

ENVIRONMENTAL AND MANAGEMENT EFFECTS
ON PLANT SPECIES COMPOSITION WITHIN
ECOLOGICAL SITES OF THE BLACK
KETTLE NATIONAL GRASSLAND
IN WESTERN OKLAHOMA

By

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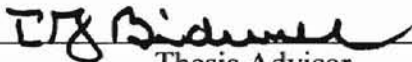
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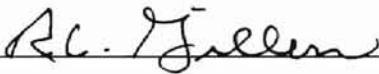
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Chapter I

Introduction

Rangeland condition is currently evaluated using a value-laden system. The resource is judged as excellent, good, fair, or poor; or as low seral, mid seral, high seral, potential natural. This is based on a hypothetical optimum, the climax plant community. This methodology fails to put the emphasis on management objectives and recognize the historical factors that impacted the ecosystem. It focuses management on trying to achieve a hypothetical optimum that may or may not ever be obtained.

Why should rangeland managers try to manage for a single vegetation state, potential natural, or climax? This is like asking timber producers to manage for old growth timber saw logs when their objective is pulp wood. Next to soil stability, the most important aspect should be the manager's goals (Task Group on Unity in Concepts 1995). For example, if a manager is interested in upland game bird management such as bobwhite quail habitat, then the unit needs to be managed for a mix of successional stages, which can be achieved using the tools of fire and or grazing. What is currently lacking is a schematic that helps connect vegetation responses to management actions.

Our goal is to break the condition assessment process into two distinct steps. The first step is to describe the vegetation and environmental factors and evaluate soil stability. The second step is to determine management goals and relate those goals to the state of vegetation. If the state of vegetation composition does not meet management objectives, changes in management practices can be used to move the vegetation

composition toward management objectives. Currently, condition and management evaluations are not independent steps. Condition and management goals are the same and are assumed to be constant for all managers, all uses, and all locations.

In the following study, vegetation composition was described in western Oklahoma on the Black Kettle National Grassland. Our objective was to break condition assessment and management goals into two steps. 1.) Evaluate soil and vegetation state and 2.) Relate management actions to the vegetation state.

Soil and plant species composition data were collected on five ecological sites and each ecological site was divided into two categories: native unplowed grassland or previously farmed grassland. Past history and management for each sample location were used as environmental variables. The data were analyzed using multivariate statistical analysis to determine if there were differences between the ecological sites' vegetation composition. If there were differences in species composition, multivariate statistics were used to determine the influence of environmental factors and management actions. This study is about reevaluating how we look at rangeland condition and to make the connection between management actions and their effects on vegetation. This methodology should be considered experimental until validated in other locations and vegetation types.

The results of this study are found in Chapters II and III and both chapters are formatted for submission to the Journal of Range Management and focus on the methodology of the study and this method's use in management. A summary of results for all of the ecological sites is available from the U.S. Forest Service in the form of a technical reference.

CHAPTER II

A MULTIVARIATE APPROACH TO DETERMINING
RANGELAND VEGETATION STATES ON ECOLOGICAL SITES

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Key Words: condition assessment, management objectives

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Abstract

We used multivariate statistical techniques to define the ecological sites on the Black Kettle National Grassland and to determine the effects of management on the plant communities found within the ecological sites. We intended to determine if the ecological sites, as defined by the Natural Resource Conservation Service (NRCS), were actually important factors in determining plant community species composition. The five ecological sites we looked at were deep sand, deep sand savanna, sandy prairie, loamy prairie, and red shale. In addition, we wanted to evaluate the effects of management practices on species composition. The dominate species of grasses were sand bluestem (*Andropogon hallii* Hack.), little bluestem (*Schizacryium scoparium* Nash.), and sideoats grama (*boutaloua curtispindula* Michx.) and the dominate shrubs species were shinnery oak (*Quercus havardii* Rydb.), sand sagebrush (*Artemisia filifolia* Torr.) and Oklahoma plum (*Prunus gracilis* Engelm. & Gray). We found that ecological sites were the most important variable in determining plant community species composition. The second most important factor was cultivation history. Use of grazing systems and season of grazing use were also important in determining species composition of plant communities.

Introduction

Within the traditional model for rangeland condition assessment vegetation is rated as poor, fair, good, or excellent based on what is thought to be the climax community. This implies that a climax or potential natural community exists and is the best state of the vegetation for all uses and optimizes plant diversity and productivity. This model also suggests that the ultimate goal of management is to achieve “excellent” condition regardless of the objectives for the site. Although this concept of rangeland condition has been dismissed (Smith 1989) by many, it is still used by some land management agencies.

Another problem with the traditional condition model is that it does not take into account past land use. Many areas in the U.S. were plowed and then abandoned during the Dust Bowl era (Savage and Runyon 1937). These sites, although technically the same ecological sites as the unplowed areas, have not regained the same potential productivity and due to soil loss may not regain that potential within our lifetime. These sites should be treated as different ecological sites with different site potentials.

The purpose of this paper is to employ multivariate statistical analyses techniques to describe upland plant communities on the Black Kettle National Grassland and determine relationships to ecological site, cultivation history, and other management factors such as grazing and fire.

Study Area

The vegetation communities of western Oklahoma have had very little research conducted on them. There is not much known about these communities or the effects cultivation in the early 1900's had on the vegetation. Effects of current management actions on the vegetation and soils are also lacking for this region. The Black Kettle National Grassland encompasses approximately 12,000 ha in western Oklahoma and was the study area.

The Black Kettle National Grassland is located in Roger Mills County, Oklahoma and is managed by the USDA Forest Service. The lands encompassed in the Grassland were primarily abandoned in the late 1930's by private landowners because of drought and poor management. Much of this area was cultivated in the early 1900's and then replanted to permanent vegetation by the 1950's. Currently, cattle grazing and recreation are the main uses of the area.

Precipitation in Roger Mills County averages 63.5 cm annually. The majority (69%) of the precipitation occurs between April and September. The daily temperature averages 3°C in January and 28°C in July. Daily high temperatures greater than 38° C are common from June through August (Burgess et al. 1959).

The topography of the area is rolling hills with breaks. The altitude ranges from 518 to 793 meters above sea level. The soils of this area can be divided into two broad categories. The eastern portion of the Grassland is characterized by loamy soils with red siltstone and sandstone as parent materials. The western portion of the Grassland is characterized by deep sandy soils. Within these two groups we will focus on five

ecological sites taken from the USDA Natural Resource Conservation Service (NRCS) range site delineation (U.S.D.A Forest Service *unpublished data*). The soils are grouped into ecological sites by the NRCS as follows: red shale, deep sand, deep sand savanna, sandy prairie, and loamy prairie (Table 1). The soils were mapped and delineated in the 1950's and little has been done to amend these descriptions since that time. The ecological sites are delineated by differences in soil structure as well as the kind and amount of vegetation present.

Red Shale ecological sites are located on gentle to steep slopes. These soils are underlain by shale red beds. These soils have low moisture holding capacity and high runoff. Loamy prairie ecological sites are located on gentle to steep slopes in uplands with some areas being very steep and hilly with occasional ravines. These soils are moderately to slowly permeable. Deep sand ecological sites consist of deep loamy fine sand located on hilly uplands. These soils are highly permeable, but they can be droughty due to permeable subsoil. Deep sand savanna ecological sites consist of deep sandy soils on uplands. The surface layer is fine sand and absorbs water rapidly. The subsurface soil has textures ranging from fine sandy loam to sandy clay loam. These ecological sites have good moisture holding capacity. Sandy prairie ecological sites are deep, permeable soils on uplands. The soils are fine sandy loam on the surface and finer textured subsoil.

Methods

Experimental Design

We first delineated areas that represent each of the five different ecological sites; deep sand, deep sand savanna, sandy prairie, loamy prairie, and red shale. From within

these selected areas, we located macroplot sites in an attempt to encompass the variation of soils, vegetation, and management practices within the Black Kettle National Grassland.

We selected a minimum of fifty macroplots per ecological site to represent the natural variability present over the Grasslands. Within each ecological site 25 of the macroplots were located in areas that had been cultivated in the early 1900's and 25 macroplots were located in areas that had not experienced cultivation. The macroplots consisted of 40 x 40-m areas that represented the state of vegetation at the macroplot. Within the macroplot, we systematically located three 40-m transects 20 m apart. Along the three transects, we estimated species canopy cover in 60 systematically located, 20x50 cm quadrats using the Daubenmire (1959) technique. We placed the quadrats every 2 meters along the transect starting at the 2 meter mark for a total of 20 quadrats per transect. We subsequently calculated average canopy cover for each species by using the midpoints of the cover scale

We collected the following information for each macroplot before field work began: we determined whether the area was native grassland or former cropland, fire history (past 10 years), livestock stocking rates (number of animal units per grazing unit per grazing period), livestock season of use (time period the unit was grazed), and livestock grazing system (one pasture grazed continuously during grazing period, two, three, four and more pasture rest rotation).

We collected the following information at each macroplot in the field: slope, aspect, limiting depth of soil (either 150 cm or at rock), grazing utilization (amount grazed if any when sampling was conducted), collected soil samples to be brought back

to the lab to determine soil texture for the surface and subsurface horizons, and we took photographs at each site.

Data Analysis

We performed our analysis on the species canopy cover data for each macroplot. We used canonical correspondence analysis (CCA) (ter Braak 1986, 1987) within CANOCO (ter Braak 1988), to determine the relationship of species to management and environmental gradients. The data was square root transformed and rare species were down weighted to reduce noise and help elucidate the major gradients within the data. Table 2 lists the environmental variables used, the abbreviation within the data, and whether it was a quantitative or nominal variable.

Results and Discussion

Importance of Ecological Site and Cultivation History

Site factors, mainly ecological site and limiting depth of soil have a major influence on the plant community species composition (Fig. 1). The deep sites ordinated to the left and the shallow sites to the right. Deep sites species scores (Fig. 2) consistent with this interpretation are on the left (*Quercus havardii* Rydb., *Prunus gracillis* Engelm. & Gray), generalist species scores in the center (*Schizocruim scoparium* Nash., *Bouteloua curtipendula* Michx.) and shallow site species scores on the right (*Calylophus berlandieri* Spach., *Mimosa borealis* A.).

Axis II of the CCA ordination (Fig. 1) is a gradient of past cultivation. The species associated with plowed sites were found on the upper part of the graph

(*Lespedeza stuevei* Nutt., *Hymenopappus tenuifolius* Pursh.) generalist species in the middle (*Schizachyrium scoparium*, *Bouteloua curtipendula*), and plowing sensitive species of on the lower portion of the graph (*Quercus havardii*, *Prunus gracilis*) (Fig. 2).

The CCA indicates strong relationships between plant communities and ecological site. All sites were fairly distinct and while this is not unexpected it illustrates the importance of ecological site on species composition and potential plant communities. It has been recommended that condition assessment be based on ecological sites (Task Group on Unity in Concepts 1995), this technique is useful because it is able to delineate areas based on ecological site and limiting depth of the soil. The technique is also useful since it supports the validity of the ecological site groupings made by the NRCS. Uresk (1990) was able to use multivariate techniques to group sites into condition classes but did not look at grouping based on ecological sites or by the effects of past cultivation or management actions. But this technique has not been used to show a relationship between ecological sites or past management actions such as cultivation.

The species graph (Fig. 2) illustrates the importance of knowing if the ecological sites had been plowed or not by the ordination of *Quercus havardii*, and *Prunus gracilis* which are mainly found on unplowed sites. These species do not appear to reestablish in sites once the sites have been plowed (Peterson and Boyd, *in press*). The ordination of the generalist species *Andropogon hallii*, *Schizachyrium scoparium*, and *Bouteloua curtipendula*, near the center further explains the gradient since they were present in all sites regardless of cultivation history. The disturbance related species *Hymenopappus tenuifolius* Pursh., *Lespedeza stuevei* Nutt., and *Schrankia nuttallii* DC. further illustrate

how important cultivation history is to plant community composition. These species were either very rare or absent in unplowed sites.

Once a site has experienced severe erosion it may not, within our lifetime, attain the same species composition as an undisturbed site. It has lost the potential to support many species characteristic of unplowed sites. This is based on the idea that soils are the most important resource of the ecological site (Task Group on Unity in Concepts 1995, NRC 1994). The difference between plowed and unplowed sites is better explained by Westoby's (1989) state and transition theory or Friedel's (1991) threshold theory than with Clement's (1916) traditional rangeland succession model. Sites that have been cultivated have crossed a threshold and have been unable to return to the plant community present before cultivation, and appear to be unable to return any time soon.

For any ecological site there is an array of vegetation communities that can occur, but once the ecological site has been plowed, these communities may not occur and a completely new array of communities will occur. Sites are judged on the basis of the same land unit classification, ecological sites (Task group on unity in concepts 1995), but if these areas, although classified as the same ecological sites, have different potentials they should be considered different ecological sites. Ecological site descriptions need to be rewritten based on potential and if the sites have lost soil to due past cultivation, these areas should be considered different ecological sites.

Effects of Management Actions

Axis I (Fig. 1), although strongly influenced by ecological site and limiting depth, is also influenced by stocking rate with sites having low stocking rates on the right and higher stocking rates on the left

In addition, fire history is an important influence on species composition. The gradient isn't as obvious because prescribed fire at Black Kettle is used primarily on unplowed sites. For the sites that had burned in the past ten years, there were lower amounts of shrub cover and higher amounts of the tallgrass species. Boyd (*unpublished data*) found the same results in a fire study on the Black Kettle National Grassland. Boyd found that tallgrass species increased after winter or spring burning regimes and shinnery oak decreased in stature and cover. The gradient is, from left to right, time since last burn; the left portion of the gradient being the shortest time since burning and the right the longest time since burning.

The CCA for the sandy prairie ecological site (Fig. 3) had an axis I that indicates a strong relationship with being unplowed or previously cultivated. Macroplots on the right of the graph had been previously cultivated and macroplots on the left were unplowed grassland sites. Unplowed grassland species (*Quercus havardii*, *Prunus gracilis*, *Bouteloua gracilis*) on the left and disturbance species (*Melilotus offinalis*, *Aster oblingifolius* Nutt., *Schrankii nuttallii*) on the right of the graph.

CCA axis II for sandy prairie macroplots and species (Fig. 3) had four management actions that had an effect on the plant species composition. There were four associated states with these actions and we have a schematic model to show the different states (Fig. 4.). The first state was located in the lower left quadrant. This state is found

in unplowed sandy prairie sites that have been grazed in a two-pasture rest rotation with moderate stocking rates. The species associated with this state are *Quercus havardii*, *Schizachyrium scoparium*, and *Bouteloua curtipendula*. The second state was located in the upper left quadrant and also consisted of unplowed sandy prairie sites, but had light stocking rates and were grazed in a four or more pasture rest rotation. The species associated with this state are *Quercus havardii*, *Bouteloua curtipendula*, and *Bouteloua gracilis*. The third state was located in the upper right quadrant and was a plowed sandy prairie site. This state was influenced by the management actions of grazing in a four or more pasture rest rotation, light stocking rates, and grazing during the spring. The species associated with this state are *Artemisia filifolia* Torr., *Schizachyrium scoparium*, and *Sorghastrum nutans* Nash.. The fourth state, located in the lower right quadrant, was a plowed sandy prairie site. The plant species composition was effected by a two pasture rest rotation and moderate stocking rates. The species associated with this state are *Schizachyrium scoparium*, *Bouteloua curtipendula*, and *Aster oblongifolius*.

The effects of grazing systems and grazing intensity on tall and midgrass communities have been well documented (Owensby et al. 1973, McIlvain and Savage 1951, Gillen et al. 1991, Gillen et al. 1998, Hart et al. 1988). Our results were similar to many of the previous studies. *Sorghastrum nutans* was found in higher amount in rotation pastures but decreased with increasing stocking rates in tallgrass prairie. *Bouteloua curtipendula* was found to decrease with increasing stocking rates in the same study. *Bouteloua gracilis* was found to increase under continuous grazing and under higher stocking rates in the same study (Gillen et al. 1998). Owensby et al. (1973) found that *Schizachyrium scoparium* and *Sorghastrum nutans* tend to increase under a 3 pasture

rest rotation in tallgrass prairie. Launchbaugh (1967) found high forb production under moderate stocking rates in mixed grass prairie in years with high precipitation as we experienced in 1996 and 1997.

Conclusion

We were able to identify the ecological sites using multivariate statistical techniques. We found that the NRCS range site delineations were effective in determining species composition for the site. Although the range site delineations were accurate in describing the unplowed sites, they did not adequately described sites that had been plowed in the past. We feel that cultivation history needs to have as much weight given to it as ecological site when describing plant communities. The ecological sites should be split into two distinct categories, unplowed and plowed.

We were able to determine the effects of grazing systems, season of use, and fire frequency on plant species composition. The lack of sites that have been degraded on the Black Kettle National Grassland and the resulting difficulty in finding degraded sites for all grazing systems and seasons of use makes us cautious in the interpreting these results. Rest-rotation grazing systems and stocking rates have an effect on plant community composition and we can group sites using CCA based on management actions. Canopy cover used in conjunction with CCA appears to be a valuable tool for determining states of vegetation and management actions related to the different states.

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Chapter II

Table 1. Summary of Ecological Sites, Soil Types, and Soil Textures

Ecological Site	Soil Type	Soil Texture
Red Shale	Vernon-Quinlan	Loam
Loamy Prairie	Carey	Silt loam
	Holdrege	Silt loam
	Kenesaw	Silt loam
	Mansker	Loam
	Quinlan-Woodward	Loam (eroded)
	St. Paul	Silt loam
	Woodward	Loam, Fine sandy loam
	Woodward-Quinlan	Loam, Fine sandy loam
Deep Sand	Brazos	Loamy fine sand
	Pratt	Loamy fine sand
	Springer	Loamy fine sand
	Miles-Dill	Loamy fine sand
	Enterprise	Very fine sandy loam
Sandy Prairie	Dalhart	Fine sandy loam
	Dill-Quinlan	Fine sandy loam
	Miles	Fine sandy loam
	Miles-Dalhart	Complex
	Miles-Springer	Complex
	Pratt	Complex
	Pratt	Fine sandy loam
	Reinach	Fine sandy loam
Deep Sand Savanna	Nobscot-Brownfield	Fine sand
	Nobscot	Fine sand

Table 2. Summary of Environmental Variables, Abbreviations, and Type of Variable.

Environmental Variable	Abbreviation	Nominal or Quantitative
Ecological site	Ecological Site	QUANTITATIVE
Limiting depth of soil	Limiting Depth	QUANTITATIVE
Slope	Slope	QUANTITATIVE
Stocking rate	Stckrate	QUANTITATIVE
Time since last fire	Fire	QUANTITATIVE
Duration of grazing period	Duration	QUANTITATIVE
Season of use by livestock	Winter, Spring, Summer, Fall	NOMINAL
Number of pastures in grazing system	1 Pasture, 2 Pasture, 3 Pasture, 4 Pasture	NOMINAL
Cultivation History	Unplowed	NOMINAL

Table 3. List of Species, Authorities, and Species Codes

Genus	Species	Authority	Code	Common Name
<i>Allium</i>	<i>drummondii</i>	Regel.	ALDR	wild onion
<i>Ambrosia</i>	<i>confertiflora</i>	DC.	AMCO	Ragweed
<i>Andropogon</i>	<i>hallii</i>	Hack.	ANHA	sand bluestem
<i>Aristida</i>	<i>purpurea</i>	Nutt.	AROL	Threeawn
<i>Artemisia</i>	<i>filifolia</i>	Torr.	ARFI	sand sagebrush
<i>Artemisia</i>	<i>ludoviciana</i>	Nutt.	ARLU	white sage
<i>Asclepias</i>	<i>viridiflora</i>	Raf.	ASPE	green milkweed
<i>Aster</i>	<i>oblongifolius</i>	Nutt.	ASOB	Aster
<i>Baptisia</i>	<i>australis</i>	L.	BAAU	blue false indigo
<i>Bouteloua</i>	<i>curtipendula</i>	Michx.	BOCU	sideoats grama
<i>Bouteloua</i>	<i>gracilis</i>	H.B.K.	BOGR	blue grama
<i>Bouteloua</i>	<i>hirsuta</i>	Lag.	BOHI	hairy grama
<i>Calylophus</i>	<i>berlandieri</i>	Spach	CABE	evening primrose
<i>Conyza</i>	<i>canadensis</i>	L.	COCA	horse-weed
<i>Elymus</i>	<i>canadensis</i>	L.	ELCA	Canada wild rye
<i>Hymenopappus</i>	<i>tenuifolius</i>	Pursh.	HYTE	woolly white
<i>Lespedeza</i>	<i>stuevei</i>	Nutt.	LEST	tall bush lespedeza
<i>Leuculene</i>	<i>ericoides</i>	Torr.	LEER	white aster
<i>Melilotus</i>	<i>officinalis</i>	L.	MEOF	yellow sweet clover
<i>Mimosa</i>	<i>biuncifera</i>	Benth.	MIBO	cat's claw mimosa
<i>Panicum</i>	<i>virgatum</i>	L.	PAVI	switch grass
<i>Physalis</i>	<i>viscosa</i>	Nutt.	PHVI	ground cherry
<i>Prunus</i>	<i>gracilis</i>	Engelm. & Gray	PRGR	Oklahoma plum
<i>Quercus</i>	<i>havardii</i>	Rydb.	QUHA	shinnery oak
<i>Rhus</i>	<i>aromatica</i>	Ait.	RHAR	Fragrant sumac
<i>Schizachyrium</i>	<i>scoparium</i>	Nash.	SCSC	Little bluestem
<i>Schrankia</i>	<i>nutallii</i>	DC.	SCNU	Catclaw sensitive briar
<i>Sorghastrum</i>	<i>nutans</i>	Nash.	SONU	Indian grass
<i>Sporobolus</i>	<i>cryptandrus</i>	Torr.	SPCR	Sand dropseed
<i>Yucca</i>	<i>glauca</i>	Nutt.	YUGL	Yucca

Chapter II
Figure 1. CCA for All Ecological Sites

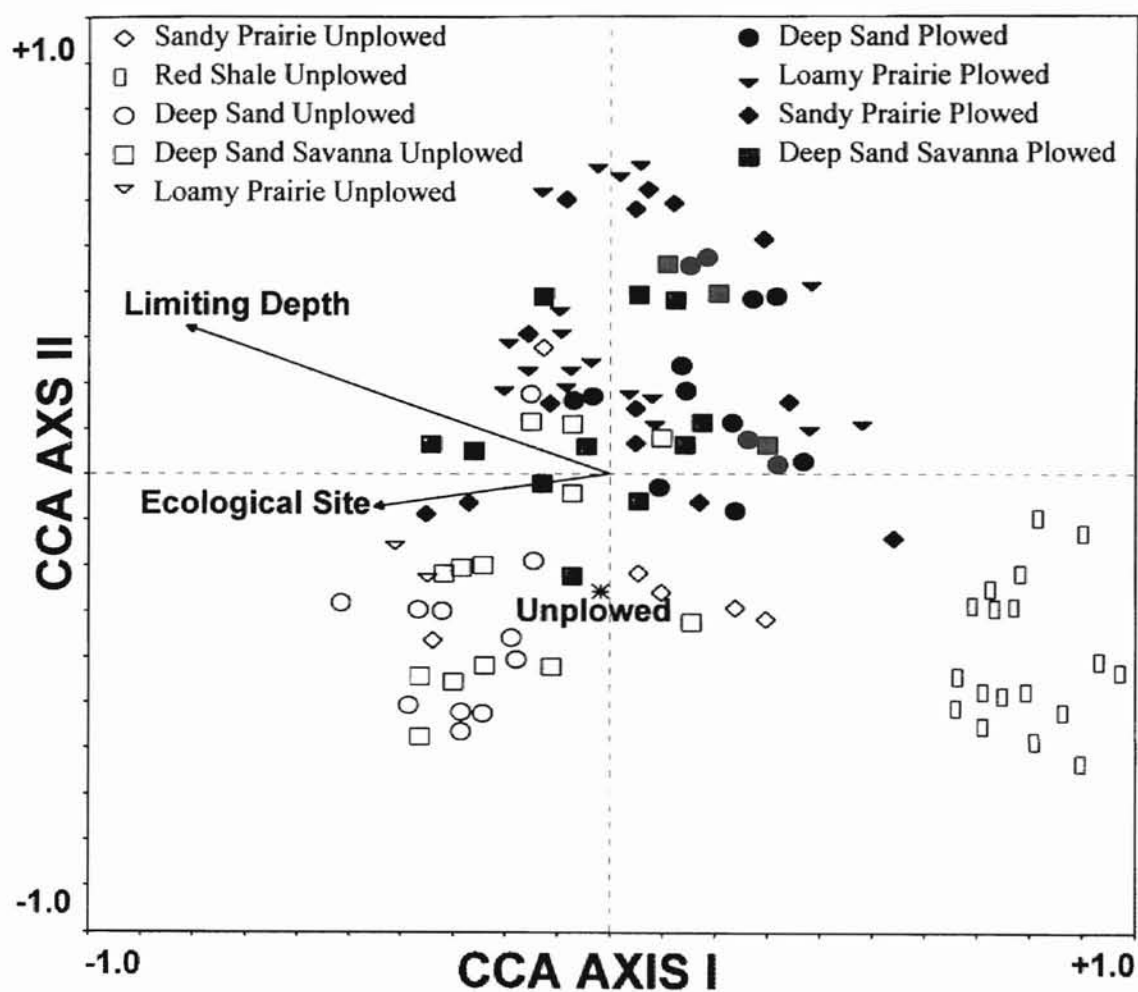


Figure 2. Species CCA for All Ecological Sites

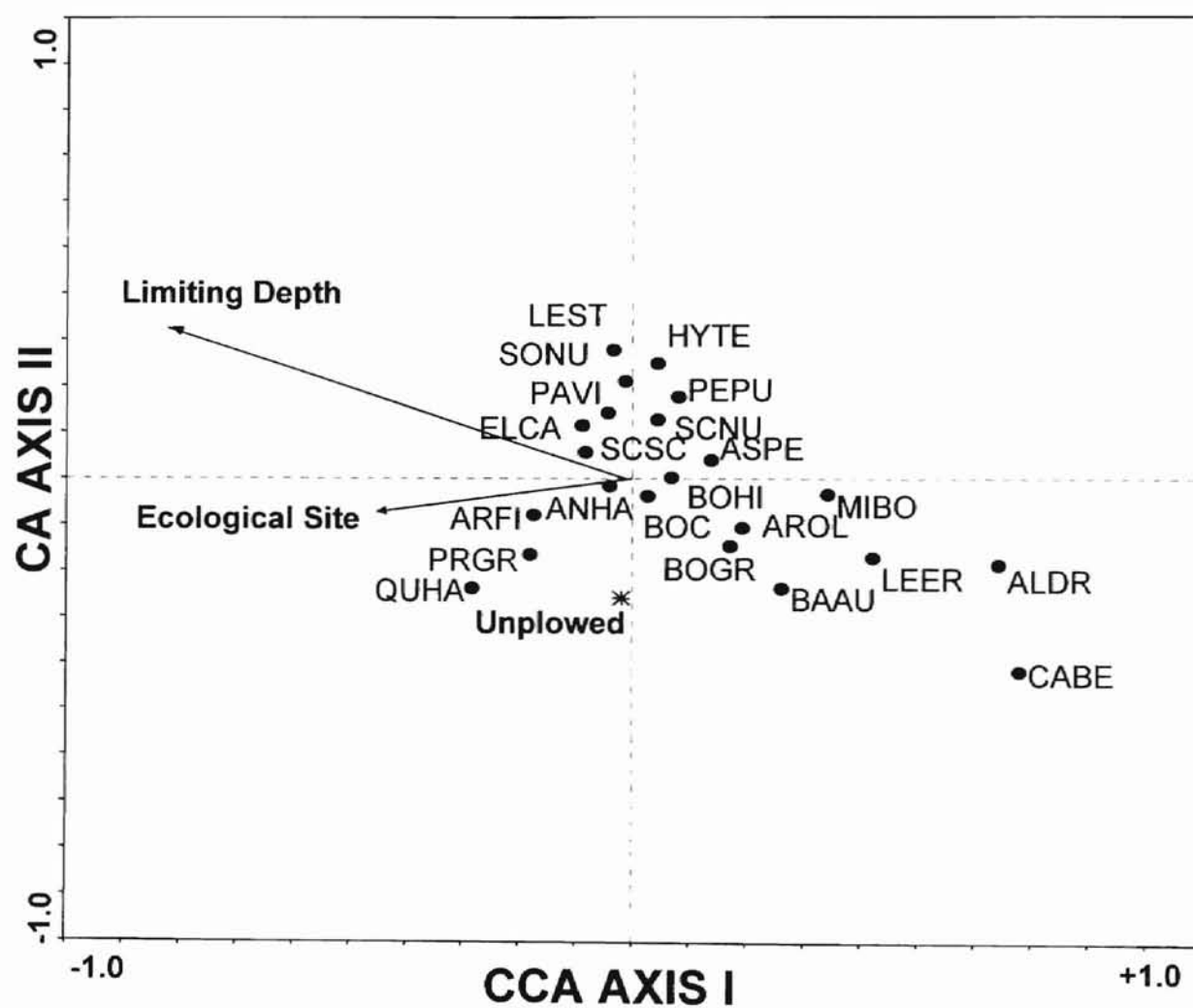


Figure 3. CCA for Sandy Prairie Ecological Sites

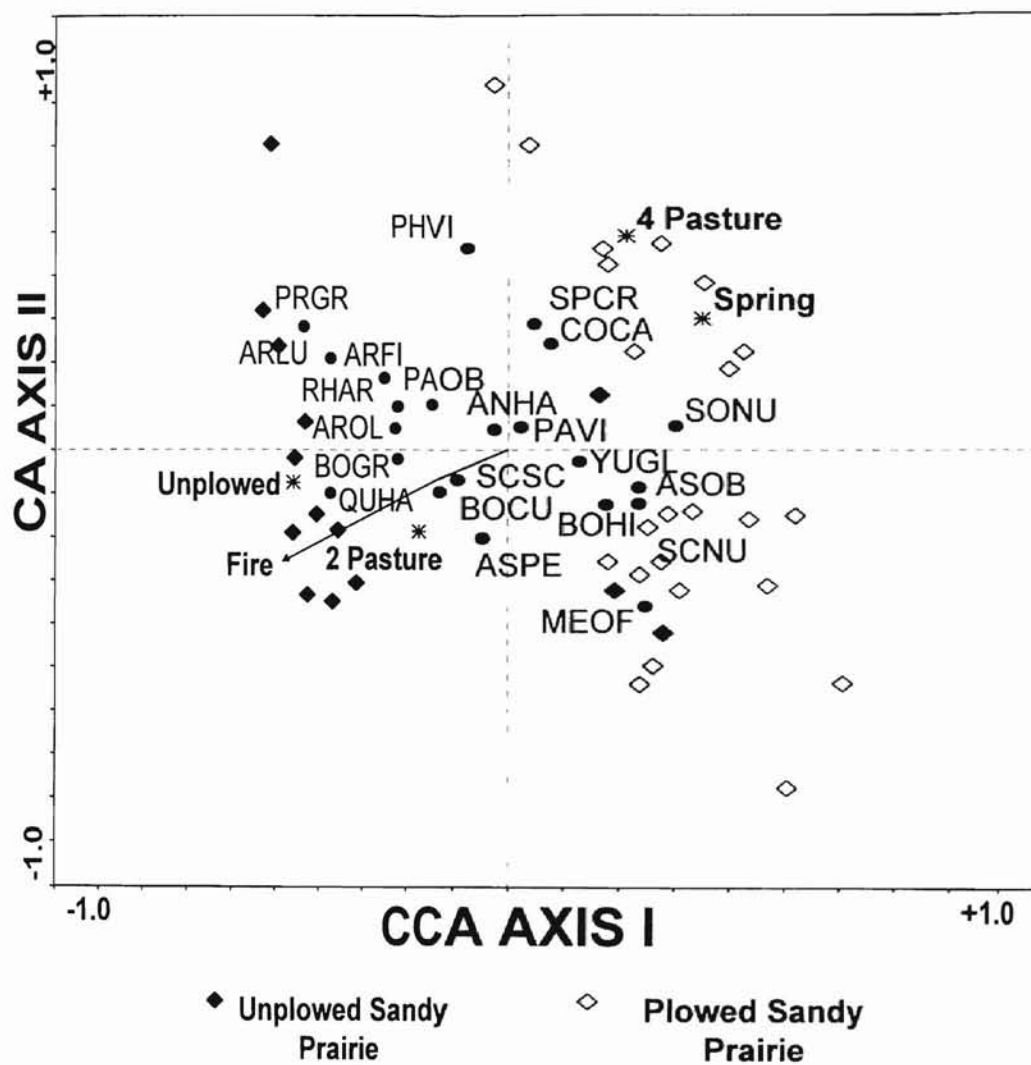
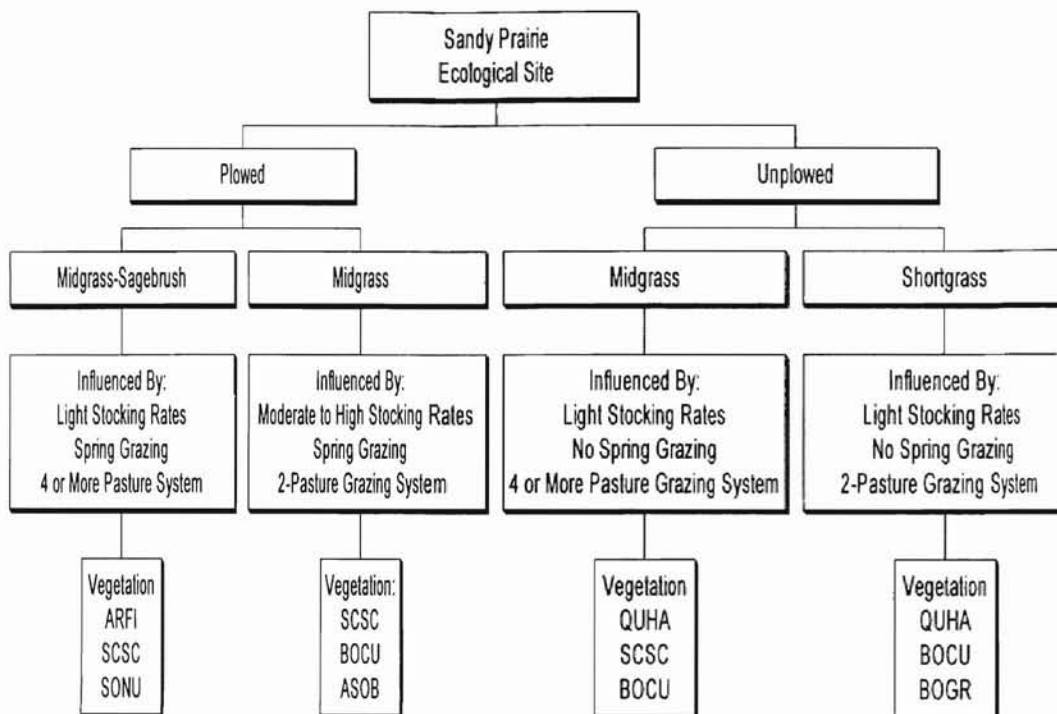


Figure 4. Sandy Prairie Vegetation States



CHAPTER III

DETERMINING THE EFFECTS OF MANAGEMENT ACTIONS
ON PLANT SPECIES COMPOSITION FOR LOAMY
PRAIRIE ECOLOGICAL SITES

Amy L. Smith and T.G. Bidwell

Key Words: vegetation monitoring, condition assessment, multivariate analysis

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Abstract

We used multivariate statistical techniques to define states of vegetation within ecological sites on the Black Kettle National Grassland and to determine the management effects on the plant communities found within the ecological sites we described. We wanted to evaluate the effects of management practices on the species composition. For each ecological site the most important factor effecting plant species composition was past cultivation. Grazing systems, season of use, and prescribed fire were also important in determining species composition of plant communities.

Introduction

The traditional model of rangeland condition assessment has boxed in managers. They have been forced to choose between managing for the climax plant community, i.e. excellent rangeland condition, or manage to meet management objectives and contend with the stigma of not having their land in “excellent” condition. The perception of mismanagement is present despite the manager meeting management objectives and having the vegetation in a state that optimizes these objectives.

Within this paper we present a method of condition assessment that takes the focus off of the value laden traditional model and the objective of managing for the climax or potential natural plant community. In place of this traditional model we are placing the emphasis on the state or states of vegetation which best meet the manager’s objectives.

The traditional model is based on plant composition by weight (Dyksterhuis 1949) compared to the climax species composition for that community using a linear succession theory (Clements 1916). Clipping and weighing plants makes this method extremely time consuming and often results in condition assessment not being conducted. Although dismissed by scientists, most Federal agencies in the United States still use this model for assessing rangeland condition (Smith 1989). Uresk (1990) found the use of canopy cover and multivariate statistical techniques to be a promising method of condition assessment that reduced the time spent conducting field-work. We based our field methodology on his work. We used the state and transition model (Westoby et al. 1989) for a theoretical model. The ecological site, past cultivation, and management

activity influence the state of vegetation associated with a particular set of species present. The states are still arbitrary for a particular ecological site, but lack the value-laden terminology of the traditional model and focuses on management actions. There may be more or fewer than four states of vegetation, unlike the traditional model, which has four condition classes regardless of management or past land use. Depending on the variation in plant species composition, management actions, and who is grouping the sites, there may be few to many states per ecological site. A manager can manage for a state that will optimize management objectives without dealing with the condition classes; excellent, good, fair, or poor. Before a manager can focus on meeting management objectives, they must first look at soil stability of the site (Fig. 2). The soil is evaluated using an ocular estimate of stability (no visible signs of pedestalling, rills, or soil movement on or off the site) (NRC 1994). After the stability of the soil is confirmed then the species data is collected using canopy cover. From the canopy cover data, state of vegetation is determined. The state is then evaluated to determine if it meets management goals. If it does meet management goals, the manager continues with periodic monitoring to maintain soil and vegetation goals. If the state does not meet management goals the manager evaluates current practices and makes changes to modify the plant community. We will focus on the results of one of the five ecological sites to illustrate the usefulness of ecological states to management.

Study Area

The USDA Forest Service manages the Black Kettle National Grassland located in western Oklahoma. The lands encompassed in the grassland were abandoned in the

late 1930's due to drought and poor land management. Much of this area was settled and then plowed in the early 1900's and then allowed to revegetate naturally or replanted to permanent plant cover by the 1950's.

Precipitation in Roger Mills County occurs mainly between April and September and averages 63.5 cm annually. The daily temperature averages 3°C in January and 28°C in July (Burgess et al. 1959).

The topography of the area is rolling hills and local breaks with an altitude from 518 to 793 meters above sea level. The soils of this area can be divided into two distinct soil types. The eastern portion of the Grassland is characterized by loamy soils and the western portion of the Grassland predominately deep sandy soils. Within these two groups we will focus on five ecological sites from NRCS range site delineation (Forest Service *unpublished data*). The soils are grouped into ecological sites as follows: red shale, deep sand, deep sand savanna, sandy prairie and loamy prairie (Table 1.).

Methods

Experimental Design

We delineated areas that represent one of the five different ecological sites for selection of macroplots, within these selected areas, we located macroplot sites in an attempt to encompass the different soils, vegetation, and management practices within the Black Kettle National Grassland. The macroplots consisted of 40 x 40-m areas that represented a vegetation state at the macroplot. We subjectively selected a minimum of 50 macroplots per ecological site to represent the natural variability present over the Grasslands. Each ecological site was divided into plowed and unplowed sites depending

on the land use history for the site. There were 25 macroplots for plowed and unplowed sites totaling the 50 macroplots per ecological site. Within the macroplot, we systematically located three equally spaced 40-m transects. Along the three transects, we estimated species canopy cover in 60 systematically located, 20 x 50 cm quadrats. We placed the quadrats every 2 meters along the transect starting at the 2 meter mark for a total of 20 quadrats per transect. We rated canopy cover using a scale of 1 to 6 (Daubenmire 1959) and calculated average canopy cover for each species by using the midpoints of the cover scale.

We collected the following information at each macroplot in the field: slope, aspect, limiting depth of soil (either 150 cm or at rock), grazing utilization (amount grazed if any when sampling was conducted), collected soil samples to be brought back to the lab to determine soil texture for the surface and subsurface horizons, and we took photographs at each site. We collected the following information for each macroplot before field work began: we determined whether the area was native grassland or former cropland, fire history (past 10 years), livestock stocking rates (number of animal units per grazing unit per grazing period), livestock season of use (time period the unit was grazed), and livestock grazing system (one pasture grazed continuously during grazing period, two, three, four and more pasture rest rotation).

Data Analysis

We performed our analysis on the species abundance data for each macroplot. We used canonical correspondence analysis (CCA) (ter Braak 1986) within CANOCO (ter Braak 1988), to determine the relationship of species to management and

environmental gradients. The data was square root transformed and rare species were down weighted to reduce noise within the data and help elucidate the major gradients within the data. Table 1 lists the environmental variables used the abbreviation within the data and whether it was a quantitative or nominal variable.

Results and Discussion

The dominant gradient on axis I (Fig. 1) is cultivation history. The high axis I species scores are associated with unplowed sites and low axis I species scores represent plowed sites. Due to the extensive cultivation historically on grasslands, we were only able to find 8 sites that were unplowed. On the CCA there were five more sites classified as having been cultivated historically, but ordinated with the unplowed sites. This may be a result of the sites only being cropped for a brief amount of time and not having the soil loss experienced by the rest of the plowed loamy prairie sites. Axis I was also influenced by the season of use with winter and fall grazing having high axis I scores and spring grazing having low axis I scores.

Axis II had several factors effecting the gradient. High stocking rates had high axis II species scores. Duration of the grazing season had low axis II scores for long grazing seasons and high scores for short grazing season. Grazing system also played a part in the axis II gradient, with a three-pasture rest rotation having high species scores and a one pasture grazing system having low species scores.

Species name, abbreviations, and authorities are found in Table 3 (see also, Fig. 3). Species associated with winter or fall grazing, low stocking rates, and a one-pasture grazing system ordinated in the lower right quadrant. The species associated with spring

grazing with low stocking rates ordinated in the lower left quadrant. The species associated with spring grazing in a three-pasture rest rotation with moderate stocking rates ordinated in the upper left quadrant. The species associated with winter or fall grazing in a one pasture grazing system with moderate stocking rates ordinated in the upper right quadrant.

By determining which of the four states are present at a particular site, and which state best meets management objectives, we can move the plant community toward the management objectives. If we are managing a plowed site and we wanted to increase the amount of indiangrass (*Sorghastrum nutans* Nash.) there are several options we could implement. We could lighten the stocking rate, shorten the grazing season, change to a one pasture grazing system, or all of the above. There are limitations to the technique, for example once a site has been plowed it does not appear to return to the species composition of the unplowed sites. So if the site has been plowed, implementing a one-pasture winter grazing system will not increase the shrub component of shinnery oak (*Quercus havardii* Rydb.) and skunkbrush (*Rhus aromatica* Alt.).

Each of the four states we delineated in the loamy prairie ecological site meets the needs of different management objectives. The plowed, shortgrass state (upper left quadrant Fig. 1, see also Fig. 3.) would meet the brood habitat requirements for some the ground nesting birds due to short stature of the grasses, high amount of forbs, and scattered patches of bare ground. The plowed, midgrass state (upper right quadrant Fig. 1. See also Fig. 3.) would provide good nesting habitat for these same ground nesting birds due to the interspersed dense grass tufts (Bidwell et al. 1994) The unplowed, tallgrass state (lower right quadrant Fig. 1. See also Fig. 5.) may be the optimal site for

livestock production due to the high amount of grass production. The plowed, tallgrass state (lower left quadrant Fig. 1. See also Fig 5.) would also be good for livestock production due to the high amount of grass production.

Besides being a useful tool for managers in meeting management goals, this method could be a useful method in ground truthing sites in a GIS application of vegetation monitoring. By having a quick field data collection technique coupled with a method for determining the effects of environmental as well as management action on the species composition, this technique could be expanded and tested in many other rangeland regions.

Conclusion

We were able to use canopy cover data coupled with multivariate statistics to delineate states of vegetation within ecological sites based on environmental and management variables. The states were based on species present under various management actions. By grouping the vegetation based on management, the focus is taken off of the climax plant community and put on soil stability and meeting management objectives. Further work needs to be done in other regions and ecological sites to determine the effectiveness of this method of condition assessment. Additionally, this technique should be tried in GIS applications to determine if states are useful and evident at the landscape level. Lastly, condition of the land base should be based on soil stability and helping managers better manage the resource, and not managing for the hypothetical goal of climax plant communities or excellent rangeland condition.

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Chapter III

Table 1. Summary of Ecological Sites, Soil Types, and Soil Textures		
Ecological Site	Soil Type	Soil Texture
Red Shale	Vernon-Quinlan	Loam
Loamy Prairie	Carey	Silt loam
	Holdrege	Silt loam
	Kenesaw	Silt loam
	Mansker	Loam
	Quilan-Woodward	Loam (eroded)
	St. Paul	Silt loam
	Woodward	Loam, Fine sandy loam
	Woodward-Quinlan	Loam, Fine sandy loam
Deep Sand	Brazos	Loamy fine sand
	Pratt	Loamy fine sand
	Springer	Loamy fine sand
	Miles-Dill	Loamy fine sand
	Enterprise	Very fine sandy loam
Sandy Prairie	Dalhart	Fine sandy loam
	Dill-Quinlan	Fine sandy loam
	Miles	Fine sandy loam
	Miles-Dalhart	Complex
	Miles-Springer	Complex
	Pratt	Complex
	Pratt	Fine sandy loam
	Reinach	Fine sandy loam
Deep Sand Savanna	Nobscot-Brownfield	Fine sand
	Nobscot	Fine sand

Table 2. Summary of Environmental Variables, Abbreviations, and Type of Variable.

Environmental Variable	Abbreviation	Nominal or Quantitative
Ecological site	Ecological Site	QUANTITATIVE
Limiting depth of soil	Limiting Depth	QUANTITATIVE
Slope	Slope	QUANTITATIVE
Stocking rate	Stckrate	QUANTITATIVE
Time since last fire	Fire	QUANTITATIVE
Duration of grazing period	Duration	QUANTITATIVE
Season of use by livestock	Winter, Spring, Summer, Fall	NOMINAL
Number of pastures in grazing system	1 Pasture, 2 Pasture, 3 Pasture, 4 Pasture	NOMINAL
Cultivation History	Unplowed	NOMINAL

Table 3. Species, Authorities and Species Codes for Loamy Prairie CCA

Genus	Species	Authority	Code	Common Name
<i>Andropogon</i>	<i>hallii</i>	Hack.	ANHA	sand bluestem
<i>Aristida</i>	<i>purpurea</i>	Nutt.	ARPU	threeawn
<i>Baptisia</i>	<i>australis</i>	L.	BAAU	blue false indigo
<i>Bothriochloa</i>	<i>saccharoides</i>	Sw.	BOSA	silver bluestem
<i>Bothriochloa</i>	<i>ischaemum</i>	L.	BOIS	King Ranch bluestem
<i>Bouteloua</i>	<i>curtipendula</i>	Michx	BOCU	sideoats grama
<i>Bouteloua</i>	<i>hirsuta</i>	Lag.	BOHI	hairy grama
<i>Elymus</i>	<i>canadensis</i>	L.	ELCA	canada wild rye
<i>Eragrostis</i>	<i>curvula</i>	Schrad.	ERCU	weeping lovegrass
<i>Eragrostis</i>	<i>trichodes</i>	Nutt.	ERTR	sand lovegrass
<i>Hymenoxys</i>	<i>odorata</i>	DC.	HYOD	bitterweed
<i>Krameria</i>	<i>lanceolata</i>	Torr.	KRLA	ratney
<i>Leptoloma</i>	<i>Cognatum</i>	Schult.	LECO	fall witchgrass
<i>Mimosa</i>	<i>borealis</i>	A.	MIBO	pink mimosa
<i>Polygala</i>	<i>alba</i>	Nutt.	POAL	white milkwort
<i>Prunus</i>	<i>gracilis</i>	Engelm. & Gray	PRGR	oklahoma plum
<i>Quercus</i>	<i>havardii</i>	Rydb.	QUHA	shinnery oak
<i>Rhus</i>	<i>aromatica</i>	Ait.	RHAR	fragrant sumac
<i>Schizachyrium</i>	<i>scoparium</i>	Nash	SCSC	little bluestem
<i>Sorghastrum</i>	<i>nutans</i>	Nash	SONU	indian grass
<i>Sporobolus</i>	<i>cryptandrus</i>	Torr.	SPCR	sand dropseed

Figure 1. CCA for Loamy Prairie Sites and Species

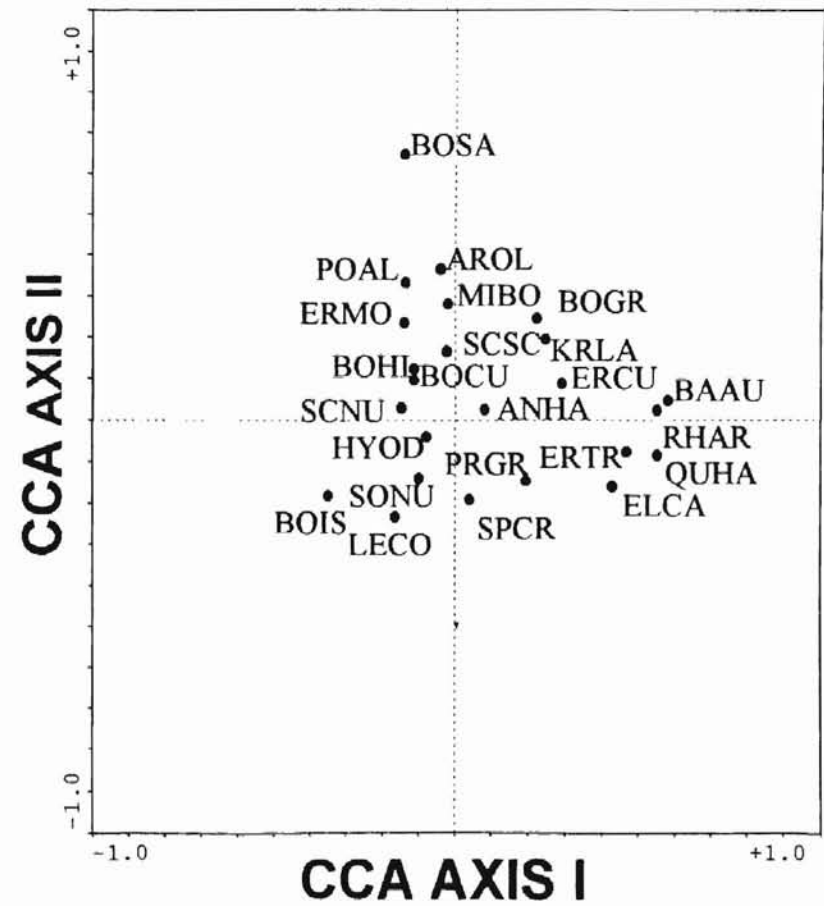
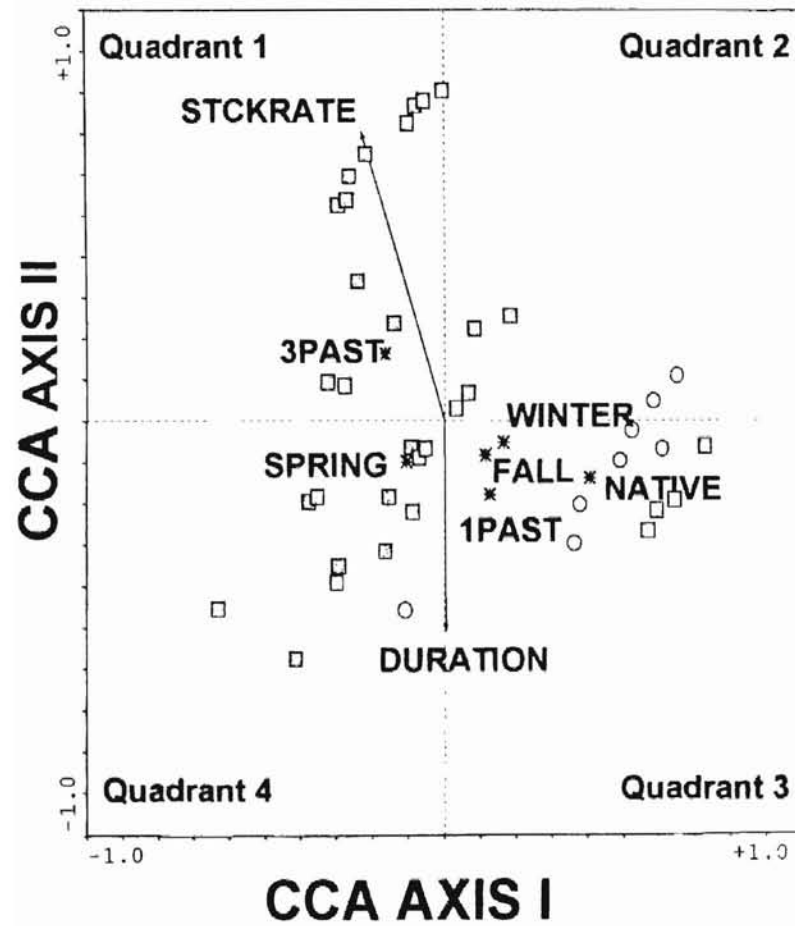


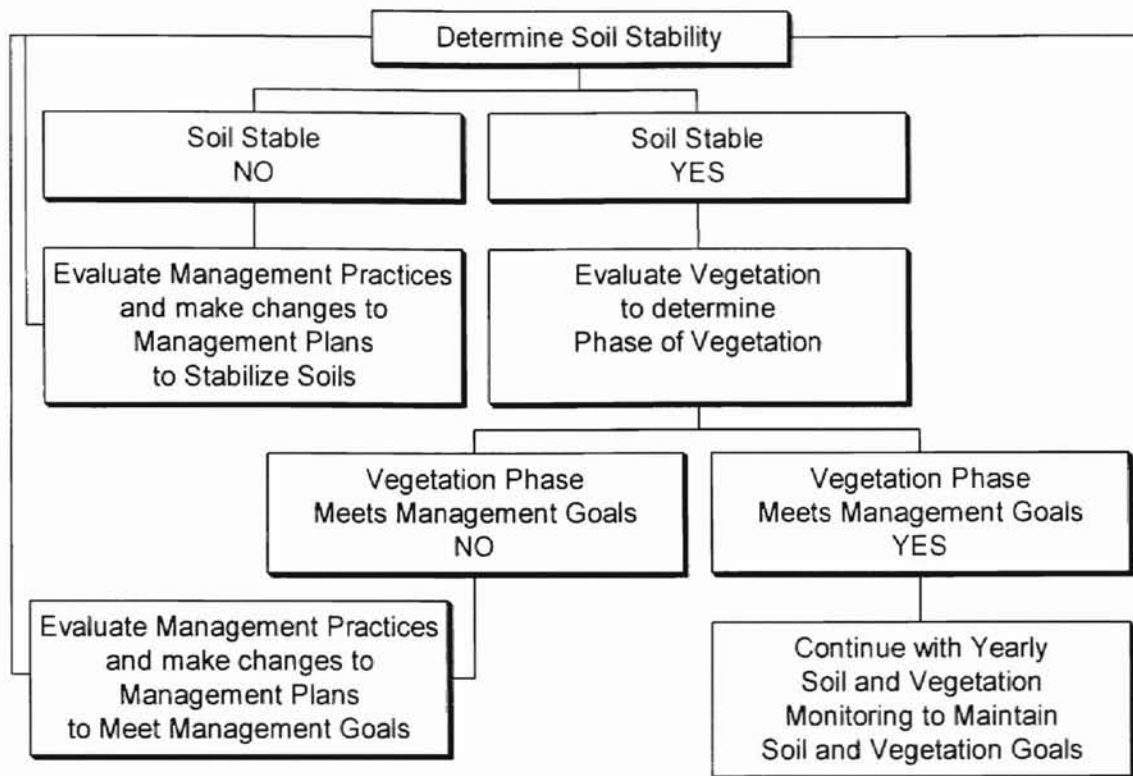
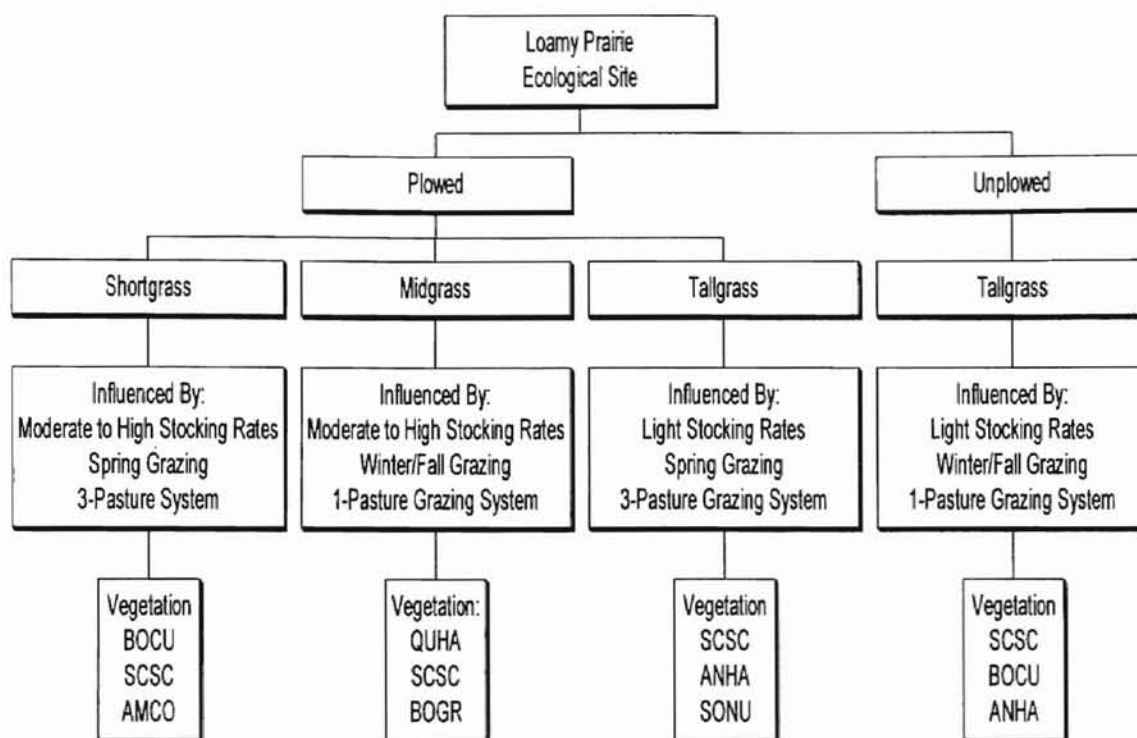
Figure 2. Schematic for Soil and Vegetation Monitoring

Figure 3. Vegetation States by Ecological Site



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Figure 4. Representative Photographs of Loamy Prairie Plowed States
Top Photograph is Shortgrass State, Bottom Photograph is Midgrass State.



Figure 5. Representative Photographs of Loamy Prairie States

Top Photograph is Tallgrass Plowed State

Bottom Photograph is Tallgrass Unplowed State.



Summary Chapter IV

Vegetation States on Upland Ecological Sites within the Black Kettle National Grassland

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Key Words: multivariate analysis, management actions

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Introduction

Descriptions of upland plant communities within the Black Kettle National Grassland are lacking. The areas within the Grassland are intermixed with private lands and the units within the Grassland range from 40 to several hundred acres.

We examined the soil and vegetation characteristics of upland ecological sites on the Black Kettle National Grassland in western Oklahoma. Some of the Grassland was cultivated in the early 1900's and subsequently abandoned during the Dust Bowl era. These communities represent the vegetation present after management actions such as plowing, grazing, recreation, and fire have taken place.

Previous Studies

Traditionally, rangeland condition assessment has been based on the idea that plant succession is a linear process (Clements 1916), and is based on comparisons of species composition, based on biomass, to what is thought to be the climax or potential natural vegetation for the site. From this comparison the vegetation is rated as poor, fair, good, excellent, or low seral, mid seral, high seral, potential natural. This comparison implies that climax or potential natural exists and is the best state of the vegetation for all uses and for soil stability, plant diversity, and productivity. Although this concept of rangeland condition has often been dismissed (Smith, 1989), some agencies still use this system.

This method fails to help managers better manage their lands. It suggests that the ultimate goal of management is to achieve "excellent" condition regardless of the

manager's objectives for the site. A manager trying to improve bobwhite quail habitat does not want their entire property in "excellent" rangeland condition; they want a mosaic of vegetation states across the landscape. This means we need to focus management on diversity in plant communities across the landscape not just the potential natural community or the climax community.

The second problem with traditional rangeland condition assessment is that it does not take into account past land use. Many areas, especially in the Great Plains were plowed and then abandoned during the Dust Bowl era, and subsequently reseeded to permanent vegetation or left to revegetate naturally (Savage and Runyon 1937). Some areas, which were previously farmed, lost several inches of topsoil. With that soil loss many of the sites have lost the potential to support vegetation communities similar to unplowed sites. These sites, although technically the same ecological sites as the unplowed sites will not within our lifetime attain the same potential as the unplowed sites. This means these sites must be treated as different ecological sites with a different potential than the undisturbed sites.

The third major problem with the traditional rangeland assessment is that it is overly time consuming because it requires estimating biomass. Some managers do not have the time to clip plots to make estimates and this results in condition assessments not being conducted. Without conducting regular inventories, managers have no idea if they are meeting their management goals, if they have stable soils, or any management problem exist. We need to base rangeland condition assessment on a more efficient method of inventory. A method of rangeland inventory that has shown some promise is canopy cover using key species (Uresk 1990).

The purpose of this paper is to describe the variation of potential upland plant communities on the Black Kettle National Grassland, and determine the relationship between ecological site, cultivation history, and other management factors such as grazing and fire by employing multivariate statistical analyses techniques.

Study Area

The Black Kettle National Grassland is located in western Oklahoma in Roger Mills County and is managed by the United States Forest Service. The lands encompassed in the grassland were primarily abandoned in the late 1930's by private landowners due to drought and poor land management. Much of this area was cultivated in the early 1900's and then replanted to permanent plant cover by the 1950's. Currently, grazing and recreation are the main uses of the area.

Climate

Precipitation in Roger Mills County averages 63.5 cm annually. The majority (69%) of the precipitation occurs between April and September. The daily temperature averages 3°C in January and 28°C in July. Daily high temperatures greater than 38° C are common from June through August. (Burgess et al. 1959).

Physiography

The topography of the area is rolling hills mixed with local breaks. The altitude of the area range from 518 to 793 meters above sea level. The soils of this area can be grouped into two distinct soil associations. The eastern portion of the Grassland is characterized by loamy soils with red siltstone and sandstone as parent materials. The western portion of the Grassland is characterized by deep sandy soils. The two soil

associations in this study, loamy soils and sandy soils, were taken from NRCS range site delineation (Forest Service *unpublished data*). Within these two groups we will focus on five ecological sites. The soils are grouped into ecological sites as follows: red shale, deep sand, deep sand savanna, sandy prairie and loamy prairie (Table 1).

Soils

Red Shale ecological sites are located on gentle to steep slopes. These soils are underlain by shale red beds. These soils have low moisture holding capacity and high runoff. Loamy prairie ecological sites are located on gentle to steep slopes in the uplands, with some areas being very steep and hilly with occasional ravines. These soils are moderately to slowly permeable. Deep sand ecological sites consist of deep loamy fine sand located on hilly uplands. These soils are highly permeable, but they can be droughty due to permeable subsoil. Deep sand savanna ecological sites consist of deep sandy soils on the uplands. The surface layer is fine sand and absorbs water rapidly. The subsurface soil has textures ranging from fine sandy loam to sandy clay loam. These ecological sites have good moisture holding capacity. Sandy prairie ecological sites are deep, permeable soils on uplands. The soils are fine sandy loam on the surface and finer textured subsoil.

Methods

Experimental Design

Sample Site Selection

We first delineated areas that represent each of the five different ecological sites; deep sand, deep sand savanna, sandy prairie, loamy prairie, and red shale. From within

these selected areas, we located macroplot sites in an attempt to encompass the variation of soils, vegetation, and management practices within the Black Kettle National Grassland.

Field Sample

We selected a minimum of fifty macroplots per ecological site to represent the natural variability present over the Grasslands. Within each ecological site 25 of the macroplots were located in areas that had been cultivated in the early 1900's and 25 macroplots were located in areas that had not experienced cultivation.

Study Design

We collected the following information at each macroplot: slope, aspect, limiting depth of soil (either 150 cm or at rock), grazing utilization (amount grazed when sampling was conducted), soil (soil texture for the surface and subsurface horizons), and photographs. Before field work began we determined whether the area was native grassland or former cropland, determined the fire history (past 10 years), livestock stocking rates (number of animal units per grazing unit per grazing period), livestock season of use (time period unit was grazed), livestock grazing system (one pasture grazed continuously during grazing period, two, three, four and more pasture rest rotation).

The macroplots consisted of 40 x 40-m areas that represented the state of vegetation at the macroplot. Within the macroplot, we systematically located three 40-m transects 20 m apart. Along the three transects, we estimated species canopy cover in 60 systematically located, 20x50 cm quadrats using the Daubenmire (1959) technique. We placed the quadrats every 2 meters along the transect starting at the 2 meter mark for a total of 20 quadrats per transect. We subsequently calculated average canopy cover for

each species by using the midpoints of the cover scale. Species codes scientific names and authorities are found in Table 4.

Data analysis

We performed our analysis on the species canopy cover data for each macroplot. We used canonical correspondence analysis (CCA) (ter Braak 1986) within CANOCO (ter Braak 1988), to determine the relationship of species to management and environmental gradients. The data was square root transformed and rare species were down weighted to reduce noise within the data and help elucidate the major gradients within the data. Table 1 lists the environmental variables used the abbreviation within the data and whether it was a quantitative or nominal variable

Nomenclature

The term “vegetation state” is used to indicate vegetation differences within an ecological site due to effects of management actions and past land use history, mainly plowing. Ecological site is the same as range site as defined by the Natural Resource Conservation Service (Task Group on Unity in Concepts 1995). Plant species are represented by a four-letter abbreviation where the first two letters of the genus and species names are used. For example BOGR represents *Bouteloua gracilis*.

Each of the five ecological sites is illustrated by a brief narrative description and a summary of the states and vegetation (Appendix A).

Results and Discussion

The effects of grazing systems and grazing intensity on tall and midgrass communities have been well documented (Owensby et al. 1973, McIlvain and Savage

1951, Gillen et al. 1991, Gillen et al. 1998, Hart et al. 1988). Our results were similar to many of the previous studies. *Sorghastrum nutans* was more abundant in rotationally grazed pastures but decreased with increasing stocking rates in tallgrass prairie.

Bouteloua curtipendula was found to decrease with increasing stocking rate in the same study. *Bouteloua gracilis* was found to increase under continuous grazing and higher stocking rates in the same study (Gillen et al. 1998). Owensby et al. (1973) found that *Schizachyrium scoparium* and *Sorghastrum nutans* tended to increase under a 3 pasture rest rotation in tallgrass prairie. Launchbaugh (1967) found high forb production under moderate stocking rates in mixed grass prairie in years with high precipitation as we experienced in 1996 and 1997.

Conclusion

We were able to identify the five ecological sites using multivariate statistical techniques. We found that the NRCS range site delineations were effective in determining the species composition for the site. In addition, we feel that cultivation history should have as much weight given to it as ecological site when describing plant communities. The ecological sites should be split into two distinct categories, unplowed and plowed.

Although cultivation history is the most dramatic land use effect on the landscape, other management actions influence on the plant communities to a lesser degree. We were able to determine the effects of grazing systems, season of use, and fire frequency on plant species composition. We can group sites using canopy cover data in conjunction with CCA based on the effects of management actions. Canopy cover data

used in conjunction with CCA appears to be a valuable tool for determining states of vegetation and the relationship of management actions to different states of vegetation.

Appendix A: Vegetation States

States of Vegetation on the Loamy Prairie Ecological Sites

Species name, abbreviations and authorities are found in Table 3. We divided the loamy prairie sites into four states representing the factors found for each ecological site (Fig. 1).

The shortgrass plowed state is influenced by a three-pasture rest rotation grazing system, moderate stocking rates, and spring grazing. The dominant vegetation within the shortgrass state is *Schizachyruim scoparium* (Nash.), *Bouteloua curtipendula* (Michx.) and *Ambrosia confertifolia* (DC.) (Table 4).

The midgrass plowed state is influenced by a one-pasture grazing system, moderate stocking rates and winter/fall grazing. The dominant vegetation on the plowed midgrass sites is *Quercus havardii* (Rybd.), *Schizachyruim scoparium*, and *Bouteloua gracilis* (Table 5).

The tallgrass unplowed state is influenced by a one-pasture grazing system, and light stocking rates, long duration, and winter or fall grazing. The dominant vegetation on the unplowed tallgrass sites is *Schizachyruim scoparium*, *Bouteloua curtipendula*, and *Andropogon hallii* (Hack.) (Table 6).

The tallgrass plowed state is influenced by a three-pasture grazing system, light stocking rates, long duration, and spring grazing. The dominant vegetation on the plowed tallgrass sites is *Schizachyruim scoparium*, *Bouteloua curtipendula*, and *Ambrosia confertifolia* (Table 7).

States of Vegetation on the Red Shale Ecological Sites

There are only three distinct states for the red shale ecological site and this may be a result of the relatively small amount of acreage in red shale within the grassland (Fig. 2).

The midgrass unplowed state is influenced by a three-pasture rest rotation grazing system, moderate stocking rates and winter grazing. The dominant vegetation is *Bouteloua gracilis* (H.B.K.), *Schizachyrium scoparium*, and *Calylophus hartwegii* (Benth.) (Table 8).

The tallgrass unplowed state is influenced by a two-pasture rest rotation, light stocking rates, and spring or summer grazing. The dominant species in the tallgrass-state is *Schizachyrium scoparium*, *Sorghastrum nutans* (Nash.), and *Andropogon hallii* (Table 9).

The shortgrass unplowed state is influenced by a three-pasture rest rotation, light stocking rates, and fall grazing. The dominant vegetation for the shortgrass state is *Bouteloua gracilis*, *Bouteloua curtipendula*, and *Astragulus mollisimus* (Torr.) (Table 10).

States of Vegetation on the Sandy Prairie Ecological Sites

We divided the sandy prairie ecological site into four states, two plowed states and two unplowed states (Fig. 3).

The shortgrass unplowed state is found on sandy prairie sites that have been grazed in a two-pasture rest rotation, with moderate stocking rates. The dominant

vegetation for the unplowed shortgrass-state is *Quercus havardii*, *Schizachyrium scoparium*, *Bouteloua curtipendula*, and *Bouteloua gracilis* (Table 11).

The midgrass unplowed state has light stocking rates and is grazed in a four or more pasture rest rotation. The dominant vegetation for the midgrass unplowed state is *Schizachyrium scoparium*, *Quercus havardii*, and *Bouteloua curtipendula* (Table 12).

The midgrass/sagebrush-plowed state is influenced by the management actions of grazing in a four or more pasture rest rotation, light stocking rates and grazing during the spring. The dominant vegetation on the midgrass-sagebrush state is *Schizachyrium scoparium*, *Sorghastrum nutans*, and *Artemisia filifolia* (Torr.) (Table 13).

The midgrass plowed state is influenced by a two-pasture rest rotation grazing system and moderate stocking rates. The dominant vegetation on the midgrass plowed state is *Schizachyrium scoparium*, *Bouteloua curtipendula*, and *Aster oblongifolius* (Nutt.) (Table 14).

States of Vegetation on the Deep Sand Ecological Sites

We divided the deep sand ecological sites into five states, two plowed states and three unplowed states (Fig. 4).

The first plowed state is a shortgrass state influenced by moderate to high stocking rates, spring grazing, and a two-pasture rest-rotation grazing system. The shortgrass-state was also influenced by fire within the last 10 years. The dominant vegetation found in the shortgrass- state is *Schizachyrium scoparium*, *Bouteloua curtipendula* and *Bouteloua gracilis* (Table 15).

The second plowed state is the midgrass state and is influenced by light to moderate stocking rates, winter grazing, and a two-pasture rest rotation grazing system. The midgrass state is also influenced by infrequent fire (fire has not occurred within the last ten years). The dominant vegetation for the midgrass state is *Schizachyrium scoparium*, *Bouteloua curtipendula*, and *Panicum virgatum* (Table 16).

The first unplowed state is the shinnery oak unplowed state and is influenced by moderate to high stocking rates, winter grazing, and one-pasture grazing system. The shinnery oak state is also influenced by infrequent fire (>10 years since last burn). The dominant vegetation in the shinnery oak-state is *Quercus havardii*, *Schizachyrium scoparium*, and *Bouteloua curtipendula* (Table 17).

The second unplowed state is the midgrass unplowed state and is influenced by light stocking rates, spring grazing, and a two-pasture rest rotation grazing system. The midgrass unplowed state is also influenced by frequent fire (less than ten years since last burn). The dominant vegetation for the midgrass unplowed state is *Quercus havardii*, *Schizachyrium scoparium*, and *Eragrostis curvula* (Table 18).

The third unplowed state is the tallgrass unplowed state and is influenced by light stocking rates, winter grazing, and an one-pasture grazing system. The dominant vegetation in the tallgrass unplowed state is *Schizachyrium scoparium*, *Quercus havardii*, and *Sorghastrum nutans* (Table 19).

States of Vegetation on the Deep Sand Savanna Ecological Sites

Deep sand savanna was broken into four states, two plowed states and two unplowed states (Fig. 5). There was very little variation within the species composition

found on the deep sand savanna ecological site. The lack of variation may be a result of increased water holding capacity of the soil making the vegetation less variable or lack in variation within the management practices or a combination of the two.

The first plowed state is the shortgrass plowed state and is influenced by moderate to high stocking rates, spring grazing, and a two-pasture rest rotation grazing system. The shortgrass plowed sites were also influenced by infrequent fire (> 10 years since last burn). The dominant vegetation in the shortgrass plowed is *Schizachyrium scoparium*, *Bouteloua curtipendula* and *Bouteloua gracilis* (Table 20).

The second plowed state is the midgrass plowed state and is influenced by light stocking rates, winter grazing and a one-pasture grazing system. The midgrass plowed state is also influenced by frequent fire (less than 10 years since last burn). The dominant vegetation in the midgrass plowed state is *Schizachyrium scoparium*, *Bouteloua curtipendula*, and *Sorghastrum nutans* (Table 21).

The first unplowed state is the shinnery oak unplowed state and is influenced by moderate to high stocking rates, summer grazing, and a two-pasture rest rotation grazing system. The shinnery oak unplowed state is also influenced by infrequent fire (>10 years since last burn). The dominant vegetation on the shinnery oak unplowed state is *Quercus havardii*, *Schizachyrium scoparium*, and *Prunus gracilis* (Table 22).

The second unplowed state is the unplowed midgrass state and is influenced by light stocking rates, summer grazing, and a one pasture grazing system. The unplowed midgrass state is also influenced by frequent fire (less than 10 years since last burn). The dominant vegetation on the unplowed midgrass state is *Quercus havardii*, *Schizachyrium scoparium*, and *Bouteloua curtipendula* (Table 23).

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Chapter IV

Table 1. Summary of Ecological Sites, Soil Types, and Soil Textures

Ecological Site	Soil Type	Soil Texture
Red Shale	Vernon-Quinlan	Loam
Loamy Prairie	Carey	Silt loam
	Holdrege	Silt loam
	Kenesaw	Silt loam
	Mansker	Loam
	Quinlan-Woodward	Loam (eroded)
	St. Paul	Silt loam
	Woodward	Loam, Fine sandy loam
	Woodward-Quinlan	Loam, Fine sandy loam
Deep Sand	Brazos	Loamy fine sand
	Pratt	Loamy fine sand
	Springer	Loamy fine sand
	Miles-Dill	Loamy fine sand
	Enterprise	Very fine sandy loam
Sandy Prairie	Dalhart	Fine sandy loam
	Dill-Quinlan	Fine sandy loam
	Miles	Fine sandy loam
	Miles-Dalhart	Complex
	Miles-Springer	Complex
	Pratt	Complex
	Pratt	Fine sandy loam
	Reinach	Fine sandy loam
Deep Sand Savanna	Nobscot-Brownfield	Fine sand
	Nobscot	Fine sand

Table 2. Environmental Variables, Abbreviations, and Type of Variable.

Environmental Variable	Abbreviation	Nominal or Quantitative
Ecological site	SOILTYPE	QUANTITATIVE
Limiting depth of soil	LMTDPTH	QUANTITATIVE
Slope	SLOPE	QUANTITATIVE
Stocking rate	STCKRATE	QUANTITATIVE
Time since last fire	FIRE	QUANTITATIVE
Animal unit month forage removed	AUM	QUANTITATIVE
Duration of grazing period	DURATION	QUANTITATIVE
Season of use by livestock	WINTER, SPRING, SUMMER, FALL	NOMINAL
Number of pastures in rotation	1PAST, 2PAST, 3 PAST, 4PAST	NOMINAL
Farming history	UNPLOWED	NOMINAL

Table 3. Species, Authorities, Species Codes, and Common Names

Genus	Species	Authority	Code	Common Name
<i>Agoseris</i>	<i>cuspidata</i>	Pursh.	AGCU	agoseris
<i>Allium</i>	<i>drummondii</i>	Regel.	ALDR	wild onion
<i>Ambrosia</i>	<i>confertiflora</i>	DC.	AMCO	ragweed
<i>Amorpha</i>	<i>canescens</i>	Pursh.	AMCA	leadplant
<i>Amphiachyris</i>	<i>dracunculoides</i>	DC.	AMDR	broomweed
<i>Andropogon</i>	<i>hallii</i>	Hack.	ANHA	sand bluestem
<i>Aphanostephus</i>	<i>riddellii</i>	T. & G.	APRI	lazy daisy
<i>Apocynum</i>	<i>cannabinum</i>	L.	APCA	indian hemp dogbane
<i>Argemone</i>	<i>polyanthemus</i>	Fedde.	ARPO	prickly poppy
<i>Aristida</i>	<i>purpurea</i>	Nutt.	AROL	threeawn
<i>Artemisia</i>	<i>filifolia</i>	Torr.	ARFI	sand sagebrush
<i>Artemisia</i>	<i>ludoviciana</i>	Nutt.	ARLU	white sage
<i>Artemisia</i>	<i>biennis</i>	Willd.	ARBI	biennial wormwood
<i>Asclepias</i>	<i>tuberosa</i>	L.	ASAS	butterfly milkweed
<i>Asclepias</i>	<i>viridiflora</i>	Raf.	ASPE	green milkweed
<i>Aster</i>	<i>patens</i>	Lindl.	ASPA	aster
<i>Aster</i>	<i>oblongifolius</i>	Nutt.	ASOB	aster
<i>Astragalus</i>	<i>mollisimus</i>	Torr.	AGMO	woolly loco
<i>Baptisia</i>	<i>australis</i>	L.	BAAU	blue false indigo
<i>Bothriochloa</i>	<i>ischaemum</i>	L.	BOIS	King Ranch bluestem
<i>Bothriochloa</i>	<i>saccharoides</i>	Sw.	BOSA	silver bluestem
<i>Bouteloua</i>	<i>curtipendula</i>	Michx.	BOCU	sideoats grama
<i>Bouteloua</i>	<i>gracilis</i>	H.B.K.	BOGR	blue grama
<i>Bouteloua</i>	<i>hirsuta</i>	Lag.	BOHI	hairy grama
<i>Brassica</i>	<i>sp.</i>	***	mustard	mustard species
<i>Bromus</i>	<i>tectorum</i>	L.	BRTE	downy brome
<i>Buchloe</i>	<i>dactyloides</i>	Nutt.	BUDA	buffalo grass
<i>Callirhoe</i>	<i>involucrata</i>	T. & G.	CAIN	purple poppy mallow
<i>Calylophus</i>	<i>berlandieri</i>	Spach	CABE	evening primrose
<i>Castilleja</i>	<i>sessiliflora</i>	Pursh.	paintb	indian paintbrush
<i>Celtis</i>	<i>reticulata</i>	Torr.	CEPA	netleaf hackberry
<i>chamaecrista</i>	<i>fasciculata</i>	L.	CACH	showy partridge pea
<i>Chenopodium</i>	<i>album</i>	L.	CHAL	Lamb's quarters
<i>Cirsium</i>	<i>undulatum</i>	Nutt.	CUIN	wavy-leaf thistle
<i>Commelina</i>	<i>erecta</i>	L.	COER	erect dayflower
<i>Conyza</i>	<i>canadensis</i>	L.	COCA	horse-weed
<i>Coreopsis</i>	<i>tinctoria</i>	Nutt.	COTI	plains coreopsis
<i>Croton</i>	<i>texensis</i>	KL.	CRTE	Texas croton
<i>Cyperus</i>	<i>schweinitzii</i>	Torr.	CYSC	umbrella sedge
<i>Dalea</i>	<i>aurea</i>	Nutt.	DAAU	silk-top dalea
<i>Delphinium</i>	<i>virescens</i>	Nutt.	larkspur	prairie larkspur
<i>Desmodium</i>	<i>sessilifolium</i>	Torr.	DESE	sessile-leaved tickclover
<i>Dithyrea</i>	<i>wislizenii</i>	Engelm.	DIWI	spectacle pod
<i>Echinacea</i>	<i>angustifolia</i>	DC.	ECAN	purple conflower
<i>Echinocactus</i>	<i>texensis</i>	Hopffer.	hedgac	hedge-hog cactus
<i>Elymus</i>	<i>canadensis</i>	L.	ELCA	Canada wild rye
<i>Eragrostis</i>	<i>curvula</i>	Schrad.	ERCU	weeping lovegrass
<i>Eragrostis</i>	<i>intermedia</i>	Hitchc.	ERIN	plains lovegrass

Table 3. Continued

Genus	species	Authority	Code	Common Name
<i>Eragrostis</i>	<i>spectabilis</i>	Pursh.	ERSP	purple lovegrass
<i>Eragrostis</i>	<i>trichodes</i>	Nutt.	ERTR	sand lovegrass
<i>Erigeron</i>	<i>philadelphicus</i>	L.	ERMO	daisy fleabane
<i>Eriogonum</i>	<i>annuum</i>	Nutt.	ERAN	annual eriogonum
<i>Euphorbia</i>	<i>prostrata</i>	Ait.	EUPR	spurge
<i>Euthamia</i>	<i>gymnospermoides</i>	L.	EUGY	euthamia
<i>Evolvulus</i>	<i>nuttallianus</i>	R. & S.	EVNU	Nuttall's evolvulus
<i>Froelichia</i>	<i>floridana</i>	Nutt.	FRFL	field snake-cotton
<i>Gaillardia</i>	<i>pulchella</i>	Foug.	GAPU	indian blanket flower
<i>Gaillardia</i>	<i>suavis</i>	Gray & Engelm.	GASU	rayless gaillardia
<i>Gutierrezia</i>	<i>sarothrae</i>	Pursh.	GUSA	snakeweed
<i>Haplopappus</i>	<i>spinulosus</i>	Pursh.	HASP	cutleaf ironplant
<i>Hedoma</i>	<i>drummondii</i>	Benth.	mint	Drummond false pennyroyal
<i>Helianthus</i>	<i>annuus</i>	L.	HEAN	common sunflower
<i>Heterotheca</i>	<i>latifolia</i>	Buchl.	HELA	camphor weed
<i>Hymenopappus</i>	<i>tenuifolius</i>	Pursh.	HYTE	woolly white
<i>Hymenoxys</i>	<i>acaulis</i>	Pursh.	HYAC	stemless hymenoxys
<i>Hymenoxys</i>	<i>odorata</i>	DC.	HYOD	bitterweed
<i>Kallstroemia</i>	<i>intermedia</i>	Rydb.	KAIN	caltrop
<i>Krameria</i>	<i>lanceolata</i>	Torr.	KRLA	ratney
<i>Lactuca</i>	<i>ludoviciana</i>	Nutt.	LALU	western wild lettuce
<i>Lepidium</i>	<i>virginicum</i>	L.	LEVI	peppergrass
<i>Leptoloma</i>	<i>cognatum</i>	Schult.	LECO	fall witchgrass
<i>Lespedeza</i>	<i>stuevei</i>	Nutt.	LEST	tall bush lespedeza
<i>Lesquerella</i>	<i>ovalifolia</i>	Rydb.	LEOV	oval-leaf bladder pod
<i>Leuculene</i>	<i>ericoides</i>	Torr.	LEER	white aster
<i>Liatrus</i>	<i>punctata</i>	Hook.	LIPU	gay-feather
<i>Linum</i>	<i>sulcatum</i>	Ridd.	LISU	groved flax
<i>Lithospermum</i>	<i>arvense</i>	L.	LIAN	Lithospermum
<i>Lithospermum</i>	<i>carolinense</i>	Michx.	LICAN	puccoon
<i>Lomatium</i>	<i>foeniculaceum</i>	Nutt.	LOFO	wild parsley
<i>Melilotus</i>	<i>officinalis</i>	L.	MEOF	yellow sweet clover
<i>Mimosa</i>	<i>biuncifera</i>	Benth.	MIBO	cat's claw mimosa
<i>Mirabilis</i>	<i>carletonii</i>	Standl.	MICA	four-o'clock
<i>Monarda</i>	<i>punctata</i>	L.	MOPU	dotted beebalm
<i>Oenothera</i>	<i>macrocarpa</i>	Nuttall	OEMA	Missouri evening primrose
<i>Oenothera</i>	<i>triloba</i>	Nutt.	OETR	stemless evening primrose
<i>Opuntia</i>	<i>macrorhiza</i>	Engelm.	OPMA	plains prickly pear
<i>Panicum</i>	<i>virgatum</i>	L.	PAVI	switch grass
<i>Paspalum</i>	<i>setaceum</i>	Michx.	PAOB	sand paspalum
<i>Penstemon</i>	****	****	PENSSP.	penstemon
<i>Penstemon</i>	<i>albidus</i>	Nutt.	PECO	white beardtongue
<i>Petalostemon</i>	<i>purpureus</i>	Rydb.	PEPU	purple prairie clover
<i>Physalis</i>	<i>viscosa</i>	Nutt.	PHVI	ground cherry
<i>Plantago</i>	<i>patagonica</i>	Jacq.	PLPA	Patagonian plantain
<i>Polygala</i>	<i>alba</i>	Nutt.	POAL	white milkwort
<i>Prunus</i>	<i>gracilis</i>	Engelm. & Gray	PRGR	Oklahoma plum
<i>Psoralea</i>	<i>tenuiflora</i>	Pursh.	PSTE	scurfy pea

Table 3. Continued

Genus	Species	Authority	Code	Common Name
<i>Pyrrhopappus</i>	<i>carolinianus</i>	Walt.	PYMU	false dandelion
<i>Quercus</i>	<i>havardii</i>	Rydb.	QUHA	shinnery oak
<i>Ratibida</i>	<i>columnifera</i>	Nutt.	RACO	prairie coneflower
<i>Rhus</i>	<i>aromatica</i>	Ait.	RHAR	fragrant sumac
<i>Rhus</i>	<i>glabra</i>	L.	sumac	smooth sumac
<i>Ruellia</i>	<i>humilis</i>	Nutt.	RUHU	fringeleaf ruellia
<i>Salvia</i>	<i>azurea</i>	Lam.	SAAZ	blue sage
<i>Schizachyrium</i>	<i>scoparium</i>	Nash.	SCSC	little bluestem
<i>Schrankia</i>	<i>nuttallii</i>	DC.	SCNU	catclaw sensitive briar
<i>Scutellaria</i>	<i>drummondii</i>	Benth.	SCRE	skullcap
<i>Sisyrinchium</i>	<i>angustifolium</i>	P.Mill.	SICA	blue-eyed grass
<i>Solanum</i>	<i>elaeagnifolium</i>	Cav.	SOEL	silver-leaf nightshade
<i>Sorghastrum</i>	<i>nutans</i>	Nash.	SONU	indian grass
<i>Sporobolus</i>	<i>cryptandrus</i>	Torr.	SPCR	sand dropseed
<i>Sporobolus</i>	<i>vaginiflorus</i>	Torr.	SPVA	poverty grass
<i>Stillingia</i>	<i>sylvatica</i>	L.	STSY	queens delight
<i>Streptanthus</i>	<i>hyacinthoides</i>	Hook.	STHY	twist-flower
<i>Tragia</i>	<i>ramosa</i>	Torr.	TRRA	noseburn
<i>Tribulus</i>	<i>terrestris</i>	L.	TRTE	puncture vine
<i>Tridens</i>	<i>pilosus</i>	Buckl.	hairtri	hairy tridens
<i>Triodanis</i>	<i>perfoliata</i>	Nieuw.	TRPE	venus' looking glass
<i>Xanthocephalum</i>	<i>texanum</i>	DC.	XATE	sleepy daisy
<i>Yucca</i>	<i>glauca</i>	Nutt.	YUGL	yucca

Table 4. Site Information: Loamy Prairie Unplowed Tallgrass State

Vegetation:	Average Percent Canopy Cover
Shrubs	
<i>Quercus havardii</i>	3.73
<i>Artemisia filifolia</i>	4.51
<i>Prunus gracilis</i>	2.90
<i>Rhus aromatica</i>	1.05
Grasses	
<i>Shcizachyruim scoparium</i>	22.95
<i>Bouteloua curtipendula</i>	6.67
<i>Andropogon hallii</i>	5.77
<i>Elymus canadensis</i>	2.28
<i>Eragrostis trichodes</i>	1.94
<i>Sorghastrum nutans</i>	1.37
<i>Leptoloma cognatum</i>	1.23
Forbs	
<i>Ambrosia confertiflora</i>	10.73
Canopy cover for above species	65.12



1 **Photograph of Representative Vegetation for Unplowed Tallgrass State**

1 Table 5. Site Information: Loamy Prairie Plowed Midgrass State

Vegetation:	Average Percent Canopy Cover
Shrubs	
<i>Quercus havardii</i>	26.20
<i>Artemisia filifolia</i>	1.84
<i>Prunus gracilis</i>	0.74
<i>Rhus aromatica</i>	0.22
Grasses	
<i>Sheizachyruim scoparium</i>	21.25
<i>Bouteloua curtipendula</i>	11.32
<i>Andropogon hallii</i>	8.52
<i>Bouteloua hirsuta</i>	1.90
Forbs	
<i>Ambrosia confertiflora</i>	11.20
<i>Asclepias viridiflora</i>	2.40
<i>Ratibida columnifera</i>	2.22
<i>Aster oblongifolius</i>	1.87
<i>Scutellaria scoparium</i>	1.39
Canopy cover for above species	91.07



Photograph of Representative Vegetation for Plowed Midgrass State

Table 6. Site Information: Loamy Prairie Plowed Tallgrass State

Vegetation:	Average Percent Canopy Cover
Shrubs	
<i>Quercus havardii</i>	2.83
<i>Artemisia filifolia</i>	1.53
<i>Prunus gracilis</i>	0.27
Grasses	
<i>Shcizachyruim scoparium</i>	21.68
<i>Bouteloua curtipendula</i>	14.29
<i>Andropogon hallii</i>	9.27
<i>Sorgastrum nutans</i>	5.38
<i>Leptoloma cognatum</i>	2.76
<i>Panicum virgatum</i>	1.33
<i>Cyperus scheinitzii</i>	1.23
Forbs	
<i>Ambrosia confertiflora</i>	10.50
<i>Conyza canadensis</i>	4.11
<i>Plantago patagonia</i>	3.90
<i>Aster oblongiflora</i>	2.47
<i>Petalastomum purpureum</i>	2.10
<i>Agstragalus mollisimus</i>	2.01
<i>Monarda punctata</i>	1.67
<i>Physalis viscosa</i>	1.54
<i>Schrankia nuttallii</i>	1.16
Canopy cover for above species	90.03

**Photograph of Representative Vegetation for Plowed Tallgrass State**

Table 7. Loamy Prairie Plowed Shortgrass State

Vegetation:	Average Percent Canopy Cover
Shrubs	
<i>Quercus havardii</i>	0.00
<i>Artemisia filifolia</i>	0.16
<i>Prunus gracilis</i>	0.04
Grasses	
<i>Shcizachyruim scoparium</i>	49.09
<i>Bouteloua curtipendula</i>	10.03
<i>Andropogon hallii</i>	5.46
<i>Bouteloua gracilis</i>	1.56
<i>Sorgastrum nutans</i>	1.37
<i>Bothriochloa saccharoides</i>	1.35
<i>Aristida purpurea</i>	0.83
Forbs	
<i>Ambrosia confertiflora</i>	7.87
<i>Asclepias viridiflora</i>	3.90
<i>Scutellaria drummondii</i>	2.19
<i>Petalastomum purpureum</i>	1.57
<i>Aster oblongiflora</i>	1.41
<i>Agstragalus mollisimus</i>	1.29
<i>Gutierrezia sarothrae</i>	1.00
<i>Psoralea tenuiflora</i>	0.93
<i>Schrankia nuttallii</i>	0.87
Canopy cover for above species	90.92

**Photograph of Representative Vegetation for Plowed Shortgrass State**

Table 8. Site Information: Red Shale Midgrass State

Vegetation:	Average Percent Canopy Cover
Shrubs	
<i>Rhus aromatica</i>	0.32
<i>Artemisia filifolia</i>	0.04
Grasses	
<i>Bouteloua gracilis</i>	19.56
<i>Shcizachyruim scoparium</i>	14.14
<i>Bouteloua curtipendula</i>	6.16
<i>Aristida oligantha</i>	3.74
<i>Bouteloua hirsuta</i>	2.17
<i>Andropogon hallii</i>	2.13
Forbs	
<i>Calylophus hartii</i>	8.93
<i>Allium drummondii</i>	6.31
<i>Astragulas mollisimus</i>	5.52
<i>Ambrosia confertifolia</i>	4.76
<i>Asclepias viridiflora</i>	3.22
<i>Amphiachryis dranunculoides</i>	2.59
Canopy cover for above species	79.59



Photograph of Representative Vegetation for Red Shale Midgrass State

Table 9. Site Information: Red Shale Tallgrass State

Vegetation:	Average Percent Canopy Cover
Shrubs	
<i>Mimosa borealis</i>	1.13
Grasses	
<i>Stachys scoparium</i>	55.81
<i>Sorghastrum nutans</i>	9.40
<i>Andropogon hallii</i>	9.18
<i>Bouteloua curtipendula</i>	6.47
Forbs	
<i>Ambrosia confertiflora</i>	10.01
<i>Melilotus officinalis</i>	4.05
<i>Asclepias viridiflora</i>	2.02
<i>Artemisia ludoviciana</i>	1.93
Canopy cover for above species	100.00

**Photograph of Representative Vegetation for Red Shale Tallgrass State**

Table 10. Site Information: Red Shale Shortgrass State

Vegetation:	Average Percent Canopy Cover
Shrubs	
<i>Mimosa borealis</i>	1.03
Grasses	
<i>Bouteloua gracilis</i>	18.37
<i>Bouteloua curtipendula</i>	11.48
<i>Aristida oligantha</i>	7.01
<i>Bouteloua hirsuta</i>	6.01
<i>Schizachyruim scoparium</i>	3.90
<i>Andropogon hallii</i>	1.84
Forbs	
<i>Agstragalus mollisimus</i>	9.71
<i>Hymenoxys acaulis</i>	7.81
<i>Amphiachryis dranunculoides</i>	4.84
<i>Leuculene ericoides</i>	4.42
<i>Scutellaria drummondii</i>	3.03
<i>Calylophus berlandieri</i>	2.35
<i>Calylophus hartii</i>	2.24
<i>Krameria lanceolate</i>	1.84
<i>Oenothera triloba</i>	1.50
<i>Asclepias viridiflora</i>	1.14
Canopy cover for above species	88.52



Photograph of Representative Vegetation for Red Shale Shortgrass State

Table 11. Site Information: Sandy Prairie Unplowed Shortgrass State

Vegetation:	Average Percent Canopy Cover
Shrubs	
<i>Quercus havardii</i>	26.32
<i>Artemisia filifolia</i>	4.60
<i>Prunus gracilis</i>	2.13
<i>Rhus aromatica</i>	1.40
Grasses	
<i>Shcizachyruim scoparium</i>	10.51
<i>Bouteloua curtipendula</i>	9.55
<i>Bouteloua gracilis</i>	8.30
<i>Aristida oligantha</i>	1.95
<i>Eragrostis trichodes</i>	1.94
<i>Bouteloua hirsuta</i>	1.14
<i>Leptoloma cognatum</i>	1.05
Forbs	
<i>Ambrosia confertiflora</i>	14.03
<i>Artemisia ludoviciana</i>	4.83
<i>Gaillardia pulchella</i>	0.95
Canopy cover for above species	88.70

Photograph of Representative Vegetation: Sandy Prairie Unplowed Shortgrass State

Table 12. Site Information: Sandy Prairie Unplowed Midgrass State

Vegetation:	Average Percent Canopy Cover
Shrubs	
<i>Quercus havardii</i>	22.02
<i>Artemisia filifolia</i>	2.62
<i>Prunus gracilis</i>	0.23
<i>Rhus aromatica</i>	1.62
Grasses	
<i>Shcizachyruim scoparium</i>	25.17
<i>Bouteloua curtipendula</i>	12.82
<i>Boutelous gracilis</i>	3.83
<i>Andropogon hallii</i>	3.46
<i>Bouteloua hirsuta</i>	1.26
Forbs	
<i>Ambrosia confertiflora</i>	10.27
<i>Asclepias viridiflora</i>	2.05
<i>Gutierrezia sarothrae</i>	0.94
<i>Aster oblongifolius</i>	2.41
Canopy cover for above species	88.70

**Photograph of Representative Vegetation: Sandy Prairie Unplowed Midgrass State**

Table 13. Site Information: Sandy Prairie Plowed Midgrass-Sagebrush State

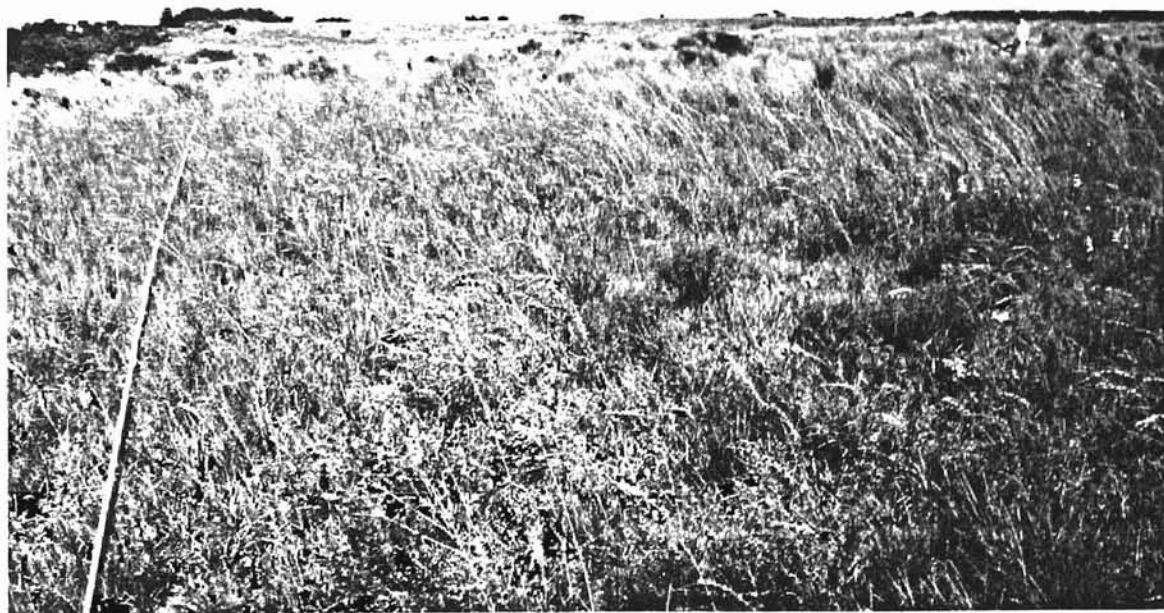
Vegetation:	Average Percent Canopy Cover
Shrubs	
<i>Artemisia filifolia</i>	6.04
Grasses	
<i>Shcizachyruim scoparium</i>	30.13
<i>Sorgastrum nutans</i>	8.83
<i>Andropogon hallii</i>	3.86
<i>Bouteloua curtipendula</i>	3.36
<i>Panicum virgatum</i>	2.86
<i>Sporobolus cryptandrus</i>	1.90
Forbs	
<i>Ambrosia confertiflora</i>	6.94
<i>Aster oblongiflora</i>	5.42
<i>Schrankia nuttallii</i>	2.52
<i>Conyza canadensis</i>	2.24
<i>Physalis viscosa</i>	1.86
<i>Artemisia ludoviciana</i>	1.72
<i>Plantago patagonica</i>	1.63
<i>Hymenopappus tenuifolius</i>	1.08
<i>Artemisia biennis</i>	0.95
Canopy cover for above species	81.34



Photograph of Representative Vegetation: Sandy Prairie Plowed
Midgrass-Sagebrush State

Table 14. Site Information: Sandy Prairie Plowed Midgrass State

Vegetation:	Average Percent Canopy Cover
Shrubs	
<i>Quercus havardii</i>	5.36
<i>Artemisia filifolia</i>	1.32
<i>Prunus gracilis</i>	0.05
Grasses	
<i>Shcizachyruim scoparium</i>	31.88
<i>Bouteloua curtipendula</i>	12.34
<i>Sorgastrum nutans</i>	6.85
<i>Bouteloua hirsuta</i>	4.23
<i>Andropogon hallii</i>	1.10
<i>Panicum virgatum</i>	0.94
<i>Bouteloua gracilis</i>	0.66
Forbs	
<i>Aster oblongiflora</i>	10.25
<i>Ambrosia confertiflora</i>	6.56
<i>Schrankia nuttallii</i>	2.50
<i>Psoralea tenuiflora</i>	1.37
<i>Melilotus officinalis</i>	1.17
<i>Asclepia viridiflora</i>	0.99
Canopy cover for above species	87.57



Photograph of Representative Vegetation: Sandy Prairie Plowed
Midgrass State

Table 15. Site Information: Deep Sand Plowed Shortgrass State

Vegetation:	Average Percent Canopy Cover
Shrubs	
<i>Quercus havardii</i>	5.88
<i>Artemisia filifolia</i>	2.40
<i>Prunus gracilis</i>	0.06
<i>Rhus aromatica</i>	0.64
Grasses	
<i>Shcizachyruim scoparium</i>	13.30
<i>Bouteloua curtipendula</i>	11.33
<i>Bouteloua gracilis</i>	8.79
<i>Aristida purpurea</i>	3.22
<i>Sorghastrum nutans</i>	2.15
<i>Sporobolus cryptandrus</i>	1.22
<i>Boutelous hirsuta</i>	1.09
Forbs	
<i>Ambrosia confertiflora</i>	4.51
<i>Hymenoxys acaulis</i>	2.41
<i>Aster oblongiflora</i>	2.01
<i>Leuculene ericoides</i>	2.00
<i>Astragalus mollisimus</i>	1.79
<i>Schrankia nuttallii</i>	1.51
Canopy cover for above species	64.31

**Photograph of Representative Vegetation: Deep Sand Plowed Shortgrass State**

Table 16. Site Information: Deep Sand Plowed Midgrass State

Vegetation:	Average Percent Canopy Cover
Shrubs	
<i>Quercus havardii</i>	0.00
<i>Artemisia filifolia</i>	2.76
<i>Prunus gracilis</i>	0.09
<i>Rhus aromatica</i>	1.11
Grasses	
<i>Shcizachyruim scoparium</i>	19.99
<i>Bouteloua curtipendula</i>	10.63
<i>Panicum virgatum</i>	4.78
<i>Bouteloua gracilis</i>	3.49
<i>Sorghastrum nutans</i>	3.34
<i>Bouteloua hirsuta</i>	2.44
<i>Sporobolus cryptandrus</i>	1.61
<i>Aristida purpurea</i>	1.47
<i>Eragrostis curvula</i>	1.40
Forbs	
<i>Ambrosia confertiflora</i>	8.17
<i>Conyza canadensis</i>	3.88
<i>Plantago patagonica</i>	1.81
<i>Aster oblongifolius</i>	1.77
<i>Heterotheca latifolia</i>	1.50
<i>Artemisia biennis</i>	1.13
Canopy cover for above species	71.37

**Photograph of Representative Vegetation: Deep Sand Plowed Midgrass State**

Table 17. Site Information: Deep Sand Unplowed Shinnery State

Vegetation:	Average Percent Canopy Cover
Shrubs	
<i>Quercus havardii</i>	56.36
<i>Artemisia filifolia</i>	6.00
<i>Prunus gracilis</i>	7.65
<i>Rhus aromatica</i>	3.82
Grasses	
<i>Shcizachyruim scoparium</i>	20.02
<i>Bouteloua curtipendula</i>	8.36
<i>Andropogon hallii</i>	4.37
<i>Eragrostis curvula</i>	3.86
<i>Eragrostis trichodes</i>	2.75
<i>Sorgastrum nutans</i>	2.25
<i>Panicum virgatum</i>	2.10
Forbs	
<i>Ambrosia confertiflora</i>	12.01
Average Canopy Cover	129.55



Photograph of Representative Vegetation: Deep Sand Unplowed Shinnery State

Table 18. Site Information: Deep Sand Unplowed Midgrass State

Vegetation:	Average Percent Canopy Cover
Shrubs	
<i>Quercus havardii</i>	36.69
<i>Artemisia filifolia</i>	5.22
<i>Rhus aromatica</i>	1.04
<i>Prunus gracilis</i>	0.41
Grasses	
<i>Shcizachyruim scoparium</i>	13.60
<i>Eragrostis curvula</i>	8.20
<i>Bouteloua curtipendula</i>	5.16
<i>Bouteloua gracilis</i>	5.15
<i>Andropogon hallii</i>	2.52
<i>Sporobolus cryptandrus</i>	2.40
<i>Panicum virgatum</i>	2.11
<i>Sorgastrum nutans</i>	1.16
Forbs	
<i>Ambrosia confertiflora</i>	15.22
<i>Heterotheca latifolia</i>	1.45
<i>Aster oblongifolius</i>	1.05
Canopy cover for above species	101.38

**Photograph of Representative Vegetation: Deep Sand Unplowed Midgrass State**

Table 19. Site Information: Deep Sand Unplowed Tallgrass State

Vegetation:	Average Percent Canopy Cover
Shrubs	
<i>Quercus havardii</i>	31.84
<i>Artemisia filifolia</i>	5.90
<i>Prunus gracilis</i>	18.27
<i>Rhus aromatica</i>	0.83
Grasses	
<i>Shcizachyruim scoparium</i>	40.00
<i>Sorghastrum nutans</i>	5.86
<i>Panicum virgatum</i>	3.67
<i>Eragrostis curvula</i>	2.00
<i>Andropogon hallii</i>	1.46
<i>Bouteloua curtipendula</i>	1.06
Forbs	
<i>Ambrosia confertiflora</i>	3.63
<i>Aster oblongiflora</i>	3.13
<i>Cyperus schweinitzii</i>	2.19
<i>Lespedeza stuevei</i>	1.75
<i>Conyza canadensis</i>	1.05
Canopy cover for above species	122.64



1 Photograph of Representative Vegetation: Deep Sand Unplowed Tallgrass State

1 Table 20. Site Information: Deep Sand Savanna Plowed Shortgrass State

Vegetation:	Average Percent Canopy Cover
Shrubs	
<i>Quercus havardii</i>	0.00
<i>Artemisia filifolia</i>	0.38
<i>Prunus gracilis</i>	0.12
<i>Rhus aromatica</i>	0.14
Grasses	
<i>Shcizachyruim scoparium</i>	35.74
<i>Bouteloua curtispindula</i>	16.64
<i>Bouteloua gracilis</i>	7.31
<i>Aristida purpurea</i>	6.42
<i>Sorghastrum nutans</i>	4.31
<i>Bothriochloa sacchrodies</i>	4.26
<i>Boutelous hirsuta</i>	4.26
Forbs	
<i>Ambrosia confertiflora</i>	7.26
<i>Aster oblongiflora</i>	4.92
Canopy cover for above species	91.76



Photograph of Representative Vegetation: Deep Sand Savanna Plowed
Shortgrass State

Table 21. Site Information: Deep Sand Savanna Plowed Midgrass State

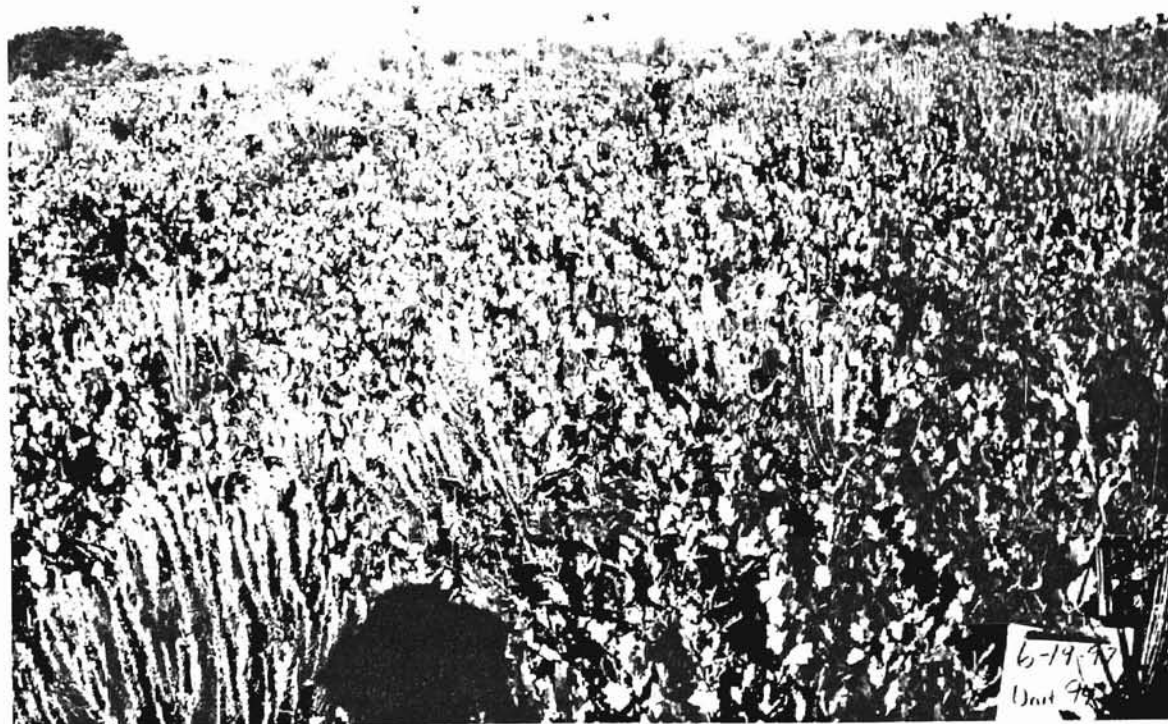
Vegetation:	Average Percent Canopy Cover
Shrubs	
<i>Quercus havardii</i>	0.14
<i>Artemisia filifolia</i>	1.04
<i>Prunus gracilis</i>	0.00
<i>Rhus aromatica</i>	1.45
Grasses	
<i>Shcizachyruim scoparium</i>	40.31
<i>Bouteloua curtipendula</i>	12.88
<i>Sorghastrum nutans</i>	7.92
<i>Bouteloua hirsuta</i>	2.47
<i>Bothriochloa sacchrodies</i>	1.50
<i>Bouteloua gracilis</i>	1.47
<i>Eragrostis curvula</i>	1.29
Forbs	
<i>Ambrosia confertiflora</i>	5.05
<i>Aster oblongifolius</i>	6.86
<i>Physalis viscosa</i>	1.34
<i>Conzya canadensis</i>	1.28
<i>Schrankia nuttallii</i>	1.25
<i>Yucca glauca</i>	1.04
Canopy cover for above species	87.29



**Photograph of Representative Vegetation: Deep Sand Savanna Plowed
Midgrass State**

Table 22. Site Information: Deep Sand Savanna Unplowed Shinnery Oak State

Vegetation:	Average Percent Canopy Cover
Shrubs	
<i>Quercus havardii</i>	52.74
<i>Artemisia filifolia</i>	3.89
<i>Rhus aromatica</i>	4.78
<i>Prunus gracilis</i>	5.78
Grasses	
<i>Shcizachyruim scoparium</i>	11.40
<i>Eragrostis curvula</i>	2.44
<i>Bouteloua curtipendula</i>	7.55
<i>Bouteloua gracilis</i>	1.93
<i>Andropogon hallii</i>	5.52
<i>Sporobolus cryptandrus</i>	1.10
<i>Aristida purpurea</i>	1.83
Forbs	
<i>Ambrosia confertiflora</i>	13.81
<i>Monarda punctata</i>	1.71
Canopy cover for above species	114.48



Photograph of Representative Vegetation: Deep Sand Savanna Unplowed
Shinnery Oak State

Table 23. Site Information: Deep Sand Savanna Unplowed Midgrass State

Vegetation:	Average Percent Canopy Cover
Shrubs	
<i>Quercus havardii</i>	28.59
<i>Artemisia filifolia</i>	3.87
<i>Prunus gracilis</i>	1.59
<i>Rhus aromatica</i>	2.19
Grasses	
<i>Shcizachyruim scoparium</i>	40.24
<i>Bouteloua curtipendula</i>	10.70
<i>Sorghastrum nutans</i>	7.13
<i>Andropogon hallii</i>	3.72
<i>Eragrostis curvula</i>	2.39
<i>Bouteloua hirsuta</i>	2.38
Forbs	
<i>Ambrosia confertiflora</i>	13.00
<i>Aster oblongifolius</i>	7.01
<i>Conyza canadensis</i>	1.95
<i>Artemisia biennis</i>	1.40
Average Canopy Cover	122.81



Photograph of Representative Vegetation: Deep Sand Savanna Unplowed
Midgrass State

Chapter IV

Figure 1. Vegetation States for Loamy Prairie Ecological Sites

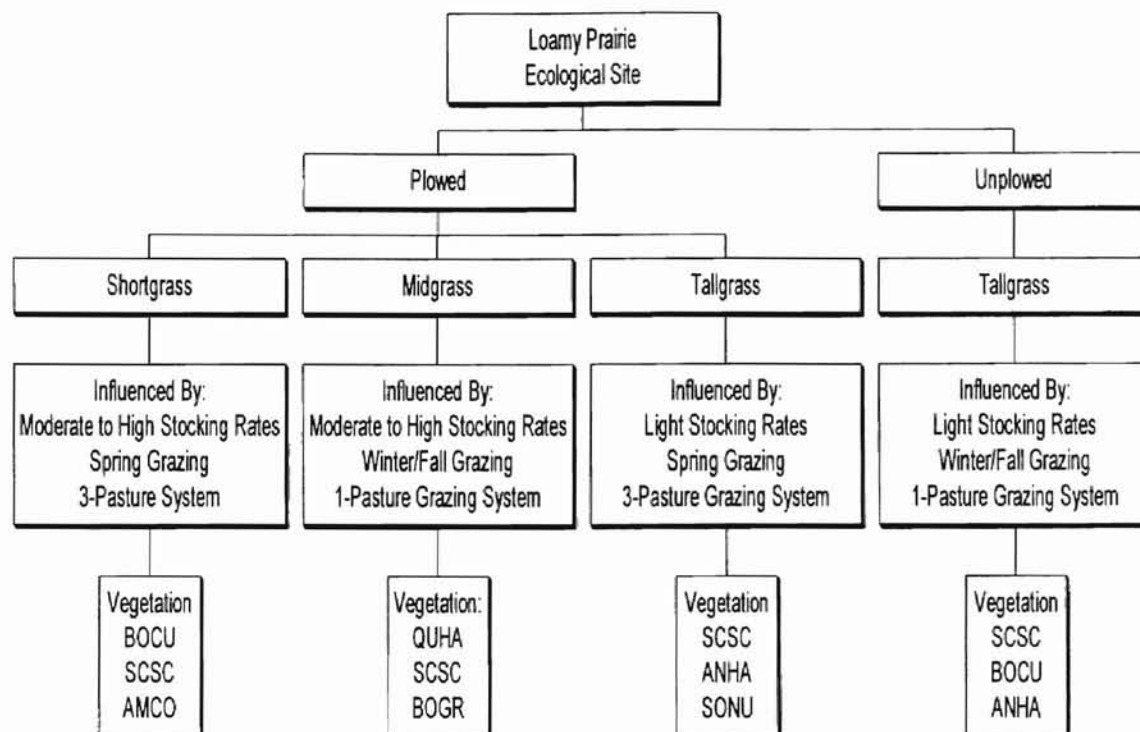


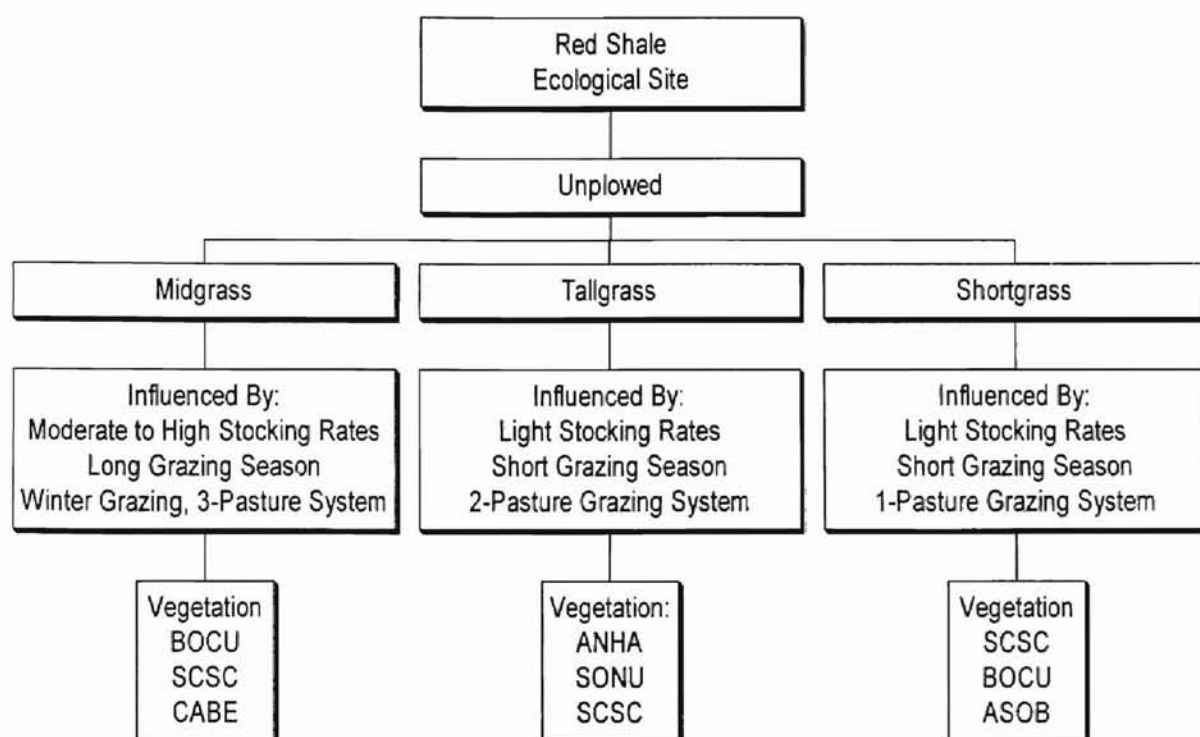
Figure 2. Vegetation States for Red Shale Ecological Sites

Figure 3. Vegetation States for Sandy Prairie Ecological Sites

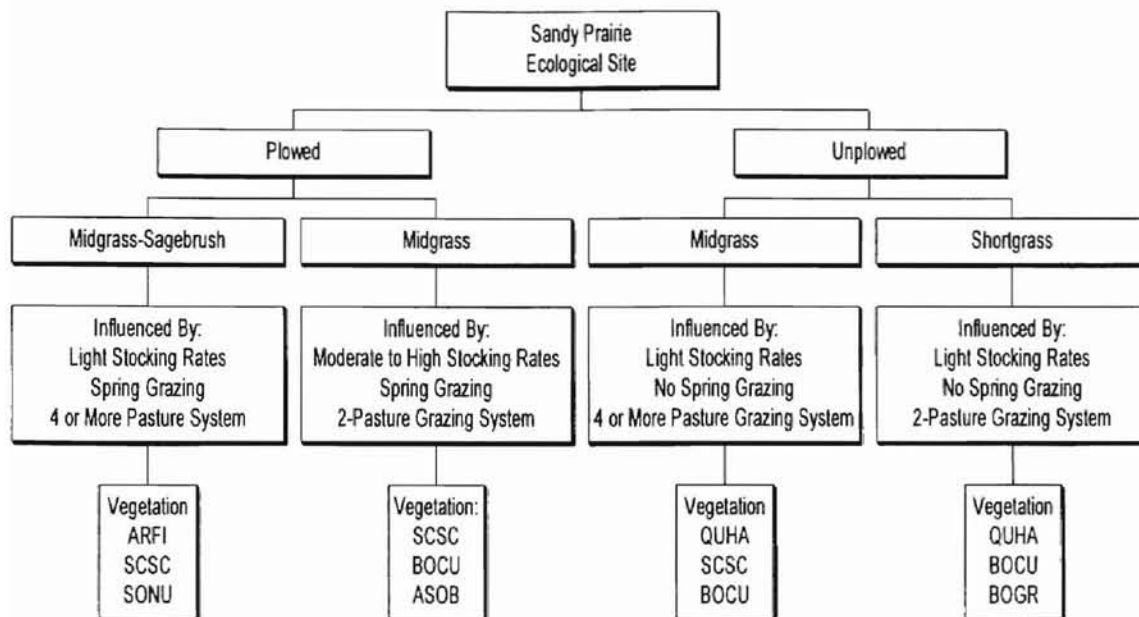


Figure 4. Vegetation States for Deep Sand Ecological Sites

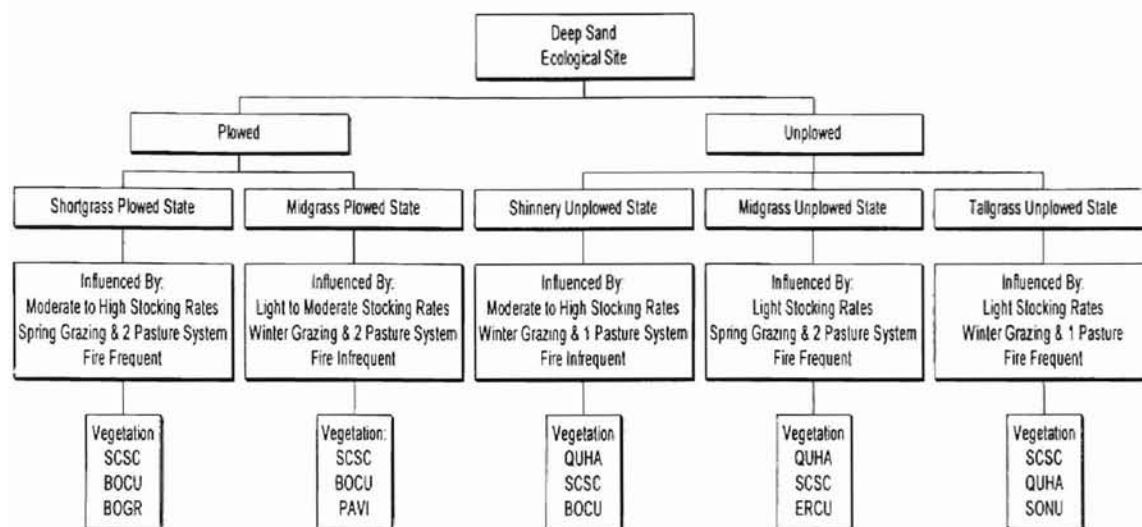
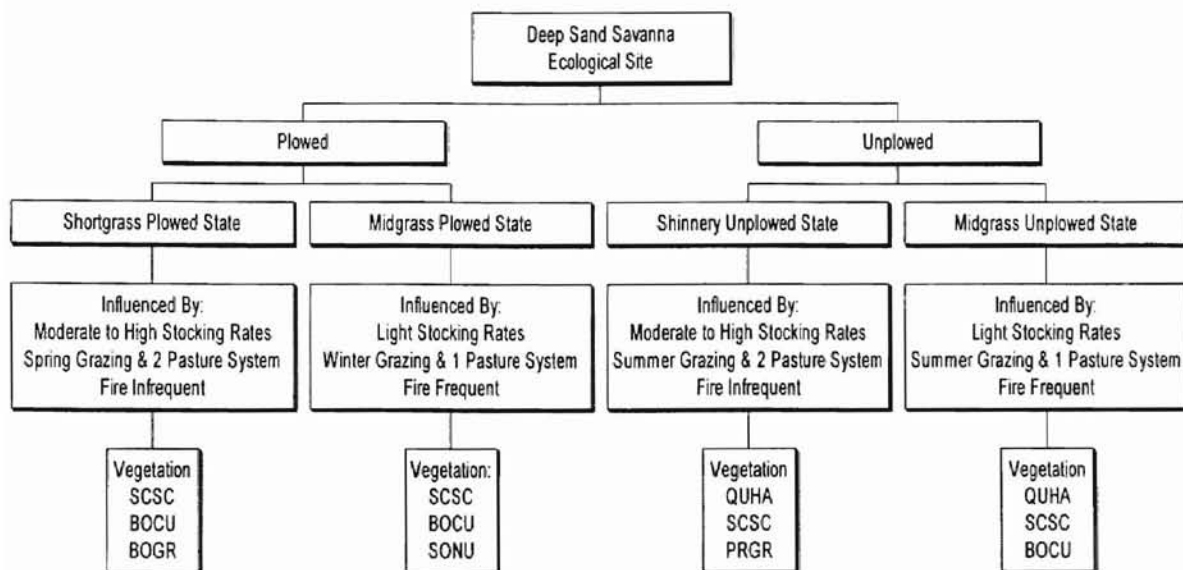


Figure 5. Vegetation States for Deep Sand Savanna Ecological Sites



VITA

Amy L. Smith

Candidate for the Degree of

Master of Science

Thesis: ENVIRONMENTAL AND MANAGEMENT EFFECTS ON PLANT
SPECIES COMPOSITION WITHIN ECOLOGICAL SITES OF THE BLACK
KETTLE NATIONAL GRASSLAND IN WESTERN OKLAHOMA

Major Field: Agronomy

Biographical:

Education: Graduated from Carson City High School, Carson City, Nevada in June 1987, attended California Polytechnic State University, San Luis Obispo, California from September 1987 to June 1991. Transferred to Utah State University, in Logan, Utah in September, 1991 and received Bachelor of Science in Rangeland Ecology June 1993. Completed the requirements for the Master of Science degree with a major in Plant and Soil Sciences specializing in rangeland ecology and management at Oklahoma State University in May, 1998.

Experience:

Employed as an assistant horse trainer summers and weekends 1985 to 1988, at Nelson Cutting Horses, at Red Bluff, California. Employed as a firefighter for the US Forest Service during the summer of 1989, at California Hot Springs, California. Employed as a technician at California Polytechnic State University, Department of Natural Resources Management, managing three greenhouses and a Christmas tree farm during summer and fall of 1990. Employed by Intermountain Range Consultants during the summers of 1991, 1992, and 1994, and all of 1995 as a rangeland scientist. Employed by Oklahoma State University, Department of Plant and Soil Sciences as a graduate research assistant, 1996 to 1998.

Professional Memberships: Society for Range Management