MODEL FOR SERAL STAGE CLASSIFICATION AND MONITORING OF BIG BLUESTEM-SIDEOATS GRAMA-WESTRN WHEATGRASS-BLUE GRAMA ECOLOGICAL TYPE IN CENTRAL SOUTH DAKOTA

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ABSTRACT

A multivariate statistical model (state and transition model) related to plant succession was developed to classify seral stages and monitor plant changes for big bluestem (*Andropogon gerardii* Vitman), sideoats grama (*Bouteloua curtipendula* (Michx.) Torr.), western wheatgrass (*Pascopyrum smithii* (Rydb.) Á. Löve), and blue grama (*Bouteloua gracilis* (Willd. ex Kunth) Lag. ex Griffiths) ecological type in central South Dakota. Soils were made up of shallow clay, shallow, shallow porous clay and defined as shallow clay soils on the Fort Pierre National Grasslands. Seral stages are quantitatively derived groupings of vegetation composition based on the range of variability within the ecological type. The model is not linear and does not always describe a linear progression through the four seral stages (plant community phases). Instead it provides the quantitative framework for state and transition models. Four ecological seral stages representing early to late succession were identified quantitatively with a classification accuracy of 96%. Information needed to define seral stages and to monitor trends is evaluated with canopy cover and frequency of occurrence data collected for the four common perennial grasses. Index values (canopy cover (%) x frequency of occurrence (%)) for big bluestem, sideoats grama, western wheatgrass, and blue grama are the only measurements required for seral stage classification and monitoring.

Keywords

Succession, state and transition, monitoring, mixed-grass, management.

INTRODUCTION

Rangeland ecological status undergoes changes over time following natural and anthropogenic induced disturbances. These changes can be quantified using multivariate statistical models (MacCracken et al. 1983; Mclendon and Dahl 1983; Huschle and Hironaka 1980; Uresk 1990; Friedel 1991; Benkobi et al. 2007; Uresk et al. 2012). Multivariate quantitative models of plant succession allow resource managers to easily obtain quantitative measurements and relate current range condition to management effects at one time and over the long-term on a repeatable basis. Once the models have been developed with key plant species, they are simple to apply in the field and produce interpretable and repeatable results for the resource manager. Changes in transition or steady states of plant succession may be monitored and identified. However, subjective data and interpretations often made it difficult to obtain consistent measurements to determine vegetation trends for transition and steady states of succession.

State and transition models for plant succession have received much attention in recent years, primarily as an approach in predicting ecological processes for plants (Friedel 1991; Laycock 1991; Tausch et al. 1993; National Research Council 1994; Briske et al. 2005). These models provided discrete categories based upon a few fundamental ecological processes and relationships of key indicators for transition or plant succession (Stringham, et al. 2003; Bestelmyer et al. 2003).

A quantitative model based on the interrelationships from a set of plant species (variables) that best characterizes the ecological type throughout the course of transition and steady states would provide managers a tool for assessment and monitoring. The objectives of this study were to (1) develop and test an ecological model for transition, steady states of seral stages and monitoring, (2) produce a classification of seral stages and (3) provide a sampling and monitoring protocol.

STUDY AREA

The study was conducted on the Fort Pierre National Grassland in central South Dakota within Stanley, Lyman, and Jones counties on big bluestem (*Andropogon gerardii* Vitman), sideoats grama (*Bouteloua curtipendula* (Michx.) Torr.), western wheatgrass (*Pascopyrum smithii* (Rydb.) Á. Löve), and blue grama (*Bouteloua gracilis* (Willd. ex Kunth) Lag. ex Griffiths) ecological type on shallow clay soils (shallow clay, shallow, shallow porous clay) (USDA-NRCS. 2008a, 2008b, 2008c). This grassland covers approximately 46,400 ha (116,000 acres). Some private lands are intermixed within the National Grassland. Topography is characterized as upland flats dissected by intermittent drainages and swales with gently rolling hills and slopes. Elevation range is 590 m (1967 ft) to 727 m (2423 ft). Soils are primarily clays derived from the Cretaceous Pierre formation (Gries 1996). Mean annual precipitation average over the last 48 years was 41cm (16 in) and ranges from 15 cm (6 in. recorded in 1976) to 61cm (24 in. recorded in 1999). Seventy-four percent of the precipitation falls during the spring and summer as short duration, intense thunderstorms. The average monthly temperature ranges from 30 °C (87 °F) in the summer to 2 °C (36 °F) in the winter. The highest and lowest daily temperatures recorded were 44 °C (111°F) in 2002 and -44 °C (-47 °F) in 1994, respectively (HPRCC 2013). At the beginning of the study in May 1991, precipitation was twice as great as the long-term average. Precipitation was greater for April-June in 1991 compared to the long-term average and about half the average precipitation recorded in July.

Common plant species on shallow clay ecological type include big bluestem, little bluestem (*Schizachyrium scoparium* (Michx.) Nash var. *scoparium*), green needlegrass (*Nassella viridula* (Trin.) Barkworth), side-oats grama, western wheatgrass, and blue grama. Common forbs include blacksamson echinacea (*Echinacea angustifolia* DC.) and scarlet globemallow (*Sphaeralcea coccinea* (Nutt.) Rydb). Plant nomenclature followed USDA-NRCS (2013).

METHODS

Data collection and analyses followed procedures developed by Uresk (1990). A preliminary visit at Fort Pierre National Grassland began mid-May 1991 to assess vegetation variability on the study area. Site selection encompassed the entire grasslands and included the full range of natural variability of vegetation.

Data were collected on 65 macroplots (sites) during the summer of 1991. Macroplots were randomly selected within one of three perceived early, mid, and late seral stages throughout the grasslands (Cochran 1977; Thompson et al. 1998; Levy and Lemeshow 1999). At each macroplot, two, 30 m (99 ft) parallel transects were established 20 m (66 ft) apart. Canopy cover and frequency of occurrence were estimated within 0.1 m^2 (20 x 50 cm) (8 x 20 in) microplots (Daubenmire 1959). These plots were placed at 1 m (3.3 ft) intervals along each transect. Macroplot data (60 microplots) were averaged for each site to generate mean percent values for individual plant species, total plant cover, litter, bare ground, life form (grass-sedge, forbs, shrubs), and plant type (annual, biennial, perennial). An index was created based on the site cover mean times the site frequency mean. Index = ((transect 1 cover + transect 2 cover)/2) x ((transect 1 frequency + transect 2 frequency)/2) (Uresk 1990). Data were analyzed with SPSS (1992) and SPSS (2003).

Stepwise discriminant analyses were used for the initial reduction of variables on the perceived three seral stages (early, mid, late) (Uresk 1990). This initial procedure was used only to reduce the number of variables for further analyses. Principal component analyses were useful for additional data reduction with fewer variables after initial reduction by discriminant analyses.

Reduced data were analyzed with non-hierarchical cluster analysis, ISODATA, which grouped the 65 sites into 4 distinct cluster groups or seral stages (Ball and Hall 1967; del Moral 1975). Discriminant analyses (SPSS 1992, 2003) identified four key variables for seral stage classification and provided a quantitative model for future classification and monitoring ($P < 0.05$). Misclassification error rates were estimated with cross validation procedures (SAS 1988, SPSS, 2003). The model was field tested during the second year (1992). Most common and abundant (> 1% index) plant species are displayed in tables or discussed in the text by seral stage.

RESULTS

Seral Stages—Discriminant analyses allowed us to select big bluestem, sideoats grama, western wheatgrass, and blue grama as the most important variables for seral stage classification and monitoring ($P < 0.05$). The shallow clay ecological type was classified into 4 seral stages (Figure 1). Big bluestem was dominant in the late seral stage, sideoats grama in the late intermediate seral stage, and western wheatgrass in the early intermediate seral stage. Blue grama was most important in the early seral stage. Distributions of index values for these 4 key plant species throughout the seral stages illustrate the dynamics of these species within this ecological type (Figure 1, Table 1).

Plant species richness is greater in the late intermediate and early intermediate seral stages when numbers of individual species are compared (Figure 2). Life form compared by seral stage shows that the early stage for species richness is

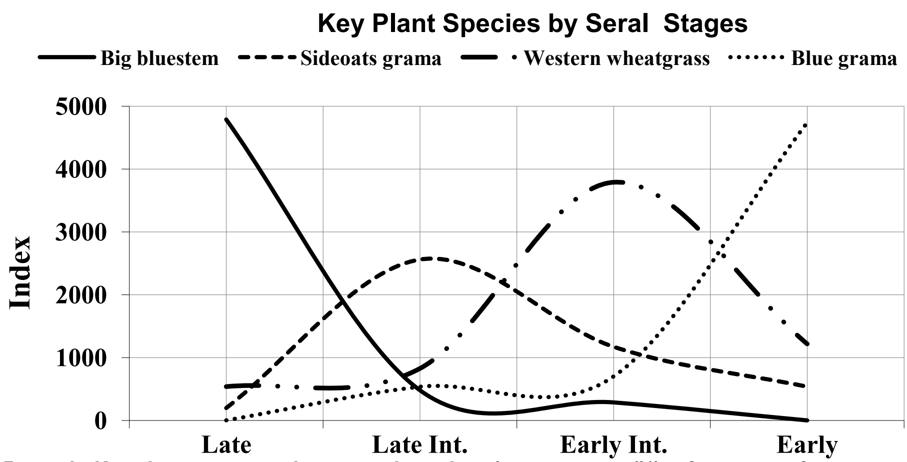

Figure 1. Key plant species with mean index values (canopy cover (%) x frequency of occurrence (%) displayed throughout the four seral stages. Graph provides an approximate mixture of species at each seral stage.

Table 1. Index of the key plant species (cover (%) x frequency (%) by seral stages used in model development for shallow clay ecological type.

Seral stage	n	Big bluestem	Sideoats grama	Western wheatgrass	Blue grama
			Index		
Late	8	4787	197	540	2
Late intermediate	27	480	2558	828	536
Early intermediate	21	286	1171	3791	700
Early	9	0	536	1219	4740

n= sample size

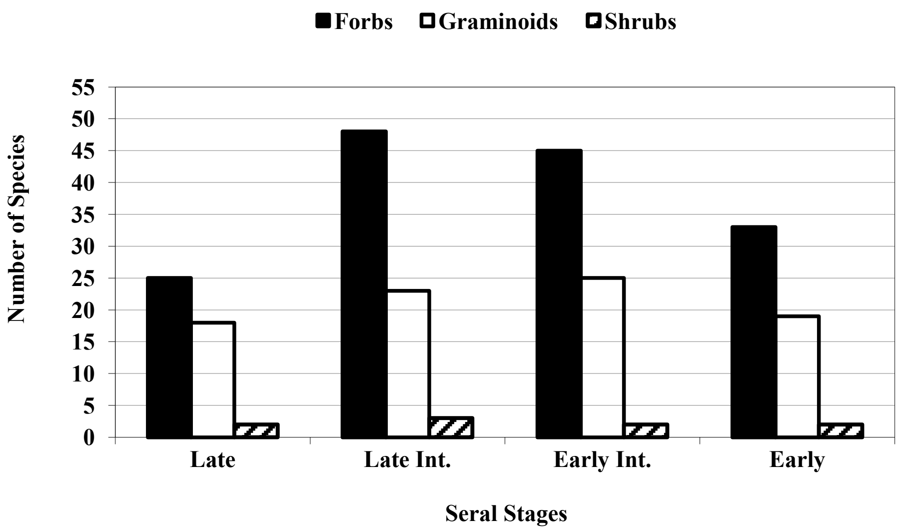

Figure 2. Number of plant species by life form category throughout the four seral stages.

less than the intermediate stages, but greater than the late seral stage. Some of these differences may be due to the number of sites sampled among seral stages.

Fisher classification coefficients from discriminant analyses provide model coefficients for predicting plant dynamics, seral stage assignment and monitoring within and among seral stages within the ecological system. The magnitude of the Fisher's classification function coefficients indicated the importance that each variable had among seral stages (Table 2). An example of seral stage assignment for new data collected in the field on a site by Fisher's classification coefficients is presented in Table 3. To obtain a score, multiply the mean site index values for big bluestem, sideoats grama, western wheatgrass and blue grama by the Fisher's coefficients for each seral stage (row) and then sum the products. The greatest score identifies assignment of seral stage. When the products summed are negative, the least negative score is used for assignment of seral stage. An example from new field data collected for canopy cover (%) and frequency of occurrence (%) on a site multiplied together for new indices are big bluestem = 400, sideo-

Table 2. Fisher's classification discriminant function coefficients used for classification of seral stages in shallow clay ecological type.

Species	Late	Late intermediate	Early intermediate	Early
Big bluestem	0.00	0.0006342	0.0013455	0.0008401
Side	-0.0005919	0.0014011	0.0005069	0.0001215
Western wheatgrass	0.0020182	0.0010648	0.0052126	0.0003574
Blue	0.0004455	0.0005978	0.0000352	0.0072227
Constant	-19.29502	-3.931707	-11.76937	-18.75304

Table 3. An example of assigning seral stages by using shallow clay Fisher's discriminant coefficients with new index data collected from the field for big bluestem, sideoats grama, western wheatgrass, and blue grama.

	Big bluestem		Sideoats grama		Western wheatgrass		Blue grama				
Seral	(Coeff[1]	* Index -	Coeff	* Index +	Coeff	* Index +	Coeff	* Index)	- Const	=	Score
Late	(0.0072795 *	400	- 0.0005919 *	2100	+ 0.0020182 *	1800	+ 0.0004455 *	800)	-19.295	=	-13.64
Late Int.	(0.0006342 *	400	+ 0.0014011 *	2100	+ 0.0010648 *	1800	+ 0.0005978 *	800)	-3.932	=	**1.66**[2]
Early Int.	(0.0013455 *	400	+ 0.0005069 *	2100	+ 0.0052126 *	1800	+ 0.0000352 *	800)	-11.769	=	-0.76
Early	(0.0008401 *	400	+ 0.0001215 *	2100	+ 0.0003574 *	1800	+ 0.0072227 *	800)	-18.753	=	-11.74

[1] Coeff = Fisher's discriminant classification coefficient, Const = Constant values from Fisher's discriminant model, Int. = Intermediate.
[2] Assigned seral stage.

ats grama = 2100, western wheatgrass = 1800 and blue grama = 800. In this example, the greatest score is 1.66, which assigns this site to the late intermediate stage. The overall accuracy of the model for seral stage assignment from cross validation is 96 % based on data analyses from SAS (1988) and SPSS (2003). Additional details on seral classification, successional trends, data collection, plot establishment, sampling and programs for a lightweight hand held computer such as a personal digital assistant (PDA) or other computers may be obtained from USDA-Forest Service web site at http://www.fs.fed.us/rangelands/ecology/ecologicalclassification/index.shtml.

Late seral stage—The late seral stage was dominated by big bluestem and western wheatgrass with canopy cover of 61% and 16% and frequency of occurrence of 78% and 34%, respectively (Table 4 and 5). Sideoats grama and blue grama had lesser amount of cover 7% and 1%, and frequency 27% and 3%, correspondingly. Little bluestem, porcupine grass (*Hesperostipa spartea* (Trin.) Barkworth), green needlegrass, and needleleaf sedge (*Carex duriuscula* C.A. Mey.) were the major perennial species in late seral stage, ranging in canopy cover from 6% to 13% and frequency from 16% to 24% (Table 4 and 5). Field brome (*Bromus arvensis* L.) was common with 6% cover and 15% frequency. The forb component was dominated by two species, sweet clover (*Melilotus officinalis* (L.) Lam.) and silverleaf Indian breadroot (*Pediomelum argophyllum* (Pursh) J. Grimes) with 20% and 3% canopy cover, respectively (Table 4). Total grass-sedge cover was 93%, forb cover was approximately 27% and shrub cover was 2%. Litter made up 46% cover while bare ground was less than 1%.

Plant species richness in the late seral stage consisted of 25 forbs, 18 grass-sedge and two shrubs (Figure 2) in 10 plant families. Eighty seven percent of the plants were perennial species.

Late Intermediate seral stage—The composition of vegetation in this seral stage was dominated by sideoats grama with 34% cover and a frequency of 75% (Table 4 and 5). Big bluestem, western wheatgrass, and blue grama cover ranged

Table 4. Canopy cover means (%) and standard errors (in parentheses) of common plant species and other variables by seral stage in shallow clay ecological type.

Variable	Late	Late Intermediate	Early Intermediate	Early
Big bluestem[1] *Andropogon gerardii*	61.4(4.5)	13.7(2.1)	11.7(2.4)	<0.1(<0.1)
Sideoats grama[1] *Bouteloua curtipendula*	7.2(2.0)	34.2(3.3)	21.5(2.5)	12.0(2.9)
Western wheatgrass[1] *Pascopyrum smithi*	15.7(3.6)	15.8(1.7)	43.0(2.2)	16.0(2.7)
Blue grama[1] *Bouteloua gracilis*	0.6(0.2)	15.2(2.1)	17.3(2.8)	51.8(3.8)
Little bluestem *Schizachyrium scoparium*	11.1(7.8)	12.3(3.3)	0.4(0.2)	0
Porcupine-grass *Hesperostipa spartea*	9.9(3.7)	7.6(1.8)	2.8(1.0)	0.1(0.1)
Green needlegrass *Nassella viridula*	6.5(2.5)	14.0(2.4)	18.6(2.9)	14.6(4.5)
Needleleaf sedge *Carex duriuscula*	6.0(4.0)	3.4(1.0)	13.2(4.0)	3.4(1.9)
Field brome *Bromus arvensis*	5.5(4.7)	1.8(0.7)	11.3(3.0)	2.9(0.8)
Prairie sandreed *Calamovilfa longifolia*	0.6(0.6)	6.1(1.8)	1.3(0.4)	0.3(0.3)
Threadleaf sedge *Carex filifolia*	<0.1(<0.1)	5.1(1.8)	5.9(2.7)	10.3(4.5)
Needle and thread grass *Hesperostipa comata*	0.1(0.1)	1.7(0.7)	1.1(0.5)	4.4(1.8)
Buffalograss *Buchloe dactyloides*	0.7(0.7)	0.2(0.1)	3.8(2.0)	1.2(0.7)
Silverleaf Indian breadroot *Pediomelum argophyllum*	3.3(0.8)	2.1(0.4)	1.8(0.7)	1.1(0.3)
Sweet clover *Melilotus officinalis*	20.2(8.2)	13.0(2.7)	16.0(4.1)	18.9(7.0)
Blacksamson echinacea *Echinacea angustifolia*	0.3(0.3)	2.9(0.8)	0.8(0.3)	0.7(0.4)
Scarlet globemallow *Sphaeralcea coccinea*	<0.1(<0.1)	0.1(0.1)	1.1(0.5)	2.2(0.9)
American vetch *Vicia americana*	<0.1(<0.1)	0.1(0.1)	0.4(0.1)	2.0(0.6)
White health aster *Symphyotrichum ericoides*	0.6(0.6)	0.4(0.2)	0.7(0.5)	1.0(0.3)
Total Grass-sedge	**92.8(2.0)**	**89.0(1.7)**	**86.9(1.9)**	**87.8(1.0)**
Total Forbs	**26.7(8.9)**	**22.8(2.9)**	**26.3(4.3)**	**28.1(6.7)**
Total Shrubs	**1.8(0.9)**	**4.1(3.2)**	**3.0(1.3)**	**0.8(0.6)**
Total Litter	**46.4(14.4)**	**33.9(5.8)**	**37.9(6.8)**	**49.1(4.5)**
Bare ground	**0.2(0.1)**	**11.7(3.0)**	**10.3(3.0)**	**21.9(6.3)**

[1]Key plant species

Table 5. Frequency of occurrence means (%) and standard errors (in parentheses) of common plant species and other variables by seral stages.

Variable	Late	Late Intermediate	Early Intermediate	Early
Big bluestem[1] *Andropogon gerardii*	77.9(5.0)	35.1(2.1)	24.5(4.0)	0
Sideoats grama[1] *Bouteloua curtipendula*	27.4(6.2)	74.8(5.7)	54.5(5.4)	44.9(9.6)
Western wheatgrass[1] *Pascopyrum smithi*	34.4(6.7)	52.3(4.7)	88.2(2.0)	76.4(8.5)
Blue grama[1] *Bouteloua gracilis*	3.2(0.9)	35.2(4.5)	40.5(5.5)	91.7(2.3)
Little bluestem *Schizachyrium scoparium*	18.1(10.9)	23.5(4.8)	1.0(0.6)	0
Porcupine-grass *Hesperostipa spartea*	23.5(8.6)	20.4(4.5)	8.9(2.9)	0.8(0.6)
Green needlegrass *Nassella viridula*	15.0(4.9)	34.9(5.3)	42.9(5.5)	48.9(7.7)
Needleleaf sedge *Carex duriuscula*	16.0(10.8)	15.6(4.5)	29.4(7.1)	16.7(8.5)
Field brome *Bromus arvensis*	15.4(10.6)	10.1(3.2)	36.8(7.5)	23.0(4.7)
Prairie sandreed *Calamovilfa longifolia*	3.1(3.1)	17.0(4.4)	4.8(1.6)	2.3(1.7)
Threadleaf sedge *Carex filifolia*	0.2(0.2)	12.9(4.4)	10.6(4.8)	26.5(8.9)
Needle and thread grass *Hesperostipa comata*	0.6(0.3)	7.5(2.8)	3.6(1.5)	16.8(5.6)
Buffalograss *Buchloe dactyloides*	2.1(2.1)	0.5(0.3)	6.4(3.1)	4.5(2.3)
Silverleaf Indian breadroot *Pediomelum argophyllum*	16.5(2.8)	12.4(2.2)	9.4(3.1)	11.9(4.0)
Sweet clover *Melilotus officinalis*	41.0(11.3)	39.2(6.0)	41.0(8.5)	58.0(9.9)
Blacksamson echinacea *Echinacea angustifolia*	2.3(1.8)	15.7(3.5)	6.8(2.2)	5.6(3.2)
Scarlet globemallow *Sphaeralcea coccinea*	0.2(0.2)	1.5(0.8)	5.8(2.2)	15.2(5.9)
American vetch *Vicia americana*	0.6(0.4)	1.1(0.4)	3.0(1.2)	17.7(6.2)
White health aster *Symphyotrichum ericoides*	2.1(1.7)	2.7(1.0)	2.5(0.9)	6.3(1.9)

[1]Key plant species

from 14% to 16% and frequency ranged from 35% to 52%. Little bluestem, porcupine grass, green needlegrass were the next most common plants and ranged from 8% to 14% canopy cover (Table 4). Frequency for these plants ranged from 20% to 35% (Table 5). The forb component was dominated by sweet clover with 13% cover and a frequency of 39%. Total grass-sedge cover was 89% followed by forb cover with 23%. Shrub cover was 4%. Litter cover and bare ground were 34% and 12% respectively.

Plant species richness consisted of 48 forbs, 23 graminoids, and 3 shrubs (Figure 2) included in 23 plant families. About 78% of the plants were perennial with 22% annuals including the biennial, sweet clover.

***Early Intermediate seral stage*—**Western wheatgrass dominated this seral stage (Table 4 and 5) and accounted for 43% canopy cover and 88% frequency of occurrence. Sideoats grama, green needlegrass, blue grama, needleleaf sedge, and field brome were the next most common species with 22%, 19%, 17%, 13%, and 11% canopy cover, respectively. Frequency of occurrence for these same plants ranged from 29% to 55%. The forb component was dominated by sweet clover with 16% canopy cover and silverleaf Indian breadroot and scarlet globemallow with cover amounts between 1-2% (Table 4). Grass-sedge canopy cover was 87%, forbs 26% and shrubs 3%. Litter and bare ground made up 38% and 10%, respectively.

Plant species richness included 45 forbs, 25 graminoids, and 2 shrubs (Figure 2) in 22 plant families. Seventy nine percent of the plants were perennial and 21% were annuals or biennials.

***Early seral stage*—**Within this seral stage, blue grama grass was widely distributed and more abundant than in other seral stages (Figure 1). Blue grama canopy cover was 52% with a 92% frequency (Table 4 and 5). Canopy cover of other common grass-sedge plants included western wheatgrass (16%), green needlegrass (15%), sideoats grama (12%), and threadleaf sedge (*Carex filifolia* Nutt.) (10%). Frequency of occurrence for these species ranged from 27% to 76%. Field brome made up 3% cover and 23% frequency of occurrence. Sweet clover was the dominant forb at 19% canopy cover and 58% frequency. Other forbs included scarlet globemallow, American vetch (*Vicia americana* Muhl. ex Willd.), and smooth white aster (*Symphyotrichum porteri* (A. Gray) G.L. Nesom) with 1-2% canopy cover and 6% -18% frequency of occurrence. Total grass-sedge canopy cover was 88%, forbs 28% and shrubs 1%. Litter was 49% and bare ground 22%.

Fourteen plant families consisting of 33 forbs, 19 graminoids, and 2 shrubs (Figure. 2) represented plant richness. In this early seral stage, 76% of the plant species are perennials with 24% annuals and biennials.

DISCUSSION

The multivariate model developed for plant succession does not necessarily move in a linear fashion through seral stages. Transition can be through various pathways (Westoby et al. 1989; Tausch et al. 1993). For example, disturbance can move plant species associations or abundance on an ecological type directly from late to early successional status or the ecological type may remain at one seral stage for many years. The developed model with indicator plant species can be incorporated easily into state and transition models for ecological types and ecological sites. This model is a way to quantify differences between community phases (seral stages) and to identify indicators of potential state shifts. Currently, most state and transition models are derived from personal judgments and observations, making these models essentially qualitative. Monitoring for trends or indicators of plant species associations and abundance can be achieved on permanent macro-plots that are re-measured over time. The new assigned seral stage provides resource managers with a quantitative method to evaluate current and past management objectives.

Knowledge of plant seral stages as related to states and transitions provides managers a powerful tool to aid in evaluating and monitoring vegetation for resource conditions and status (Uresk 1990; Benkobi and Uresk 1996; Uresk et al. 2012). Our quantitative model describes the key plant species with interrelationships occurring throughout the four seral stages from early to late succession. The model developed was based on data collected from a full range of vegetation values (canopy cover and frequency of occurrence) that can be used to determine seral stages regardless of hypothetical past or future climax vegetation.

Managing for all four seral stages can be viewed as management alternatives (early, early intermediate, late intermediate, late). Resource management for multiple seral stages increases plant and animal diversity over the landscape (Figures 1 and 2) (Holechek et al. 1989; Benkobi and Uresk 1996; Fritcher et al. 2004; Vodehnal et al. 2009). Because one seral stage is not practical for multiple-use management, the entire seral range (from early to late) is required to accommodate greatest plant species diversity, wildlife habitat diversity, and livestock production. In addition, management of rangelands for livestock, wildlife, and plant diversity with the developed seral stage model will provide resource managers with a tool that can be easily applied across the landscape. A recommendation of 10-15% of the landscape should be in each of the early and late seral stages and the remainder in the intermediate stages (Kershaw 1973; Mueller-Dombois and Ellenberg 1974; Steel and Torie 1980). This would provide a mixture of stages (habitat) for plant and animal diversity on the landscape (Uresk 1990; Rumble and Gobeille 1995; Fritcher et al. 2004; Benkobi et al. 2007; Vodehnal et al. 2009; Uresk et al. 2012).

Livestock grazing can be a tool that is useful for regulating seral stages and condition (Severson and Urness 1994). By adjusting the stocking rate of livestock and timing of grazing during the plant-growing season, plant species composition can result in a change from a non-preferred seral stage or management alternative to the preferred management alternative (desired seral stage). The model can quantify changes in plant species composition with data collected at various grazing levels for management strategies necessary to maintain or restore the desired successional status of the vegetation.

The four seral stages that we developed allow land managers discrete categories that they can manage at different spatial levels favorable to meet objectives of management. For example, land managers can easily determine seral condition for each pasture within each grazing allotment. Depending upon the land management objectives for an allotment or pasture, increased or decreased cattle grazing will modify plant succession and move the current seral condition toward the desired seral condition or stay it at a steady state.

The developed classification and monitoring system used multivariate statistical methods to determine key plant species that best predict seral stages within the western wheatgrass, big bluestem, sideoats grama, blue grama ecological type. As a consequence, four seral stages (early to late) were quantitatively identified with an accuracy level greater than 96%. Canopy cover and frequency of occurrence for the key plants are the only required field measurements on western wheatgrass, big bluestem, sideoats grama, and blue grama is all that is required to determine seral stage classification from the model and to monitor plant changes resulting from management or environmental influences. Data collection may be conducted yearly or once every few years. Recommendations are to establish a minimum of two macro-plots per section, 259 ha (640 acres) within the ecological type (Benkobi et al. 2007). See aforementioned website for additional information. Because the four perennial plants required for this model are some of the most common species within this ecological type, they can be monitored easily to determine seral transition and status.

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