegetation Classification (USNVC) System. The USNVC System has been adopted by the Federal Geographic Data Committee (FGDC) as an information and classification standard to be used by federal agencies, with additional refinements to be adopted in the future in cooperation with the Ecological Society of America (Grossman et al. 1998). The USNVC System uses a hierarchical structure, beginning at the lowest level with growth form and structure (Class, e.g;, tree, shrub, grass) to the highest level, the Association (or Community, e.g., *Quercus havardii*/*Schizachyrium scoparium* Shrubland), with various levels in between**.** A key to the nomenclature used to assign a community name follows:

- A hyphen ("-") indicates species occurring in the same Class (strata)
- A slash ("/") indicates species occurring in different strata.
- Species that occur in the uppermost stratum are listed first, followed successively by those in lower strata.
- Order of species names generally reflects decreasing levels of dominance, constancy, or indicator value.
- Parentheses around species name indicate species less consistently found either in all associations of an alliance, or in all occurrences of an association.

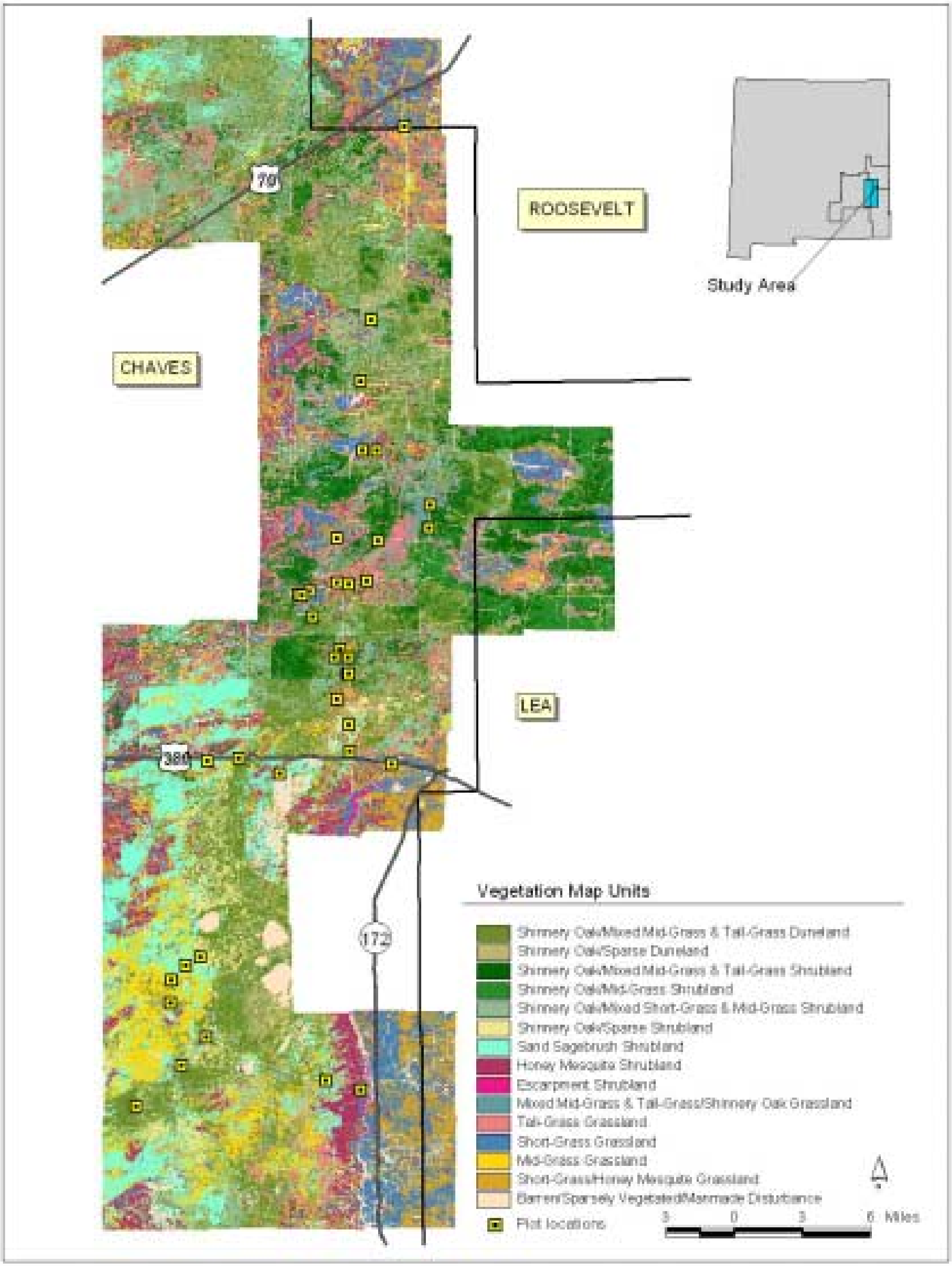
The system focuses on existing, rather than potential, vegetation, which provides a baseline standard for use in monitoring vegetation status and its response to management (Grossman et al. 1998). .

Detailed descriptions of each map unit are provided in Appendix A. The dominant plant communities and the communities considered inclusions included within each map unit are provided. Communities designated as inclusions were either too small to differentiate into separate map units or are considered very similar to the dominant plant communities represented in the map unit. Map unit definitions were based on the biology of LPCH and the land management in the study area (see Discussion).

Table 2. Vegetation map units. Area calculated using ERDAS Imagine software.

MU#	MU Description	Totals	Ac.	Ha.
1	Shinnery Oak/Mixed Mid-Grass & Tall-Grass Duneland		78,076	31,596
2	Shinnery Oak/Sparse Duneland		24,255	9,816
3	Shinnery Oak/Mixed Mid-Grass & Tall-Grass Shrubland		35,479	14,358
4	Shinnery Oak/Mid-Grass Shrubland		15,061	6,095
5	Shinnery Oak/Mixed Short-Grass & Mid-Grass Shrubland		56,709	22,949
6	Shinnery Oak/Sparse Shrubland		10,979	4,443
	Total shin-oak habitat (ac)	220,559		
	Total shin-oak habitat (ha)	89,257		
7	Sand Sagebrush Shrubland		40,248	16,288
8	Honey Mesquite Shrubland		30,986	12,540
9	Escarpment Shrubland		585	237
	Total non shin-oak shrubland (ac)	71,819		
	Total non shin-oak shrubland (ha)	29,065		
10	Mixed Mid-Grass & Tall-Grass/ Shinnery Oak Grassland		7,276	2,944
11	Tall-Grass Grassland		33,446	13,535
12	Short-Grass Grassland		34,648	14,021
13	Mid-Grass Grassland		26,336	10,658
14	Short-Grass/Honey Mesquite Grassland		24,478	9,906
	Total grassland (ac)	126,184		
	Total grassland (ha)	51,064		
15	Barren/Sparsely Vegetated/Manmade Disturbance		25,432	10,292
	Total (ac)	587,948		
	Total (ha)	169,386		

Figure 1. Vegetation map of Lesser Prairie-chicken habitats in the Caprock Wildlife Habitat Management Area, showing vegetation plot locations



Although field sampling was insufficient to allow comparative statistical analysis of MUs, differences in shrub and grass density among shinnery oak communities are apparent (Figure 2). In general (five of six), shrublands had higher shrub cover than grass cover. For the exception, MU 4, data were available from only one 20 X 20 m plot, and therefore cover values may not be reflective of the entire MU. We compared these data to data collected on short transects within 10 feet of nests (Johnson 2000). The units of the latter data set are percent basal cover (Figure 3), as opposed to canopy cover; thus, the studies are not quantitatively comparable. However, it is interesting that the two datasets show dominance of shrubs over grasses in MUs 1-3. The other two MUs represented in both datasets do not agree with respect to dominant vegetation type. This may occur because only one sample was taken in either or both datasets, or because nests are sited in areas with greater cover than the pasture as a whole. The discrepancy between the datasets suggests that canopy cover values in the MU descriptions may be more accurate in MUs with multiple 20 X 20 m data plots.

Figure 2. Mean percent canopy cover of grass versus shrub in shin-oak-containing map units of LPCH habitat on CWHMA. MUs 1-2 are dune shrublands; MUs 3-6 are shrublands; MU 12 is grassland. Numbers in parenthesis indicate the number of plots used to develop the mean cover values.

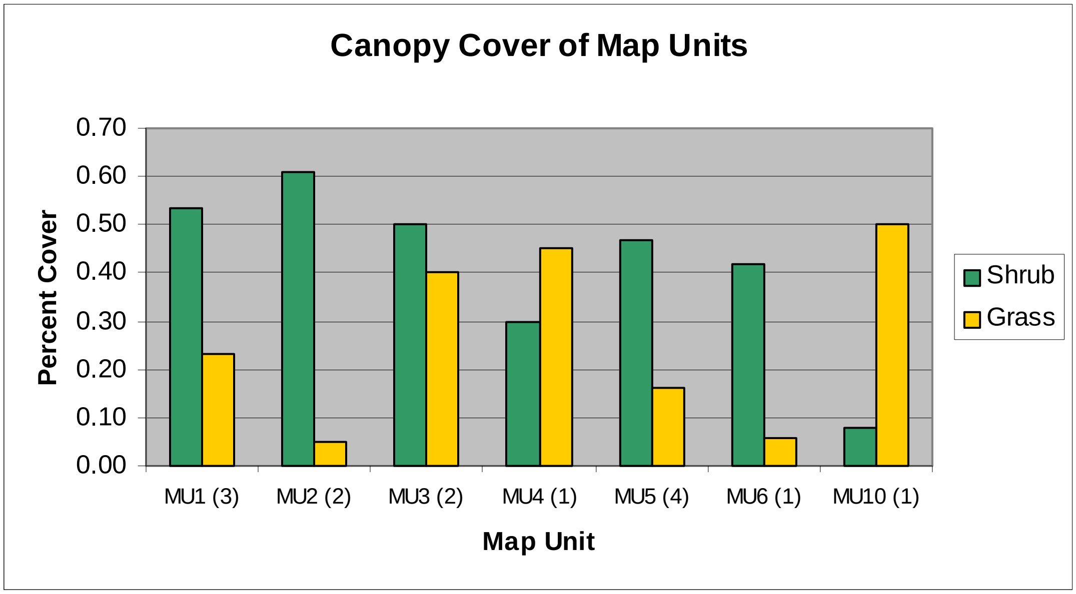
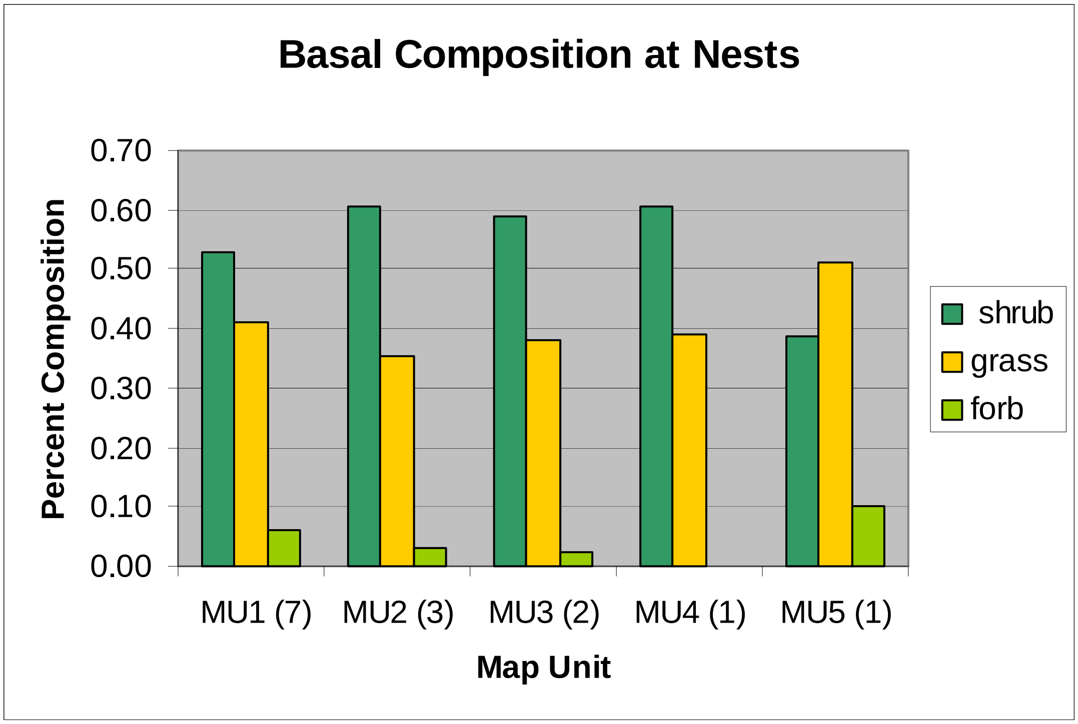


Figure 3. Mean percent basal composition of vegetation within ten feet of nests, by MU. Data from Johnson 2000. MU for each nest was determined using GIS. Numbers in parentheses indicate number of nests at which data were collected.



Discussion

We defined MUs based on two different kinds of information. The technical information that generally goes into vegetation mapping is detailed in Methods, above. The unique feature of this particular map is that it depicts habitats according to their expected use by Lesser Prairie-chickens.

Given this goal, it is clear from existing literature (e.g., Davis et al. 1979, Giesen 1998) and our own studies (Johnson 2000) that the shinnery oak communities are the most important communities on the study area, because they are heavily used for nesting, brood rearing, and wintering (see Introduction for additional references and review). The primary challenge in constructing a habitat map is partitioning this general vegetation type into relevant and realistic subdivisions. Several types of information guided the MU definitions for this map.

First, LPCH use dunes and inter-dune areas differently. For example, in one study, 34 of 37 nests at the CWHMA were placed in dunes (Davis et al. 1979). LPCH reportedly prefer to place nests on north- or northeast-facing slopes, for protection from prevailing southwest winds and direct sun. (Davis et al. 1979). Ten of 14 nests on the CWHMA (nest locations from Johnson 2000) occurred in the two duneland MUs (MU1 and MU2), and 14 of 14 nests occurred in MUs dominated by shin-oak. In addition, the sandy soil layers are deeper on dunes, allowing greater shrub heights on the dunes than in inter-dune areas. Brood rearing habitats have taller shrubs and greater canopy cover than surrounding areas (Davis et al. 1979, Giesen 1994, Mote et al. 1999 and references therein), and taller trees and shrubs are used for shade in summer (Copelin 1963). It is therefore important to distinguish the duneland from the shrubland shinnery oak communities.

Second, height and density of forbs and residual grasses are greater at nest sites than on adjacent rangeland (Giesen 1998, Mote et al. 1999 and references therein). Nest success is positively correlated with height, density, and abundance of residual grasses, especially sand bluestem, near nests (Riley 1978, Davis et al. 1979, Riley et al. 1992). Brood foraging sites are typically more shrubby and less grassy than overall vegetation, presumably because insect availability is greater in shrubbier areas. Thus, it is important to differentiate habitats that differ in shrub versus grass density.

Third, some grass species provide better nesting habitat than others; e.g., nesting success was higher for nests sheltered by sand bluestem plants (Davis et al. 1979). Our habitat classification contains six shin-oak-dominated MUs (MUs 1-6). These MUs differ in the relative composition of shin-oak, topography (dunes versus flat areas), and the grass species associated with the shin-oak. The associated grasses range from the high-quality sand bluestem to moderately good little bluestem to poorer-quality three-awn (Davis et al. 1979). Thus, division into MUs based on the grass species associated with the shin-oak identifies nesting habitats of differing quality.

In addition, percent composition of grasses, grass height, and cover value of grasses can vary in the study area, depending on stocking rates of livestock and rainfall amounts. It is useful to know how plant communities vary with livestock management practices. For purposes of this map, grass composition is most important in the shinnery oak communities preferred by the LPCH. For that reason, some grassland communities were aggregated in MUs that are rarely used by the birds because they contain few or no shrubs (MUs 11-14).

Pasture-scale treatment with the herbicide tebuthiuron occurred in the study area from the 1980s until the early 1990s. The Roswell BLM Field Office has supported research to determine whether LPCH use these treated habitats (which contain substantially less shin-oak cover than untreated areas) differently from untreated areas (Johnson 2000). This map will facilitate answers to this and related management questions. Nearly twenty years after treatment, differences in vegetation composition between treated and untreated pastures remain, providing further rationale for distinguishing shrub-dominated from grass-dominated habitats.

A formal accuracy assessment for the map is planned but was not in the scope of work for this project. There are several reasons why an accuracy assessment should be completed:

1. The budget for this map limited the number of field plots to only 15, 20 X 20m plots and 28 quick plots. Plots were concentrated in known preferred LPCH nesting habitat, and those MUs sampled several times are expected to be more accurately defined and mapped than MUs which are little-used by LPCH.
2. Because we expect more errors in some MUs than in others, an accuracy assessment will allow us to evaluate the usefulness of the map for different purposes. For example, if the map is highly accurate in MUs preferred by LPCH but not areas preferred by other species, its use may be limited to planning for LPCH.
3. Tests of hypotheses or models of LPCH habitat preference based on the map will only be as reliable as the map is. Before the map can be used for these purposes, its accuracy must be known.
4. Accuracy assessment will provide valuable information regarding methodology and sampling intensity in case the map is revised in the future or for future efforts at similar maps.

Finally, we include a word about appropriate use of the map. The minimum map unit size (resolution) is 20 X 20 m, meaning that the map units were designed to be optimally useful at the 1:24,000 scale. Use of the map at finer scales is not recommended. Future refinement of map unit categories at a larger scale might be possible but would not necessarily be appropriate for most natural resource management applications. This map is the first vegetation map classified specifically as a habitat map for the LPCH. As such, there were bound to be errors in its creation. Formal accuracy assessment and use of the map for management and planning or scientific studies will reveal its strengths and weaknesses. While we expect the map to be useful for managing wildlife species other than the Lesser Prairie-chicken, MUs were designed with the LPCH in mind. Exactly how applicable the map will be for other species remains to be seen.

REFERENCES

Ahlborn, G. 1980. Brood-rearing habitat and fall-winter movements of Lesser Prairie Chickens in Eastern New Mexico. M.S. thesis, Wildlife Science, New Mexico State University, Las Cruces, New Mexico. 73pp.

Bailey, R. G. 1998. Ecoregions map of North America: Explanatory note. Miscellanheous Publication no. 1548. Washington, D.C.: U.S. Department of Agriculture, Forest Service. 10 pp.

Bednarz, J.C., T. Hayden, and T. Fischer. 1990. The raptor and raven community of the Los Medanos Area in Southeastern New Mexico: A unique and significant resource. In *Ecosystem management: Rare Species and significant habitats*, ed. R.S. Mitchell, C.J. Sheviak, and D.J. Leopold, pp. 92-101. Proceedings of the 15th Annual Natural Areas Conference. Albany, N.Y.: New York State Museum Bulletin No. 471.

Bennett, I. 1986. Wind. In *New Mexico in Maps*, ed. Jerry L. Williams, p. 50-51.

Copelin, F.F. 1963. The Lesser Prairie Chicken in Oklahoma. Okla. Wildl. Conserv. Dep. Tech. Bull. 6.

Correl, D.S. and M.C. Johnson. 1979. *Manual of the Vascular Plants of Texas*. Renner, Tex.: Texas Research Foundation.

Davis, C.A., T.Z. Riley, R.A. Smith, H.R. Suminski, and D.M. Wisdom. 1979. Habitat evaluation of Lesser Prairie Chickens in eastern Chaves County, New Mexico. New Mexico Agric. Experi. Sta., Las Cruces.

Davison, V.E. 1940. An 8-year census of Lesser Prairie Chickens. *Journal of Wildlife Management*. 4:55-62.

Dhillion, S.S., M.A. McGinley, C.F. Friese, and J.C. Zak. 1994. Construction of sand shinnery oak (*Quercus havardii*) communities of the Llano Estacado: Animal disturbances, plant community structure and restoration. *Restoration Ecology* 2:51-60.

Dhillion, S.S. and M.H. Mills. 1999. The sand shinnery oak (*Quercus havardii*) communities of the Llano Estacado: History, Structure, Ecology, and Restoration. In *Savannas, Barrens, and Rock Outcrop Plant Communities of North America*, p. 262-274, (eds.) Anderson, R., J. Fralish, and J. Baskin. Cambridge University Press. Cambridge. 470 p.

ERDAS 1997. *ERDAS Field Guide*, 4th Edition, ERDAS, Inc. Atlanta, Georgia. 656 p.

Everitt, J.H., D.E. Escobar, R. Villarreal, M.A. Alaniz, and M.R. Davis. 1993. Canopy light reflectance and remote sensing of shin oak (*Quercus havardii*) and associated vegetation. *Weed Science* 41:291-297.

French, R. 2001. Rand French, Bureau of Land Management, Roswell Field Office.

Garmin Corporation 2001. http://www.garmin.com/

Giesen, K. 1994. Movements and nesting habitat of Lesser Prairie-Chicken hens in Colorado. Southwest. Nat. 39:96-98.

Giesen, K.M. 1998. The Lesser Prairie-chicken. In *Birds of North America*, (eds.) A. Poole and G. Gill. Philadelphia: The Academy of Natural Sciences, Washington, D.C.: The American Ornithologists' Union.

Grossman, D.H., D. Faber-Langendoen, A.S. Weakley, M. Anderson, P. Bourgeron, R. Crawford, K. Goodin, S. Landaal, K. Metzler, K. Patterson, M. Pyne, M. Reid, and L. Sneddon. 1998. *International Classification of Ecological Communities: Terrestrial Vegetation of the United States, Volume 1. The National Vegetation Classification System: Development, Status, and Applications*. The Nature Conservancy, Arlington, Virginia, USA. 126 pp.

Haukos, D.A and L.M. Smith. 1989. Lesser Prairie Chicken nest site selection and vegetation characteristics in tebuthiuron-treated and untreated sand shinnery oak in Texas. *Great Basin Naturalist* 49:624-626.

Holland, M. 1994. Disturbance, environmental heterogeneity, and plant community structure in a sand shin-oak community. Masters thesis, Texas Tech University, Lubbock. *In* Peterson, R. and C.S. Boyd 1998. Ecology and management of sand shinnery communities: a literature review. USDA Forest Service. RMRS-GTR-16. Rocky Mountain Research Station, Fort Collins, CO. 44pp.

Johnson, K. and H. Smith. 1998. Radio telemetry study of Lesser Prairie Chicken habitat use in the Caprock Wildlfe Habitat Management Area. New Mexico Natural Heritage Program technical report to the Bureau of Land Management, Roswell Field Office.17pp.

Johnson, K. and H. Smith. 1999. Lesser Prairie-chicken habitat use on the Sand Ranch and population status in the Caprock Wildlfe Habitat Management Area, 1999. New Mexico Natural Heritage Program technical report to the Bureau of Land Management, Roswell Field Office.19 pp.

Johnson, K. 2000. Lesser Prairie-Chicken Habitat Use on the Sand Ranch and Population Status in the Caprock Wildlife Habitat Management Area. 24pp. Unpublished.

Lenfesty, C. 1980. Soil Survey of Chaves County, New Mexico Northern Part. United States Department of Agriculture, Soil Conservation Service, in cooperation with the United States Department of the Interior, Bureau of Land Management and the New Mexico Agricultural Experiment Station, 224 pp.

Lillesand, T.M. and R.W. Kiefer, 1987. *Remote sensing and image interpretation*, 2nd Edition, New York: John Wiley & Sons, 721 pp.

Merchant, S.S. 1982. Habitat-use, reproductive success, and survival of female Lesser Prairie Chickens in two years of contrasting weather. M.Sc. thesis, New Mexico State Univ., Las Cruces.

Mote, K.D., R.D. Applegate, J.A. Bailey, K.E. Giesen, R. Horton, and J.L. Sheppard. 1999. Assessment and Conservation Strategy for the Lesser Prairie-chicken (*Tympanuchus pallidicinctus*). Emporia, KS: Kansas Department of Wildlife Parks.

Muller, C.H. 1951. The oaks of Texas. *Renner: Contributions from the Texas Research Foundation* 1:21-323.

New Mexico Department of Game and Fish. 1996. List of Threatened and Endangered Species. Title 19 New Mexico Administrative Code Chapter 33 Part 1 (19 NMAC 33.1).

Peterson, R. and C.S. Boyd. 1998. *Ecology and management of sand shinnery communities: a literature review*. Gen. Tech. Rep. RMRS-GTR-16. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 44p.

Pettit, R.D. 1978. Soil-vegetation relationships on dune sands. Research Highlights 1977 Noxious Brush and Weed Control; Range, Wildlife, & Fisheries Management 8:10. Lubbock: Texas Tech University, College of Agricultural Sciences and Natural Resources.

Pettit, R.D. 1979. Effects of picloram and tebuthiuron pellets on sand shinnery oak communities. *Journal of Range Management*. 32:196-200.

Pettit, R.D. 1986. Sand shinnery oak: control and management. Management Note 8. Lubbock: Texas Tech University, Range and Wildlife Management. 5 pp.

Riley, T.Z. 1978. Nesting and brood rearing habitat of Lesser Prairie Chickens in southeastern New Mexico. M.Sc. thesis, New Mexico State University, Las Cruces.

Riley, T.Z., C.A. Davis, M. Ortiz, and M.J. Wisdom. 1992. Vegetative characteristics of successful and unsuccessful nests of Lesser Prairie-chickens. Journal of Wildlife Management 56:383-387.

Riley, T.Z. and C.A Davis. 1993. Vegetative characteristics of Lesser Prairie-chicken brood foraging sites. Prairie Naturalist 25:243-248.

Riley, T.Z., C.A. Davis, and R.A. Smith 1993a. Autumn and winter foods of the Lesser Prairie-chicken (*Tympanuchus pallidicinctus,* Tetraonidae). Great Basin Naturalist 53:186-189.

Riley, T.Z., C.A. Davis, and R.A. Smith 1993b. Autumn-winter habitat use of lesser prairie chickens (*Tympanuchus pallidicinctus*, Tetraonidae). *Great Basin Naturalist* 53:409-411.

Scifres, C.J. 1972. Sand shinnery oak response to silvex sprays of varying characteristics. *Journal of Range Management* 25:464-466.

Sears, W.E., C.M. Britton, D.B. Wester, R.D. Pettit. 1986. Herbicide conversion of a sand shinnery oak (*Quercus havardii*) community: effects on biomass. *Journal of Range Management* 39(5):399-403.

Sullivan, J.C. 1980. Differentiation of sand shinery oak communities in West Texas. M.S. thesis, Texas Tech University, Lubbock, Tex. 100 pp.

Taylor, M.A. and F.S. Guthery. 1980. Fall-winter movements, ranges, and habitat use of lesser prairie chickens. *Journal of Wildlife Management* 44:521-524.

Vines, R.A. 1982. *Trees of North Texas*. Austin, Tex.: University of Texas Press.

Wickland, Diane E. 1991. Mission to Planet Earth: The ecological perspective, *Ecology*, 72(6), pp.1923-1933.

Wiedeman, V.E. and W.T. Penfound. 1960. A preliminary study of the shinnery in Oklahoma. *The Southwestern Naturalist* 5(3): 117-122.

Wilhite, A.T., Jr. 1960. Range Management. In *Texas Soil Survey*, Soil Survey Staff, USDA Soil Conservation Service, Yoakum Co. Washington D.C.: U.S. Government Printing Office.

Woodward, A.J., S.D. Fuhlendorf, D.M. Leslie, Jr., and J. Shackford. 2001. Influence of landscape composition and change on Lesser Prairie-chicken (*Tympanuchus pallidicinctus*) populations, Am. Midl. Nat. 145:261-274.

Appendix A. VEGETATION MAP UNIT DESCRIPTIONS

VEGETATION MAP UNITS

MU#	MU DESCRIPTION	AC	HA
1	**Shinnery Oak/Mixed Mid-Grass & Tall-Grass Duneland**	78,076	31,596

This MU contains semi-stabilized, 2-10 m- (6-32 ft) tall dunes dominated by shin-oak. The eolian soils are predominantly the Roswell series, described as excessively well drained, light brown, fine sands (Lenfesty 1980). Total vegetative cover ranges between 66 and 86%, with a shrub component between 50 and 70%, and a grass component between 15 and 30%. Bare soil averages 30%. Little bluestem is typically the dominant grass, but sand bluestem and purple threeawn (*Aristida purpurea*) are consistently found within this map unit. Soapweed yucca (*Yucca glauca*) and sand sagebrush, making up less than 5% of total cover, are also found consistently within this map unit. To the south, giant dropseed (*Sporobolus giganteus*) begins to dominate the grass cover. This MU represents the plant community most often utilized by the LPCH for nesting (Johnson unpublished).

Shinnery Oak/Little Bluestem Duneland	69%
Inclusions:	
Shinnery Oak/Giant Dropseed Duneland	31%

MU#	MU DESCRIPTION	AC	HA
2	**Shinnery Oak/Sparse Duneland**	24,255	9,816

This MU is a transition community between MU #1 and barren dunelands. Roswell series sands make up most of the soils within this MU (Lenfesty 1980). It consists of dunelands dominated by shin-oak, with total vegetative cover ranging between 67 and 69%, a shrub component between 60 and 62%, and a grass component averaging 5%. Bare soil averages 33%. Soapweed yucca and purple threeawn are consistently found within this map unit. This community is found in association with the barren dunelands (MU #15) and sand sagebrush shrublands (MU #7) scattered throughout the study area, but it is concentrated along the downslope of the Caprock escarpment. The complex terrain has a varied vegetation mosaic interspersed throughout with pockets of nearby plant community types. This MU is utilized by the LPCH for nesting and brood-rearing. Under proper management, mid- and tall-grasses could increase, which would improve the habitat for LPCH.

Shinnery Oak/Sparse Duneland	100%

MU#	MU DESCRIPTION	AC	HA
3	**Shinnery Oak/Mixed Mid-Grass & Tall-Grass Shrubland**	35,479	14,358

This MU is similar to the Shinnery Oak/Mixed Mid-Grass & Tall-Grass Duneland, but the terrain consists of fewer, smaller dunes and Faskin series sand sheets (Lenfesty 1980). Total vegetative cover ranges between 90 and 96%, with a shrub component between 45 and 55%, and a grass component that averages 40%. Bare soil ranges from 20 to 35%. The total vegetative cover is higher and grass cover is considerably higher in this MU than in the duneland community that contains similar species (MU#1). The dominant grass is little bluestem with less but locally-dominant cover of hairy grama, sand bluestem, and purple threeawn. The height of shin-oak on the sand sheets is typically half that in the duneland communities. This MU provides good nesting and brood-rearing habitat and is heavily utilized by the LPCH (Johnson 2000).

Shinnery Oak/Little Bluestem –Hairy Grama	100%

MU#	MU DESCRIPTION	AC	HA
4	**Shinnery Oak/ Mid-Grass Shrubland**	15,061	6,095

This MU is characterized by rolling to flat Faskin series sand sheets and sandy soils (Lenfesty 1980) dominated by shin-oak and mid-grasses. Total vegetative cover averages 75%, with a shrub component of 30% and a grass component of approximately 45%. Bare soil averages 30%. Shin-oak accounts for about 25% of cover. This community is found in the central part of the study area and increases to the east. Within the study area, the dominant grass is New Mexico needlegrass (*Stipa neomexicana*), but sand dropseed may also dominate in portions of this MU, especially to the east. This MU is considered a more degraded version of MU #3, because the shin-oak is considerably less dense and the grasses are the less drought-tolerant mid-grasses. The higher grass to shin-oak ratio is less suitable for LPCH brood-rearing habitat. This MU is utilized by the LPCH within the study area for nesting and foraging.

Shinnery Oak/New Mexico Needlegrass	100%

VEGETATION MAP UNITS

MU#	MU DESCRIPTION	AC	HA
5	**Shinnery Oak/Mixed Short-Grass & Mid-Grass Shrubland**	56,709	22,949

This community is found on flat to rolling eolian sandy plains with few dunes. This MU generally occurs in close proximity to treated areas. Soils are brown fine and loamy fine sand of the Faskin series (Lenfesty 1980). Total vegetative cover ranges between 63 and 77%, with a shrub component between 45 and 53%, and a grass component between 10 to 30%. Bare soil ranges from 25 to 30%. Grasses are dominated by purple threeawn and in some areas black grama (*Bouteloua eriopoda*). Little bluestem, sand bluestem, hairy grama, soapweed yucca, and sand sagebrush are found as minor components throughout this unit. This MU is utilized occasionally by the LPCH for nesting and foraging (Johnson 2000).

Shinnery Oak/Purple Threeawn Shrubland	69%
Inclusions:	
Shinnery Oak/Black Grama Shrubland	31%

MU#	MU DESCRIPTION	AC	HA
6	**Shinnery Oak/Sparse Shrubland**	10,979	4,443

This MU tends to be found on the fringes of the other shinnery oak communities, especially in the southern part of the study area. Soils are brown fine and loamy fine sand of the Faskin series (Lenfesty 1980). Total vegetative cover averages 48%, with a shrub component of approximately 42%, and a grass component of about 6%. Bare soil can be as high as 50%. There is a moderate cover of shin-oak, which tends to average less than 40% of the total cover. Sand sagebrush and purple threeawn comprise less than 10% of the remaining vegetative cover. There is no evidence that LPCH utilize this MU for nesting or brood-rearing. This may be due to the absence of grasses such as little bluestem and sand bluestem.

Shinnery Oak/Sparse Shrubland	100%

VEGETATION MAP UNITS

MU#	MU DESCRIPTION	AC	HA
7	**Sand Sagebrush Shrubland**	40,248	16,288

This MU is found on flat to rolling eolian plains on the edges of barren dunelands and in shinnery oak habitat that has been treated with tebuthiuron. Sand sagebrush is the dominant shrub component within this MU, comprising 10 to 50% of the vegetative cover. This MU has a high percentage of bare ground (ca. 60%) and low litter (7 to 10%) in comparison to shin-oak shrublands, which have approximately 30% bare ground and 20 to 35% litter. Soapweed yucca can be found scattered within this MU and can approach 10% of the total cover. Although sand sagebrush can provide wintering habitat for the LPCH (R. French, pers. comm.), no nesting has been observed within this MU.

Sand Sagebrush / Purple Threeawn Shrubland	64%
Inclusions:	
Sand Sagebrush/Little Bluestem Shrubland	18%
Sand Sagebrush/Sparse Shrubland	18%

MU#	MU DESCRIPTION	AC	HA
8	**Honey Mesquite Shrubland**	30,986	12,540

This MU is dominated by honey mesquite and is found on the western edge of the study area west of the shinnery oak habitats, the toe slopes of the Caprock escarpment, and at the margins and scattered within the short-grass grasslands (MU #12). Soils are typically the Ima series, which are deep, well-drained, yellowish-brown fine sandy loams on gently sloping alluvial material (Lenfesty 1980). Total vegetative cover ranges between 70 and 100%, with a shrub component between 40 and 50%, and a grass component between 40 and 50%. Bare soil can be as high as 30%. The honey mesquite cover ranges from 25 to 45% of the total cover. The dominant grasses found in association with honey mesquite are black grama, blue grama, vine mesquite (*Panicum obtusum*), and bush muhly (*Muhlenbergia porteri*). Soapweed yucca and snakeweed are minor shrub components found consistently in this MU. This is not suitable nesting habitat, and LPCH use it rarely in winter (Davis et al. 1979).

Honey Mesquite/Black Grama Shrubland	68%
Honey Mesquite/Blue Grama Shrubland	20%
Honey Mesquite/Vine Mesquite Shrubland	12%

VEGETATION MAP UNITS

MU#	MU DESCRIPTION	AC	HA
9	**Escarpment Shrubland**	585	237

This smallest of the MUs is found only along the cliffs of the Caprock escarpment. The torriorthent soils on very steep slopes (15% to 30%) are shallow and comprised of calcareous colluvium (Lenfesty 1980). This unit was not sampled for this study. However, according to Lenfesty (1980), the intermixed rock outcrops of sandstone, red shale, and indurated caliche have a diverse assemblage of shrubs and grasses. The shrubs include: *Yucca* spp., honey mesquite, littleleaf sumac (*Rhus microphylla*), wavyleaf oak (*Quercus undulata*), skunkbush sumac (*Rhus trilobata*), and catclaw acacia (*Acacia neovernicosa*) (Lenfesty 1980, Rand French, pers. comm. 2001). The grasses include blue grama, black grama, sideoats grama (*Bouteloua curtipendula*), bush muhly, three-awn, and sand dropseed. Junipers (*Juniperus* sp.) are scattered throughout this MU. Although small, this may be an important habitat providing perches for raptors and taller canopies than found in the rest of the study area. This MU also provides cover for larger game species, such as mule deer (Rand French, pers. comm. 2001).

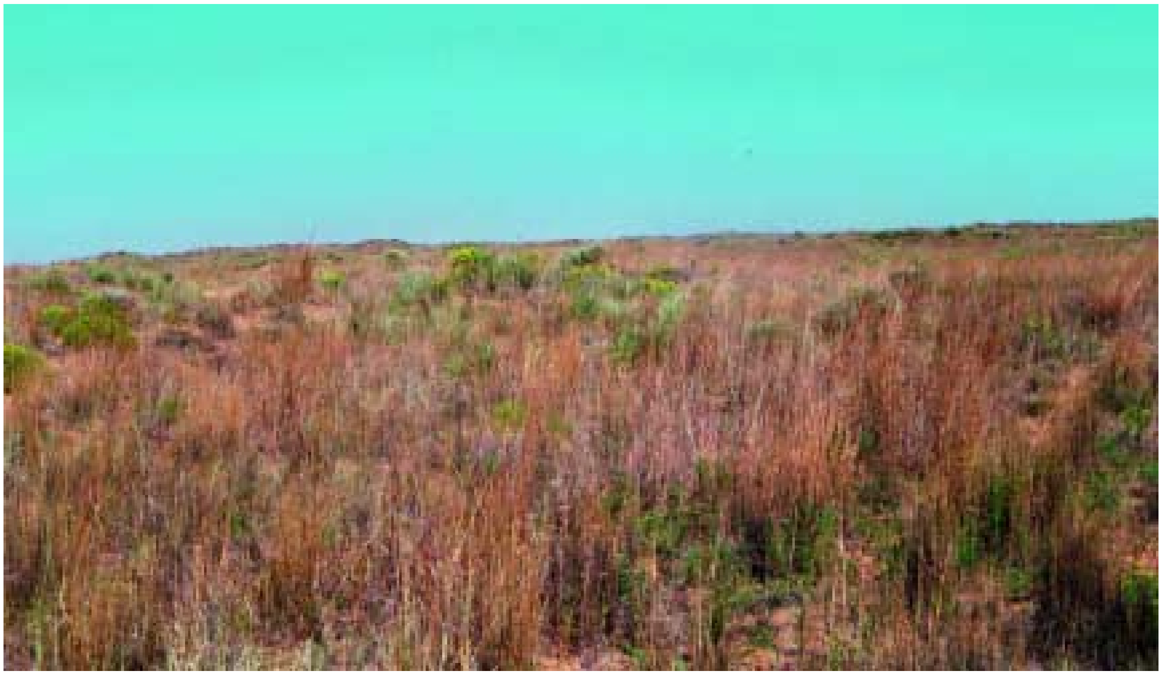
Escarpment Shrubland	100%

MU#	MU DESCRIPTION	AC	HA
10	**Mixed Mid-Grass & Tall-Grass/Shinnery Oak Grassland**	7,276	2,944

This grassland is found on flat or rolling eolian soils and is dominated by little bluestem and sand bluestem, which account for about 59% of the total cover. Soils are brown, fine, and loamy fine sand of the Faskin series (Lenfesty 1980). The shin-oak component ranges from 5 to 10% but may be much lower in some portions of this MU. Soapweed yucca and honey mesquite are found scattered throughout this MU. This MU is typically found in areas that were shinnery oak shrublands and dunelands before treatment with tebuthiuron. Because sparse shinn-oak remains, these may be areas which could be reconverted to LPCH habitat.

Little Bluestem-Sand Bluestem/Shinnery Oak Grassland	100%

MU#	MU DESCRIPTION	AC	HA
11	**Tall-Grass Grassland**	33,446	13,535



This grassland is found on flat and rolling eolian plains dominated by little bluestem in the shallower sandy areas, with sand bluestem dominating the deeper sands. Soils are brown, fine, and loamy fine sand of the Faskin series (Lenfesty 1980). These are tebuthiuron-treated areas where shin-oak is almost completely absent. Instead, soapweed yucca tends to be the dominant shrub, in some places approaching 20% cover.

Sand Bluestem/Soapweed Yucca Grassland	51%
Sand Bluestem-Little Bluestem/Soapweed Yucca Grassland	25%
Sand Bluestem Grassland	24%

MU#	MU DESCRIPTION	AC	HA
12	**Short-Grass Grassland**	34,648	14,021

This grassland community is dominated by black grama and in some areas, blue grama. The unit is found in large inter-dune plains or swales and up on the Caprock. Although it represents different landscape positions, both of these areas are on flat terrain with shallow, calcareous soils. Black grama and blue grama grasslands within the inter-dune plains or swales are on the Chispa and Blakeney soil series. The Chispa are well drained, brown, fine sandy loams that originated in calcareous alluvial and lacustrine sediments, often in depressions (Lenfesty 1980). The Blakeney series are shallow, well-drained, brown fine sandy loams that have a layer of indurated caliche below the surface (Lenfesty 1980). The Blakeney series originated in calcareous alluvial and eolian deposits (Lenfesty 1980). The upland grasslands on the Caprock are dominated by the Kimbrough soil series, on flat to gently sloping, brown, fine sandy loam surfaces. The moderately calcareous soils overlay indurated caliche (Lenfesty 1980). Black grama, which dominates the typical Chihuahuan Desert grassland, increases in dominance further to the south and below the Caprock. Blue grama, which dominates the typical Great Plains grassland, becomes more dominant to the north and may be dominant on top of the Caprock, but this area was not sampled. The convergence of the black grama and blue grama grasslands is indicative of a transition area between two large biogeographic provinces; ie., the Great Plains and Chihuahuan Desert. Snakeweed and honey mesquite are consistently found scattered throughout this MU. Tobosa grass (*Hilaria mutica*) dominates in more clay-rich playas and drainage areas found on the Alama soil series. The Alama series are well-drained soils formed in alluvium and underlain by strongly calcareous clay and clay loams (Lenfesty 1980). Prairie dog towns and leks are found in this MU.

Black Grama-Blue Grama/Soapweed Yucca Grassland	45%
Blue Grama-Black Grama Grassland	33%
Black Grama-Purple Threeawn Grassland	16%
Black Grama-Vine Mesquite Grassland	6%

MU#	MU DESCRIPTION	AC	HA
13	**Mid-Grass Grassland**	26,336	10,658

This MU is dominated by little bluestem and purple threeawn grasses that typically co-occur with soapweed yucca. These treated areas are found in the flats and depressions west of the shinnery oak MUs. Soils are brown, fine, and loamy fine sand of the Faskin series (Lenfesty 1980). Tobosa grass increases in depressions, with soapweed yucca occurring on sandier soils. Honey mesquite and sand sagebrush are also components of this community and can be locally dominant. Although not common, patches of shin-oak can also be found in this MU.

Little Bluestem/Soapweed Yucca Grassland	42%
Little Bluestem-Purple Threeawn/Soapweed Yucca Grassland	32%
Purple Threeawn/Soapweed Yucca Grassland	26%

MU#	MU DESCRIPTION	AC	HA
14	**Short-Grass/Honey Mesquite Grassland**	24,478	9,906

This map unit is dominated by purple threeawn and co-occurs with other short grasses such as Fall's witchgrass (*Digitaria cognata*), blue grama, tobosa grass, and hairy grama. To a lesser extent, honey mesquite, cholla (*Opuntia imbricata*), sand sagebrush, soapweed yucca, New Mexico needlegrass, and little bluestem are scattered throughout. This unit is found in association with MU 12 (Short-Grass Grassland) within large inter-dune plains or swales and up on the Caprock. The largest occurrences are in the southern part of the image on the Caprock. Within the inter-dune plains the relatively high percentage of forbs (15%) is dominated by collegeflower (*Hymenopappus flavescens* var. canotomentosus). On the Caprock, the unit can have a high occurrence of snakeweed and cholla. This MU is a highly disturbed grassland.

Purple Threeawn-Hairy Grama	51%
Tobosa grass-Blue Grama/Honey Mesquite	49%

VEGETATION MAP UNITS

MU#	MU DESCRIPTION	AC	HA
15	**Barren/Sparsely Vegetated/Manmade Disturbance**	25,432	10,292

This MU is largely composed of dune fields, escarpment outcrops, barren swales and playas, roads and drill pads. Although vegetation is sparse to non-existent, it can include scattered canopies of trees such cottonwood and elm in the dunelands, along roads, surrounding wells, and old home sites.