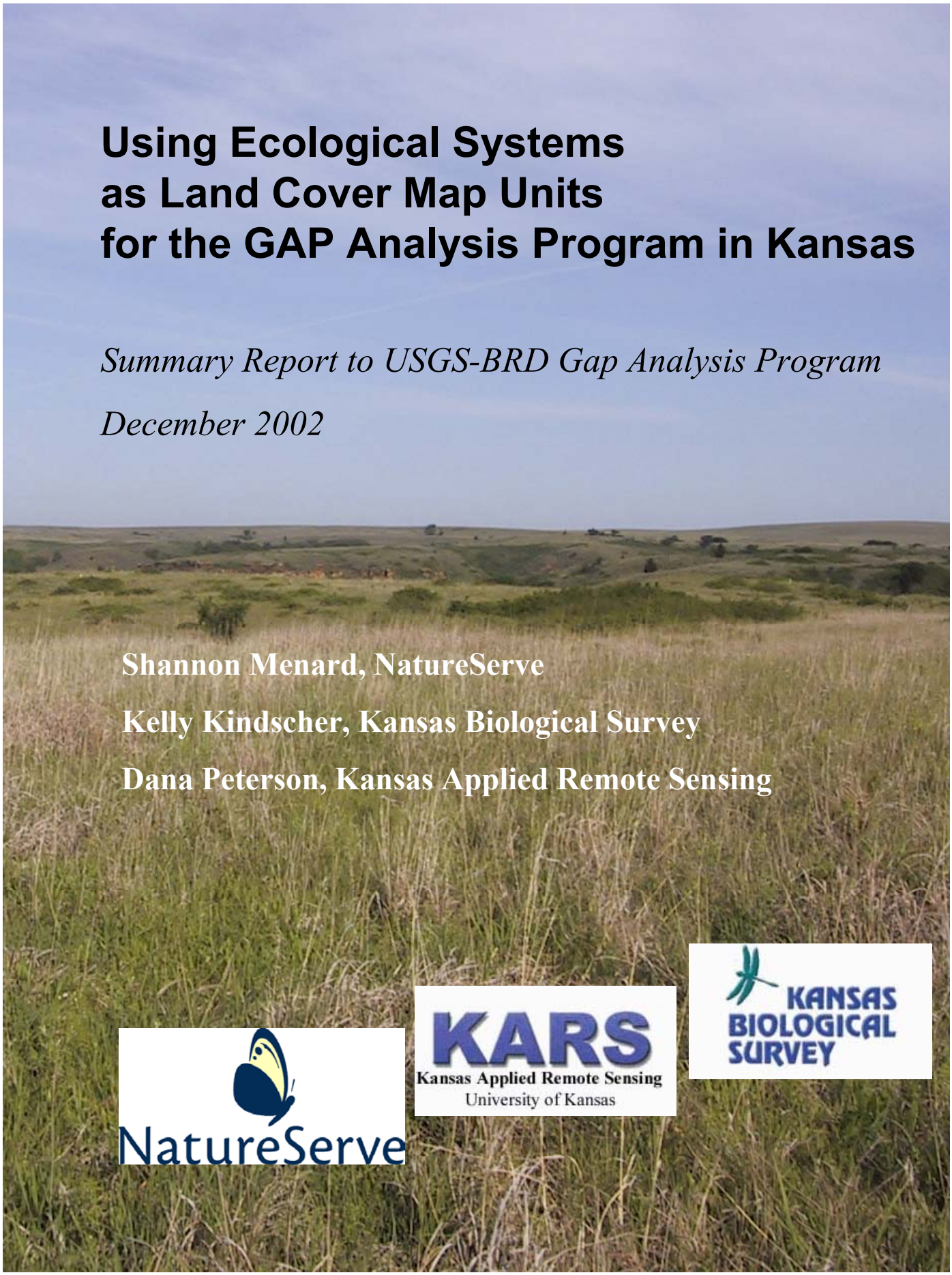

Using Ecological Systems as Land Cover Map Units for the GAP Analysis Program in Kansas

Summary Report to USGS-BRD Gap Analysis Program

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KANSAS BIOLOGICAL SURVEY

USING ECOLOGICAL SYSTEMS AS LAND COVER MAP UNITS FOR THE GAP ANALYSIS PROGRAM IN KANSAS

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Cover Photo: The photo on the cover shows a spring view of the South-Central Great Plains Mixedgrass Prairie Ecological System. This site is from Horse Thief Canyon, which is found in the Dakota Sandstone, Smoky Hills Physiographic Province in Ellsworth County, Kansas. *Photo by Shannon E. Menard*.

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Abstract

The USGS-GAP Analysis Program and NatureServe have collaborated to map existing vegetation using the U.S. National Vegetation Classification (USNVC) classification standard at the alliance level. Many state and regional GAP programs have needed to develop map units at varying levels from finer than alliances to aggregating alliances into coarser units. Ecological systems present an alternative and consistent method to develop vegetation units across states. Ecological systems are directly linked to the USNVC classification standard and are defined as groups of plant associations from one or more alliances that occur together on a given landscape due to similar ecological dynamics, underlying environmental features, and/or environmental gradients. A pilot study was initiated in the state of Kansas to develop ecological systems in that region and link them to the original Kansas GAP Vegetation Map. The original map was recoded to reflect the 17 upland and wetland ecological systems attributed to Kansas. Accuracy assessment analyses indicated at least a 2% increase in the accuracy compared to the original map. These results indicate that using ecological systems could increase the accuracy of vegetation maps and also help regionalize GAP maps such that they could be more easily used for modeling vertebrate habitat ranges.

Introduction

GAP uses the U.S. National Vegetation Classification (USNVC) maintained by NatureServe as a classification standard for mapping existing vegetation for each state (FGDC 1997, Grossman *et al.* 1998). The map units are intended to be attributed at the alliance level of the USNVC. However, many state GAP programs have used a variety of methods to derive map units, from mapping associations (finer than alliances) to aggregating alliances into coarser units that can encompass different upper physiognomic units. The different states in the Great Plains chose various ways of combining alliances. This will lead to potential problems when crosswalking map units across state borders to derive a regional, ecologically meaningful map, which also can lead to problems in developing consistent maps that predict distributions of vertebrate species across a region.

Ecological systems are groups of plant associations from one or more alliance that occur together on a given landscape due to similar ecological dynamics (e.g., fire, riverine flooding), underlying environmental features (e.g., deep soils, serpentine bedrock), and/or environmental gradients (elevation) (NatureServe 2002). For example, within Kansas and the Great Plains, floodplain systems include several willow and cottonwood-dominated plant associations and some small wetlands that all require periodic flooding. They also include vegetation from multiple successional stages that are supported by riverine dynamics. In the Great Plains, ecological systems can form spatially contiguous units and provide a standardized classification structure for lumping associations or alliances that share ecological processes. Ecological systems may take two forms similar in scope and concept to compositional groups and ecological complexes, units already being used

by GAP that explicitly relate alliances to specific map units (Pearlstine *et al.* 1998). Because ecological systems are defined with a strong emphasis on environmental settings and dynamics, they should provide a more practical and ecologically meaningful goal for mapping at regional scales where alliance-scale mapping is not feasible (Menard and Lauver 2000). NatureServe is dedicated to the mapping of ecological systems in a consistent manner across the United States. This ecological systems layer will provide the a consistent finer level classification of ecological units with biological and conservation value that is requested and required for many biological, ecological, conservation and resource management and decision-making applications. It will also provide intuitive or widely understood concepts for grouping vegetation types that managers and other users can more readily understand.

Ecological systems can allow for useful integration and scaling among species because many animal and plant species are likely restricted to one or several ecological systems. More mobile vertebrates that use a wider variety of ecological systems typically require specific habitat components nested within ecological system units. Because systems are directly tied to environmental conditions, features and processes, these units will be highly correlated to other variables such as topography and climate that can be used to develop vertebrate habitat models. Thus systems could provide a way to "regionalize" GAP maps while still maintaining conservation units that are ecologically meaningful and can be successfully used to model habitats of specific species.

Ecological systems have recently evolved from several years of work of ecologists from NatureServe, TNC and the Natural Heritage Network, and NatureServe is currently developing a classification of Terrestrial Ecological Systems for the coterminous United States (NatureServe, in prep.). Significant progress has been made towards the conceptual and actual development of systems in the Great Plains. However, the utility of Systems in developing spatial units for projects such as GAP needs to be addressed in more detail. Ecological systems could be a valuable tool in unifying state GAP maps across a region by developing more ecologically meaningful map units where individual alliances cannot be distinguished. The Kansas land cover map has units from multiple spatial scales and provides a valuable test case to determine the utility of these units for state GAP maps. The vegetation of Kansas is representative of the Great Plains, and lessons learned from this pilot project in refining and applying systems will be beneficial to applications in other states. The methods used in this pilot study could be applied to neighboring states to evaluate the use of ecological systems at a regional level. Potentially, the systems approach could lead to more accurate maps of vegetation communities across the region. This pilot study addresses these and other issues by reformulating the current Kansas GAP land cover map to show ecological systems. Map units used in the current Kansas GAP map range from associations to alliances to mosaics of these levels (Egbert *et al.* 2001, KARS 2002). This procedure encompasses much of the variety of map units in other state GAP maps in the Great Plains, and presents a good test case to assess the use of systems in unifying and crosswalking map units across these states and multiple spatial scales. The Kansas GAP project offers an ideal mechanism to address how systems can be used to develop accurate, ecological map units. Specifically, the objectives in this pilot study are to 1) develop a list and descriptions of

ecological systems found in Kansas; 2) recode the existing Kansas GAP map to reflect ecological systems attributed to the state of Kansas; 3) compare the accuracy of the recoded ecological systems map to the original Kansas GAP landcover map; and 4) evaluate the use of ecological systems for a Great Plains Regional land cover map.

Methods

Development of Ecological Systems for Kansas and Surrounding Areas

Ecological systems for Kansas and similar areas in the Great Plains were defined using both "top-down" and "bottom-up" approaches. Initially, sub-continental landscapes modified from Bailey (1996 and 1997) were used to geographically bound systems to reflect broad similarities in climate and biogeography (Figure 1).

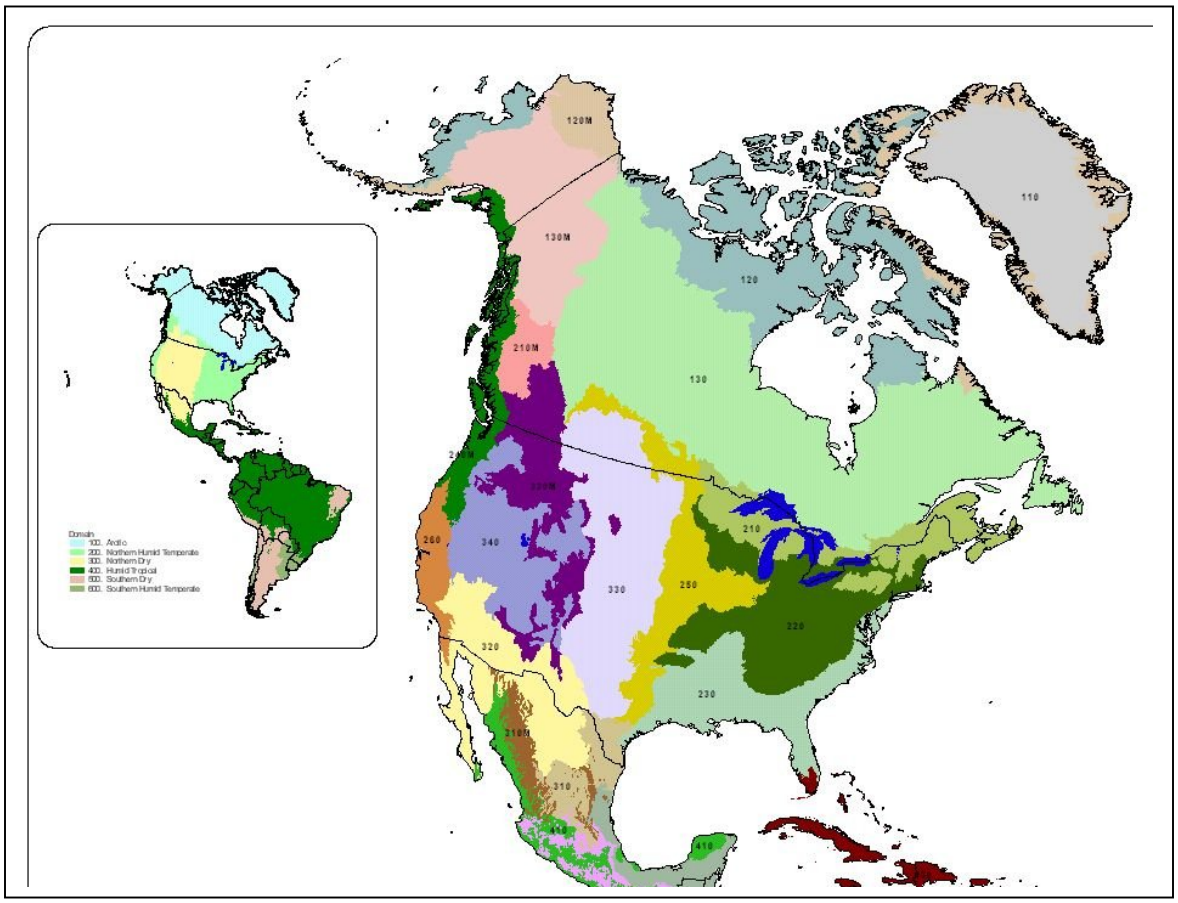

Figure 1. Bioclimatic Divisions in the United States and Canada modified from Domains and Division of Bailey (1996, 1997). (From NatureServe 2002).

In Kansas, two Divisions were present, the Great Plains Division to the west (Division 330) and the Temperate Prairie Division to the east (Division 250). These Divisions also form part of the ecological system's name (e.g. Temperate Prairie Floodplain System) for those systems found primarily within that Division (i.e. >80% of its range was in that Division).

Ecological systems were then defined as groups of USNVC alliances and/or associations that share similar ecological processes, substrates, and/or environmental gradients. These criteria were first used at a coarse scale to further subdivide ecological systems. This "top-down" approach was then used in combination with more detailed knowledge about USNVC alliances and their more specific environmental requirements (i.e. "bottom-up" approach). Figure 2 demonstrates this process of starting with broad characteristics and then integrating more precise characteristics at lower levels with specific examples of wetland ecological systems in the Great Plains and Kansas. Appendix A details the primary and secondary ecological and geographic criteria that could be used to define ecological systems.

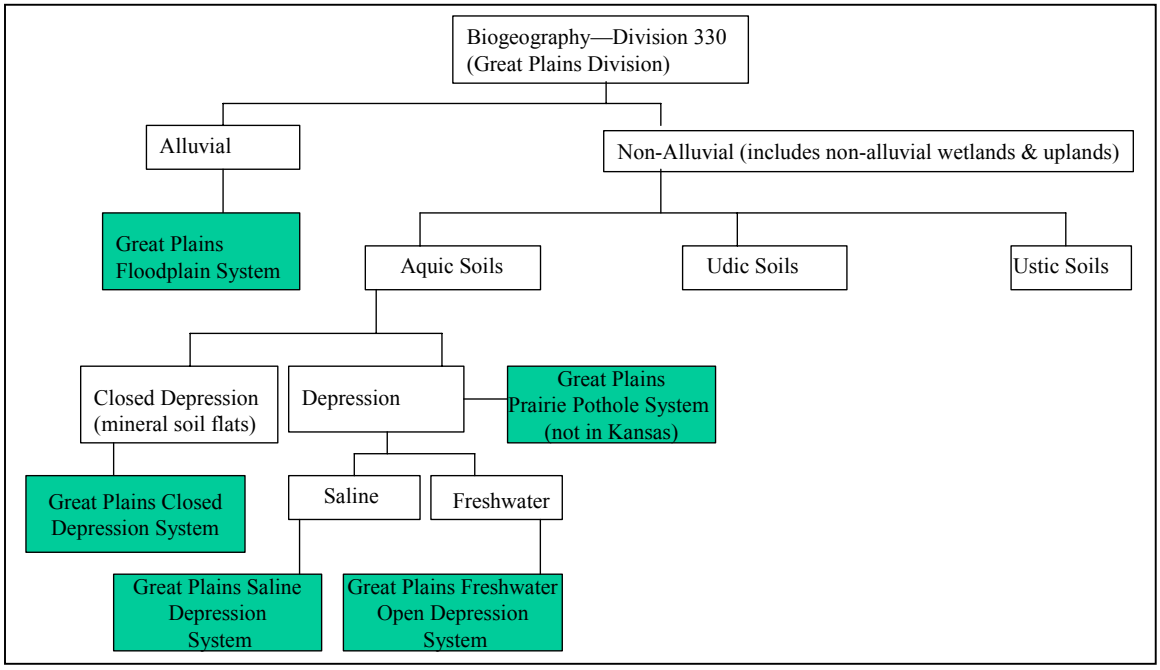

Figure 2. Example decision matrix for wetland systems in the Great Plains Division. This demonstrates the use of coarse and fine criteria to define ecological systems in this region.

Ecological systems were named based on the Division they were predominately found (in some cases this was further subdivided into distinct regions such as South-Central Great Plains), the determinant environmental factor, and/or the predominant vegetation structure (e.g. forest, woodland, shrubland) and/or composition (e.g. shortgrass prairie).

Recoding of Original Kansas Vegetation Map

Kansas GAP used TM imagery to develop their landcover map of alliances and groups of alliances (Figure 3; see Egbert *et al.* 2001 for full description of these methods). These landcover classes were recoded to ecological systems based on the component USNVC alliance and association information used in their development (see above). Documented USNVC alliances and associations (NatureServe 2002) were used as descriptors of the ecological systems, so USNVC alliances and/or the original Kansas vegetation classes were easily reassigned to an ecological system.

The USGS 1:100k Surface Water Information Management System hydrology database was used to separate several upland and lowland systems. A 250m buffer was created around the stream networks and water bodies. Systems occurring within the 250m buffer were coded as a floodplain system type while systems occurring outside the 250m buffer were coded as upland system types.

A systems division map from NatureServe was used to differentiate between Great Plains and Temperate Prairie systems in Kansas (Figure 1).

Accuracy Assessment of Ecological Systems Landcover Map

Kansas GAP has recent field data from several sites. A selected number of these sites were used to compare the accuracy of the ecological system map to the original Kansas land cover map. Accuracy levels of the ecological systems landcover map were calculated by comparing the classified data (systems land cover map) with 828 field or reference sites that were collected throughout the state in 2000. Accuracy assessments were conducted using three approaches; (1) a centered point within the digitized polygon, (2) three-by-three window buffered around the point, and (3) centered point of the focal majority within the polygon. The centered point within the polygon compared the center pixel in the field site with the corresponding pixel in the classified data. The three-by-three window compared nine pixels positioned around the center point within the polygon with the corresponding nine pixels in the classified data. The focal majority function calculated the dominant land cover type in the classified data within each polygon for each field site and was then compared to the centered point.

Accuracy levels were also calculated by physiographic province. Reference sites within each physiographic province were compared to the systems land cover map. Accuracy assessments by physiographic province were conducted using the focal majority approach.

Results

Ecological Systems

A total of 17 wetland and upland Great Plains and Temperate Prairie ecological systems were identified to occur within Kansas, and were assigned to the original landcover classes in the Kansas Vegetation Map. The Kansas Vegetation Map Based on Ecological Systems, was created based on these new assignments (Figure 4). Table 1 shows the renumbering or recoding scheme used to assign GAP alliance level classes to systems level classes and the linkage between the original map and the new ecological system classification. Note that there are some semi-natural and/or exotic cover types that were not assigned an ecological system. These represent heavily disturbed or invaded sites that likely will not become a natural system and thus should be handled independently of the ecological system classification. Also, some of the original vegetation units originally defined by Kansas may occur in the 2 different Divisions. In each Division, they were assigned an ecological system defined for that particular Division. These systems were also directly linked to the USNVC alliances in the Great Plains and Temperate Prairie Divisions. The number of USNVC alliances related to a particular ecological system ranged from 4 to over 20 (in Kansas, ecological systems relate to associations from 1 to 10 USNVC alliances). Specific criteria used to define systems varied but could include biogeography, total floristic composition, physiognomy (vertical structure), spatial pattern (horizontal structure), physical environment (e.g. soil type),

chemical variables (e.g. pH, salinity), and prevailing dynamic processes (e.g. fire, flooding). Wetland systems were typically defined more using hydrologic and flooding regimes and thus the component USNVC alliances and associations used to define systems do not necessarily share physiongnomic or floristic characteristics. In contrast, upland systems tended towards broad patterns in vegetative physiognomy that were more constant over larger areas and diagnostic of environmental and ecological processes. Appendix B contains more detailed descriptions of the individual ecological systems attributed to Kansas along with a list of the USNVC alliances related to each system.

Table 1: Original Kansas GAP Vegetation Map classes and relationship new ecological system classification.

Gap Alliance Class Number	Kansas Gap Map Name	Temperate Prairie Systems Name	TPS Class	Great Plains Systems Name	GPS Class
1	Maple-Basswood Forest	Temperate Prairie Mesic Hardwood Forest and Woodland System	1		
2	Oak-Hickory Forest	Central Temperate Prairie Dry Oak Forest and Woodland System	2		
3	Post Oak-Blackjack Oak Forest	Cross Timbers Oak Forest and Woodland System	3	Cross Timbers Oak Forest and Woodland System	3
4	Pecan Floodplain Forest	Central Temperate Prairie Floodplain System	4		
5	Ash-Elm-Hackberry Floodplain Forest	Temperate Prairie Wooded Draw and Ravine System	5	Great Plains Floodplain System	8
		Central Temperate Prairie Floodplain System	4	Great Plains Wooded Draw and Ravine System	9
6	Cottonwood Floodplain Forest	Central Temperate Prairie Floodplain System	4	Great Plains Floodplain System	8
7	Mixed Oak Floodplain Forest	Central Temperate Prairie Floodplain System	4		
8	Bur Oak Floodplain Woodland	Central Temperate Prairie Floodplain System	4	Great Plains Floodplain System	8
9	Mixed Oak Ravine Woodland	Temperate Prairie Wooded Draw and Ravine System	5		
10	Post Oak-Blackjack Oak Woodland	Cross Timbers Oak Forest and Woodland System	3	Cross Timbers Oak Forest and Woodland System	3

Gap Alliance Class Number	Kansas Gap Map Name	Temperate Prairie Systems Name	TPS Class	Great Plains Systems Name	GPS Class
11	Cottonwood Floodplain Woodland	Central Temperate Prairie Floodplain System	4	Great Plains Floodplain System	8
12	Sandsage Shrubland			Great Plains Sandhills Shrubland System	10
14	Willow Shrubland			Great Plains Floodplain System	8
15	Buttonbush (Swamp) Shrubland	Central Temperate Prairie Floodplain System	4		
		Central Temperate Prairie Wet Meadow/Prairie System	6		
17	Tallgrass Prairie	Flint Hills Temperate Prairie System	7	Great Plains Tallgrass Prairie System	11
18	Sand Prairie			Great Plains Sand Prairie System	12
20	Western Wheatgrass Prairie			South-Central Great Plains Mixedgrass Prairie System	13
21	Sandstone Glade/Prairie	Flint Hills Temperate Prairie System	7		
22	Mixed Prairie			South-Central Great Plains Mixedgrass Prairie System	13
24	Alkali Sacaton Prairie			Great Plains Saline Depression System	14
25	Shortgrass Prairie			Great Plains Shortgrass Prairie System	15
26	Grass Playa Lake			Great Plains Closed Depression System	16
27	Salt Marsh/Prairie			Great Plains Saline Depression System	14
28	Spikerush Playa Lake			Great Plains Closed Depression System	16
29	Playa Lake			Great Plains Closed Depression System	16
30	Low or Wet Prairie	Central Temperate Prairie Floodplain System	4	Great Plains Closed Depression System	16

Gap Alliance Class Number	Kansas Gap Map Name	Temperate Prairie Systems Name	TPS Class	Great Plains Systems Name	GPS Class
				Great Plains Floodplain System	8
31	Freshwater Marsh	Central Temperate Prairie Wet Meadow/Prairie System	6	Great Plains Closed Depression System	16
32	Bulrush Marsh	Central Temperate Prairie Wet Meadow/Prairie System	6	Great Plains Closed Depression System	16
33	Cattail Marsh	Central Temperate Prairie Wet Meadow/Prairie System	6	Great Plains Closed Depression System	16
		Central Temperate Prairie Floodplain System	4	Great Plains Floodplain System	8
				**Great Plains Open Freshwater System	
38	Forb Playa Lake			Great Plains Closed Depression System	16
51	Maple Floodplain Forest	Central Temperate Prairie Floodplain System	4	Great Plains Floodplain System	8
55	Deciduous Woodland	Central Temperate Prairie Dry Oak Forest and Woodland System	2	Great Plains Floodplain System	8
		Central Temperate Prairie Floodplain System	4	Great Plains Tallgrass Prairie System	11

Table 2: Current Kansas GAP Land Use/LandCover Not Assigned to a System Type.

Gap Alliance Class Number	Kansas Gap Map Name	TPS Class
40	Non-native Grassland	17
41	CRP (Conservation Reserve Program)	18
42	Salt Cedar or Tamarisk Shrubland	19
44	Cultivated Land	20
50	Deciduous Forest-Mined Land	21
52	Evergreen Forest-Disturbed Land	22
60	Mixed Prairie-Disturbed Land	23
70	Weedy Marsh	24
71	Weedy Upland	25
81	Urban Areas	26
82	Water	27

Map Creation and Accuracy Assessment

The map created with this project represents the first statewide map of ecological systems based on a recoding of a state GAP map. Although detailed analyses of the distribution of ecological systems across Kansas was not part of this pilot, results show broad patterns of vegetation across the state. Areas influenced by human activity such as CRP land, agriculture, and heavily disturbed forests primarily dominate the vegetation of Kansas. Natural ecological systems demonstrate the distribution of the natural vegetation, which comprises approximately 26% of the area, and reflect biogeographic regions of Kansas. The majority of eastern Kansas is comprised the matrix Flint Hills Tallgrass Prairie System with inclusions of woodlands and floodplain systems. The most predominate system in central Kansas is the South-Central Great Plains Mixedgrass Prairie System. Natural vegetation in western Kansas is predominately Great Plains Shortgrass and Sandhill Shrubland Systems. These matrix systems typify the difference between the Temperate Prairie Division where tallgrass prairie is the characteristic vegetation, and the Great Plains Division, which has thinner, drier soils and thus is distinguished by mixedgrass and shortgrass prairies along with dry shrublands.

Accuracy assessment results are summarized in the following tables (see Egbert *et al.* for a complete description of the results for the original Kansas GAP Vegetation Map). The overall accuracy for the alliance level ranged from 49 to 51% (Tables 3, 4). The assessment of ecological systems yielded an overall accuracy of approximately 53% (Table 3). Although this is only a 2% increase, key individual classes had much higher values (Table 5) and outperformed alliances for specific classes.

Table 3: Overall accuracy by classification level.

	Point	Focal Majority	3x3 window
Overall Alliance Accuracy	49.28%	51.69%	49.76%
Alliance Kappa	43.21%	45.84%	43.70%
Overall System Accuracy	53.10%		
System Kappa	47.13%		

Table 4: USNVC alliance accuracy by alliance class.

Vegetation Types	Alliance #	User's Accuracy			Producer's Accuracy		
		Point	Focal Maj	3x3 window	Point	Focal Maj	3x3 window
Maple-Basswood Forest	**01**						
Oak-Hickory Forest	**02**	**26.32%**	**26.32%**	**25.71%**	**71.43%**	**71.43%**	**71.43%**
Post Oak-Blackjack Oak Forest	**03**	**38.46%**	**46.15%**	**49.43%**	**71.43%**	**85.71%**	**68.25%**
Pecan Floodplain Forest	**04**				**0.00%**	**0.00%**	**0.00%**
Ash-Elm-Hackberry Floodplain Forest	**05**	**42.31%**	**41.38%**	**41.03%**	**34.38%**	**37.50%**	**33.33%**
Cottonwood Floodplain Forest	**06**	**8.33%**	**12.50%**	**11.39%**	**100.00%**	**100.00%**	**100.00%**
Mixed Oak Floodplain Forest	**07**	**0.00%**	**0.00%**	**0.00%**			
Bur Oak Floodplain Woodland	**08**				**0.00%**	**0.00%**	**0.00%**
Mixed Oak Ravine Woodland	**09**	**0.00%**	**40.00%**	**15.71%**	**0.00%**	**100.00%**	**61.11%**
Post Oak-Blackjack Oak Woodland	**10**	**50.00%**	**33.33%**	**31.82%**	**33.33%**	**33.33%**	**25.93%**
Cottonwood Floodplain Woodland	**11**	**25.00%**	**30.77%**	**25.20%**	**36.36%**	**36.36%**	**31.31%**
Sandsage Shrubland	**12**	**46.88%**	**51.61%**	**48.13%**	**51.72%**	**55.17%**	**49.43%**
Willow Shrubland	**14**						
Buttonbush (Swamp) Shrubland	**15**						
Tallgrass Prairie	**17**	**48.03%**	**47.56%**	**49.14%**	**68.87%**	**73.58%**	**72.01%**
Sand Prairie (with Sand Bluestem)	**18**	**61.11%**	**61.11%**	**61.59%**	**39.29%**	**39.29%**	**40.08%**
Western Wheatgrass Prairie	**20**	**10.00%**	**15.79%**	**15.10%**	**8.00%**	**12.00%**	**12.89%**
Sandstone Glade / Prairie (with Little Bluestem and Threeawn)	**21**						
Mixed Prairie (with Little Bluestem and Sideoats Grama)	**22**	**43.17%**	**44.39%**	**41.64%**	**63.71%**	**70.16%**	**64.59%**
Alkali Sacaton Prairie	**24**						
Shortgrass Prairie	**25**	**68.00%**	**66.20%**	**68.75%**	**48.11%**	**44.34%**	**48.43%**
Grass Playa Lake (with Western Wheatgrass and / or Buffalograss)	**26**						
Salt Marsh / Prairie (with Saltgrass)	**27**						
Spikerush Playa Lake	**28**						
Playa Lake (with Smartweed and / or Barnyard grass)	**29**						

Low or Wet Prairie (with Prairie Cordgrass and Sedges)	**30**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Freshwater Marsh (with Bulrush and Cattail)	**31**						
Alkaline Marsh (with Bulrush)	**32**	**0.00%**	**0.00%**	**0.00%**			
Cattail Marsh	**33**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Forb Playa Lake	**38**						
Non-native Grassland (e.g. Smooth Brome or Tall Fescue)	**40**	**60.00%**	**69.12%**	**62.06%**	**42.86%**	**44.76%**	**45.19%**
CRP (Conservation Reserve Program)	**41**	**68.04%**	**76.40%**	**69.14%**	**50.38%**	**51.91%**	**48.26%**
Salt Cedar or Tamarisk (non-native) Shrubland	**42**	**0.00%**		**0.00%**	**0.00%**	**0.00%**	**0.00%**
Cultivated Land	**44**	**82.93%**	**80.95%**	**81.10%**	**68.00%**	**68.00%**	**65.78%**
Deciduous Forest - Mined Land	**50**	**50.00%**	**50.00%**	**39.13%**	**100.00%**	**100.00%**	**100.00%**
Maple Floodplain Forest	**51**						
Evergreen Forest - Disturbed Land	**52**						
Deciduous Woodland	**55**	**0.00%**		**0.00%**	**0.00%**	**0.00%**	**0.00%**
Mixed Prairie - Disturbed Land	**60**	**14.29%**	**22.73%**	**18.09%**	**11.54%**	**19.23%**	**14.53%**
Weedy Marsh	**70**	**50.00%**	**0.00%**	**19.05%**	**33.33%**	**0.00%**	**14.81%**
Weedy Upland	**71**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Urban Areas	**81**						
Water	**82**				**0.00%**	**0.00%**	**0.00%**

Table 5: Ecological system accuracy by system.

	Ecological System	**User's Accuracy (commission accuracy)**	**Producer's Accuracy (omission accuracy)**
01	Temperate Prairie Mesic Hardwood Forest and Woodland System		
02	Temperate Prairie Oak Forest and Woodland System	26.3%	62.5%
03	Cross Timbers Forest and Woodland System	53.3%	80.0%
04	Temperate Prairie Riparian System	33.3%	25.0%
05	Temperate Prairie Wooded Draws and Ravines	0.0%	0.0%
06	Temperate Prairie Freshwater Depression	0.0%	
07	Temperate Tallgrass Prairie System	54.1%	74.2%
08	Great Plains Riverine System	60.0%	72.7%
09	Great Plains Wooded Draws and Ravines	25.0%	100.0%
10	Great Plains Sandhills Shrubland System	46.9%	51.7%
11	Great Plains Tallgrass System	9.5%	18.2%
12	Great Plains Sand Prairie System	68.8%	39.3%
13	South-Central Great Plains Mixedgrass Prairie System	47.3%	64.4%
14	Great Plains Saline Depression System		

15	Great Plains Shortgrass Prairie System	68.0%	48.1%
16	Great Plains Closed Depression System	0.0%	0.0%
17	Non-native Grassland	60.0%	42.9%
18	CRP (Conservation Reserve Program)	68.0%	50.4%
19	Salt Cedar or Tamarisk Shrubland	0.0%	0.0%
20	Cultivated Land	82.9%	68.0%
21	Deciduous Forest-Mined Land	50.0%	100.0%
22	Evergreen Forest-Disturbed Land		
23	Mixed Prairie-Disturbed Land	14.3%	11.5%
24	Weedy Marsh	50.0%	33.3%
25	Weedy Upland	0.0%	0.0%
26	Urban Areas		
27	Water		0.0%

Discussion

Ecological systems currently being developed by NatureServe demonstrate a viable alternative to using USNVC alliances and uneven lumping of alliances. Kansas GAP used TM imagery to develop their map of USNVC alliances (Egbert *et al.* 2001), but researchers often found it difficult to distinguish individual alliances using remotely sensed data. Simply recoding the original Kansas Vegetation Map from USNVC alliances to ecological systems increased the accuracy of the landcover by approximately 2%. Although the accuracy increased just slightly, this increase in accuracy does suggest that ecological systems would provide a more accurate approach to GAP vegetation maps. If ecological systems were used to classify the original TM imagery, it would likely increase the accuracy of the natural vegetation layer even further.

Using criteria such as biogeography, hydrology, soils, etc. more directly in the development of systems also allow for using ancillary data sources such as the USGS 1:100k Surface Water Information Management System hydrology database. This would aid in identifying systems such as wetlands that not obviously apparent in TM imagery and also would help model the distribution of these systems across the landscape. Likewise, further developments and refinements to the definitions of ecological systems in the region would likely increase the accuracy even further.

The ecological systems identified for Kansas range into other states in the Great Plains and Temperate Prairie Divisions. These systems would help regionalize these maps. For example, sand prairies in SD, NE, and KS are all defined slightly differently as Sand Hills High Cover Grassland, Sandhills Upland Prairie, and Sand Prairie, respectively. These groupings contain slight differences in the listed USNVC alliances found in the region (e.g. South Dakota contains two component USNVC alliances whereas Kansas only lists one), but would be considered the same ecological system. Thus the issues associated with trying to parse the different grouping of alliances in South Dakota and

comparing that to how the alliances used by Kansas would be eased by using ecological systems to regionalize that vegetation type.

Currently, a project independently funded by USGS-GAP is underway to address this issue in five Great Plains states (NE, KS, SD, WY, and CO) based on a request by the USFS to aid them in the development of their wildlife habitat models. This project also involves a recoding of the original GAP maps to ecological systems and some comparison of that method versus using the original TM imagery to classify landcover to ecological systems. Initial results suggest that regionalizing these states using ecological systems will alleviate some of the current issues with differences among the states in how alliances were attributed in each state. The wildlife habitat models developed for this region will likely be more consistent and cover the range of each species more completely. Likewise, the environmental data used to develop ecological systems will further relate to species requirements beyond vegetation and help refine range models even further.

Finally, because ecological systems are directly linked the USNVC hierarchy, these units would still be FGDC compliant and allow for state and regional GAP programs to map USNVC alliances or associations where possible while maintaining a comprehensive ecological system layer. This would allow users flexibility in the scale of information needed for various objectives and may allow for expanded use of GAP landcover data by other agencies.

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Appendix A: Diagnostic classifiers used to develop ecological systems (From NatureServe 2002).

Diagnostic Classifiers for Terrestrial Ecological Systems				
	CRITERIA	**PRIMARY VALUES**	**SECONDARY VALUES**	**DESCRIPTION (also: Source/Literature)**
GENERAL STRATIFIERS				
NATURALNESS				
	NATURAL/NEAR-NATURAL			
	PLANTED/CULTIVATED			
PREDOMINANT EDAPHIC CONDITION				
	WETLAND			
	UPLAND			
NATURAL VEGETATED UPLANDS				
FIRST TIER - GENERAL CLASSIFIERS				
	LIFE ZONES			thresholds vary by global bioclimatic zone: Polar, Boreal/Austral, Temperate, Mediterranean, Tropical (see Rivas-Martinez et al. 1999. *Itinera Geobotanica* 12:5-316)
		ALPINE	thermotype belts: Athermic, Cryoro-	
		MONTANE	thermotype belts: Oro-, Supra-, Meso-	
		LOWLAND	thermotype belts: Thermo-, Infra-	
		User defined		
	MAJOR PHYSIOGNOMY			FGDC 1997
		FOREST AND WOODLAND (TREE)		
		SHRUBLAND (SEMI-DESERT, CHAPPARAL, ETC.) (SHRUB)		
		GRASSLAND, SAVANNA, STEPPE (HERBACEOUS)		
		MOSS/LICHEN (NON-VASCULAR)		
	LANDFORMS			
		USER DEFINED (E.G. CANYON BOTTOM, CLIFF FACE, BADLANDS, ETC.		
	TOPOGRAPHY			
		HIGH RIDGE/UPPER SLOPE		
		HIGH-LOW SLOPE		
		TOESLOPE/BOTTOM/VALLEY		
		OTHER		
	SPECIALIZED SUBSTRATES			

		CLIFF		
		TALUS		
		DUNE		
		ROCK OUTCROPS/BARRENS/GLADES		
		TUFA		
		PLAYA LAKE BED		
		OTHER		
SECOND TIER - SPECIFIC CLASSIFIERS				
	SUBSTRATE			
	GLACIAL HISTORY			
		GLACIATED		
		UNGLACIATED		
		PERIGLACIAL		
	SOIL FERTILITY			NRCS
		EUTROPHIC		
		MESOTROPHIC		
		OLIGOTROPHIC		
	SOIL PH			
		ALKALINE		NRCS
		CIRCUMNEUTRAL		
		ACIDIC		
	SPECIALIZED SUBSTRATE CHEMISTRY			
		USER DEFINED (E.G. SERPENTINE, ETC.)		
	SOIL DEPTH			NRCS
		VERY SHALLOW (<15 cm) (<30)		
		SHALLOW (15-100 cm) (30 - 100)		
		DEEP (>100 cm)		
	SOIL ORGANIC MATTER			NRCS
		ORGANIC PEAT(> 40 cm)		
		MUCK		
		MINERAL: W/ A HORIZON> 10 CM		
		MINERAL: W/ A HORIZON <10 CM		
	SOIL TEXTURE			NRCS
		SAND (sand, loamy sand)		
		LOAM (loam, sandy loam, sandy clay loam)		
		SILT (silt, silt loam)		
		CLAY (clay, clay loam, sandy clay, silty clay, silty clay loam)		
	SOIL MOISTURE			NRCS

		AQUIC		
		ARIDIC		
		UDIC		
		USTIC		
		XERIC		
	SUBSTRATE CONSOLIDATION			
		CONSOLIDATED		
		UNCONSOLIDATED		
		OTHER		
	DISTURBANCE			
	RETURN INTERVAL	VERY SHORT (<1-6 YRS)	Periodicity/nonrandom	
		SHORT (7-12 YRS)	Periodicity/irregular	
		INTERMEDIATE (13-25 YRS)	Perodicity/polycyclic	
		LONG (26-100 YRS)	Seasonality/Spring	
		VERY LONG (>100 YRS)	Seasonality/Summer	
			Seasonality/Fall	
			Seasonality/Winter	
	FIRE INTENSITY/SPATIAL CHARACTER	PATCH/HIGH INTENSITY		High= stand replacement >70% mortality, soil surface effects, increased stand homogeneity (Buckner & Turrill 1999. Peine John D. 1999).
		PATCH/MEDIUM INTENSITY		Medium = partial stand replacement (30-70% mortality, moderate soil surface effects, increasing stand heterogeneity
		PATCH/LOW INTENSITY		Low = e.g. forest underburns w/ <30% mortality, negligible soil surface effects, no impact on stand heterogeneity
		LANDSCAPE/HIGH INTENSITY		Patch: Relatively small and/or discontinuous. In natural conditions, typical size ranges from 1-2,000 ha.
		LANDSCAPE/MEDIUM INTENSITY		Landscape: Generally large and continuous (>2,000 ha)
		LANDSCAPE/LOW INTENSITY		
	GRAZING INTENSITY/SPATIAL CHARACTER	PATCH/HIGH INTENSITY		
		PATCH/MEDIUM INTENSITY		
		PATCH/LOW INTENSITY		
		LANDSCAPE/HIGH INTENSITY		
		LANDSCAPE/MEDIUM INTENSITY		
		LANDSCAPE/LOW INTENSITY		
	MASS MOVEMENT TYPE	FLOOD SCOURING		

		LANDSLIDE		
		AVALANCHE		
		LAVA FLOW		
	WIND INTENSITY/SPATIAL CHARACTER	PATCH/HIGH INTENSITY		
		PATCH/MEDIUM INTENSITY		
		PATCH/LOW INTENSITY		
		LANDSCAPE/HIGH INTENSITY		
		LANDSCAPE/MEDIUM INTENSITY		
		LANDSCAPE/LOW INTENSITY		
	OTHER	USER DEFINED		
	LIFE FORM			
		NVCS categories		FGDC
	MICROCLIMATE			Climatic gradients within a division, or specialized microclimate, e.g. cold air drainages.
		USER DEFINED		
THIRD TIER - SPATIAL/TEMPORAL				
	GEOGRAPHIC SCALE AND PATTERN			
		LINEAR		
		SMALL PATCH		
		LARGE PATCH		
		MATRIX		
	JUXTAPOSITION			
		USER DEFINED		
	TEMPORAL PERSISTENCE			
		SHORT - 50-100 YRS		
		MODERATE - 100-500 YRS		
		LONG - > 500 YRS		
NATURAL VEGETATED WETLANDS				
FIRST TIER - GENERAL CLASSIFIERS				
	HYDROGEOMORPHIC UNITS			BRINSON et al. 1993
		SEEPAGE-FED SLOPING (SEEPAGE FLOW)		
			MINERAL	
			PEATY	
		EXTENSIVE WET FLAT(SHEET FLOW, SEEPAGE FLOW)		

		DEPRESSIONAL (RAINWATER, LOCAL SHEET FLOW)		
			LAKESHORE (COULD BE FRINGE)	
			POND	
			VERNAL POOL	
		RIVERINE / ALLUVIAL (STREAM FLOW)		
			OPTIONAL (COWARDIN HYDROLOGY)	
			OPTIONAL (BLACKWATER, BROWNWATER)	
		TIDAL / ESTUARINE (TIDAL FLOW, FRINGE)		
			FRESHWATER	
			HALINE	
			OLIGOHALINE	
SECOND TIER - SPECIFIC CLASSIFIERS				
	LANDFORM/TOPOGRAPHY/ SPECIAL SUBSTRATES			
		USER DEFINED		
	SUBSTRATE			
	AQUATIC TROPHIC STATUS			
		EUTROPHIC		
		MESOTROPHIC		
		OLIGOTROPHIC		
	WATER ACIDITY			
		ALKALINE		
		CIRCUMNEUTRAL		
		ACIDIC		
	SPECIALIZED WATER CHEMISTRY			
		USER DEFINED (E.G SERPENTINE, ETC.)		
	WATER DEPTH			
		SHALLOW (<15 CM)		
		DEEP (>15 CM)		
	SOIL ORGANIC MATTER			NRCS
		PEAT (> 40 CM PEAT)		
		MUCK		
	SUBSOIL TEXTURE			NRCS
		SAND		
		LOAM		
		SILT		

		CLAY		
	SUBSOIL STRUCTURE	USER DEFINED (E.G HARDPAN, CALLICHE, ETC.)		
	SOIL MOISTURE REGIME	SATURATED	PERIODICITY/SEASONALITY	
	SUBSTRATE TEXTURE			NRCS
		CONSOLIDATED		
		UNCONSOLIDATED		
		OTHER		
	DISTURBANCE			
	FLOODING RETURN INTERVAL			
		INTERMITTENT	Periodicity/nonrandom	
		SHORT (<5 YRS)	Periodicity/irregular	
		INTERMEDIATE (5-25 YRS)	Perodicity/polycyclic	
		LONG (>25 YRS)	Seasonality/Spring	
		OTHER	Seasonality/Summer	
			Seasonality/Fall	
			Seasonality/Winter	
	HYDROPERIOD	<24 HOURS		
		1-29 DAYS		
		30-180 DAYS		
		>180 DAYS		
	LIFE FORM			
		NVCS categories		FGDC
THIRD TIER - SPATIAL/TEMPORAL				
	GEOGRAPHIC SCALE AND PATTERN			
		LINEAR		
		SMALL PATCH		
		LARGE PATCH		
		MATRIX		
	JUXTAPOSITION			
		USER DEFINED		
	TEMPORAL PERSISTENCE			
		SHORT - 50-100 YRS		
		MODERATE - 100-500 YRS		
		LONG -> 500 YRS		

Appendix B: Descriptions of Ecological Systems occurring within Kansas.

Temperate Prairie Flint Hills Prairie System--landscaped dominated by tallgrass prairie (*Andropogon gerardii* and *Schizacharium scoparium*) with scattered trees in the ravines.

Photo by S. Menard

Great Plains Sandhill Shrubland System--in the foreground (with *Schizacharium scoparium* and *Artemisia filifolia*) with the Kansas Red Hills and South-Central Great Plains Mixedgrass Prairie System in the distance.

Photo by S. Menard

SYSTEM NAME: CENTRAL TEMPERATE PRAIRIE WET MEADOW/PRAIRIE SYSTEM

Element Summary

The Central Temperate Prairie Wet Meadow/Prairie System is found along creeks and streams from Nebraska and Iowa and Illinois to Texas. It is often adjacent to the Central Temperate Prairie Floodplain System, but is devoid of trees and riparian vegetation. It is also distinct from upland prairie systems by having more hydrology, especially associated with silty, dense clay soils that are often hydric soils, classified as Vertic Haplaquolls. The landform is usually floodplain or poorly drained, relatively level land. The vegetation is dominated by prairie cordgrass (*Spartina pectinata*), Eastern gama grass (*Tripsacum dactyloides*), numerous large sedges, such as *Carex frankii* and *C. hyalinolepis*, and in wetter areas, *Eleocharis* spp. Forbs can include: *Helianthus grosseserratus*, *Venonia fasciculata*, and *Physostegia virginiana*. Fire has had the primary influence on keeping these wet areas free of trees. Other dynamic processes include grazing and flooding (often in the late spring). Many areas have been converted to agricultural, but this usually requires some sort of drainage.

Environment Summary

This ecological system is found primarily on silty and/or dense clay, hydric soils, usually classified as Vertic Haplaquolls. It is often found within a floodplain or poorly drained, relatively level areas.

Vegetation Summary

Prairie cordgrass (*Spartina pectinata*), Eastern gama grass (*Tripsacum dactyloides*), numerous large sedges, such as *Carex frankii* and *C. hyalinolepis* dominate this system. In wetter areas, *Eleocharis* spp. may be significant. Forbs such as *Helianthus grosseserratus*, *Venonia fasciculata*, and *Physostegia virginiana* also may be common. Trees and shrub species are usually not present in this system.

Dynamic Processes Summary

Fire is the major dynamic process that helps maintain the herbaceous nature of this system and prevents trees from establishing. Grazing and periodic flooding can also influence this system.

Element Range

This system is found throughout the central Temperate Prairie Division ranging from eastern Kansas to western Illinois.

Component Alliances in Original Kansas Vegetation Map

TYPHA (ANGUSTIFOLIA, LATIFOLIA) - (SCHOENOPLECTUS SPP.) SEMIPERMANENTLY FLOODED HERBACEOUS ALLIANCE *(V.A.5.N.l.9)*

CEPHALANTHUS OCCIDENTALIS SEMIPERMANENTLY FLOODED SHRUBLAND ALLIANCE *(III.B.2.N.f.1)*

SPARTINA PECTINATA TEMPORARILY FLOODED HERBACEOUS ALLIANCE *(V.A.5.N.j.11)*

TYPHA SPP. - (SCHOENOPLECTUS SPP., JUNCUS SPP.) SEASONALLY FLOODED HERBACEOUS ALLIANCE *(V.A.5.N.k.33)*

DISTICHLIS SPICATA - (HORDEUM JUBATUM) TEMPORARILY FLOODED HERBACEOUS ALLIANCE *(V.A.5.N.j.5)*

SYSTEM NAME: CENTRAL TEMPERATE PRAIRIE FLOODPLAIN SYSTEM

Element Summary

The Central Temperate Prairie Floodplain System is found along rivers across the region. It occurs from rivers edge across the floodplain or to where it meets the Central Temperate Prairie Wet Meadow/Prairie System. It can have a variety of soil types found within the floodplain from very well-drained sandy substrates to very dense clays. It is this variety of substrate and flooding that creates the mix of vegetation that includes cottonwood (*Populus deltoides*), willows, especially (*Salix nigra*) and sycamore, (*Platanus occidentalis*) in the wettest areas and green ash (*Fraxinus pennsylvanica*) and American elm (*Ulmus americana*) and bur oak (*Quercus macrocarpa*) in more well-drained areas. Within this system are oxbows that may support *Nelumbo lutea* and *Typha latifolia*. Understory species are mixed, but include shrubs, such as *Cornus drummondii* and *Asimina triloba* (in Kansas and south), sedges and grasses, which sometimes help form savanna vegetation. Flooding is the primary dynamic process, but drought, grazing, and fire have all had historical influence on this system. Federal reservoirs have had a serious and negative effect on this system, along with agriculture that has converted much of this system to drained agricultural land.

Environment Summary

This ecological system occurs in floodplains of medium to large rivers. It primarily is found on alluvial soils ranging from sandy to very dense clays.

Vegetation Summary

The variety of soil properties association with this system can create a mixture of vegetation. Cottonwood (*Populus deltoides*), willows, especially (*Salix nigra*), and sycamore, (*Platanus occidentalis*) are commonly found in the wettest areas with green ash (*Fraxinus pennsylvanica*) and American elm (*Ulmus americana*) and bur oak (*Quercus macrocarpa*) occurring in more well-drained areas. Understory species can vary across the range of this system but can include shrubs such as *Cornus drummondii* and *Asimina triloba* and sedge and grass species. Oxbows within this system may have species such as *Nelumbo lutea* and *Typha latifolia*

Dynamic Processes Summary

This system is primarily controlled by moderately to frequent flooding. Grazing can also impact this system and can lead to decreased cover of many graminoid species in some areas.

Element Range

This system is found along medium and large river floodplains throughout the Central Temperate Prairie Region ranging from eastern Kansas and western Missouri to western Illinois.

Component Alliances in Original Kansas Vegetation Map

SPARTINA PECTINATA TEMPORARILY FLOODED HERBACEOUS ALLIANCE *(V.A.5.N.j.11)*

POPULUS DELTOIDES TEMPORARILY FLOODED FOREST ALLIANCE *(I.B.2.N.d.15)*

POPULUS DELTOIDES TEMPORARILY FLOODED WOODLAND ALLIANCE *(II.B.2.N.b.4)*

TYPHA SPP. - (SCHOENOPLECTUS SPP., JUNCUS SPP.) SEASONALLY FLOODED HERBACEOUS ALLIANCE *(V.A.5.N.k.33)*

QUERCUS MACROCARPA WOODLAND ALLIANCE *(II.B.2.N.a.20)*

FRAXINUS PENNSYLVANICA - ULMUS AMERICANA - CELTIS (OCCIDENTALIS, LAEVIGATA) TEMPORARILY FLOODED FOREST ALLIANCE *(I.B.2.N.d.11)*

TYPHA (ANGUSTIFOLIA, LATIFOLIA) - (SCHOENOPLECTUS SPP.) SEMIPERMANENTLY FLOODED HERBACEOUS ALLIANCE *(V.A.5.N.l.9)*

SALIX (EXIGUA, INTERIOR) TEMPORARILY FLOODED SHRUBLAND ALLIANCE *(III.B.2.N.d.6)*

CARYA ILLINOINENSIS - (CELTIS LAEVIGATA) TEMPORARILY FLOODED FOREST ALLIANCE *(I.B.2.N.d.7)*

QUERCUS MACROCARPA - QUERCUS BICOLOR - (CARYA LACINIOSA) TEMPORARILY FLOODED FOREST ALLIANCE (I.B.2.N.d.18)

SYSTEM NAME: TEMPERATE PRAIRIE WOODED RAVINE AND DRAW SYSTEM

Element Summary

The Temperate Prairie Wooded Ravine and Draw System is found in dissected ravines and draws throughout the region, usually in a topographic position where there is a significant elevation gradient, which encourages tree growth. The system can have a variety of soils, however loess based soils are especially common. Primary materials such as rock outcrops can also be prevalent in some examples of this system. Trees found in this system include oaks (*Quercus* species), shagbark hickory (*Carya ovata*), red elm (*Ulmus rubra*), hackberry (*Celtis occidentalis*) and redbud (*Cercis canadensis*). Understory species and species found in some steep areas include tallgrass prairie species, especially *Andropogon gerardii*, *Panicum virgatum*, *Sorghastrum nutans*, and *Schizacharium scoparium*, and numerous woodland and prairie forbs. Fire, grazing and browsing, and upstream land uses are primary determinants of this system and its vegetation. With fire suppression and changes in hydrology due to adjacent and upstream agricultural land uses, this system has developed more tree cover.

Environment Summary

This system is found in dissected areas, often with a significant or sharp elevation gradient compared to the surrounding area. Soils are primarily wet to mesic and based on loess with primary materials such as rocky outcrops often present. This system is most often associated with smaller rivers and/or temporary streams.

Vegetation Summary

The dissected topography associated with this system encourages tree growth thus this system is dominated by species such as oaks (*Quercus* species), shagbark hickory (*Carya ovata*), red elm (*Ulmus rubra*), hackberry (*Celtis occidentalis*) and redbud (*Cercis canadensis*) that range in cover from 25% to full canopy closure in areas where fire has been suppressed. Many species of woodland and prairie forbs can be found in the understory with predominately tallgrass prairie graminoids such as *Andropogon gerardii*, *Panicum virgatum*, *Sorghastrum nutans*, and *Schizacharium scoparium*.

Dynamic Processes Summary

Fire, grazing, and browsing are the primary dynamic processes impacting this system. The topographic position of this system often protects it from the more frequent fires that occur in the surrounding areas, which allows for the development of tree species. Fire suppression allows for even further canopy development leading to an almost closed canopy. Overgrazing and overbrowsing of this system can often lead to a decrease in the number of understory grass and forb species. Also, land use practices in adjacent areas can have a profound impact.

Element Range

This system can be found throughout the Temperate Prairie Division.

Component Alliances in Original Kansas Vegetation Map

FRAXINUS PENNSYLVANICA - ULMUS AMERICANA - CELTIS (OCCIDENTALIS, LAEVIGATA) TEMPORARILY FLOODED FOREST ALLIANCE *(I.B.2.N.d.11)*

QUERCUS MUEHLENBERGII WOODLAND ALLIANCE *(II.B.2.N.a.21)*

SYSTEM NAME: TEMPERATE PRAIRIE MESIC HARDWOOD FOREST SYSTEM

Element Summary

The Temperate Prairie Mesic Hardwood System can be found within the northern and central portions of the Temperate Prairie division. It is likely the western and southern extension of the maple-basswood-beech forests found primarily within the Central Hardwoods and Laurentian-Acadia Divisions. This forest system is distinct from the upland oak systems in the Temperate Prairie Division by the underlying mesic soils and the predominance of mesic deciduous species forming a moderately dense to dense canopy. Examples of this system occur on valley slopes and bottoms often with northern or eastern aspects. Soils are moderately well drained, fertile, and moderate to deep loams that have developed from glacial till or loess parent material. Sugar maple (*Acer saccharum*) typifies this system with basswood (*Tilia americana*), red oak (*Quercus rubra*), and ironwood (*Ostrya virginiana*), often occurring as common associates. The dense canopy allows for a rich mixture of shrub and herbaceous species in the understory. Examples of common herbaceous species include *Anemone quinquefolia*, *Adiantum pedatum*, *Arisaema triphyllum*, and *Sanicula* spp. Dynamic processes such as wind and fire can impact this system over long return cycles, however the most immediate threats to remaining examples of this system are grazing and conversion to agriculture.

Environment Summary

This system is found primarily on mesic soils that are moderately well drained and fertile. These are mostly moderate to deep loams that have developed from glacial till or loess. This system occurs primarily on valley slopes and bottoms often with northern or eastern aspects.

Vegetation Summary

Mesic deciduous trees form a moderately dense to dense canopy in examples of this system. Sugar maple (*Acer saccharum*) is the most common tree species forming the majority of the canopy and sapling layers. Common associates include basswood (*Tilia americana*), red oak (*Quercus rubra*), and ironwood (*Ostrya virginiana*). The understory contains a rich mixture of shrub and herbaceous species such as Anemone *quinquefolia*, *Adiantum pedatum*, *Arisaema triphyllum*, and *Sanicula* spp.

Dynamic Processes Summary

Wind and fire can impact this system over long return intervals. Small gap development and replacement due to tree death is more frequent than more catastrophic fire or wind. The greatest impacts on this system are due to grazing and conversion to agriculture.

Element Range

This system is found throughout the central and northern Temperate Prairie Division. It ranges from Oklahoma north to Minnesota and from eastern Kansas and Nebraska west to Indiana.

Component Alliances in Original Kansas Vegetation Map

ACER SACCHARUM - TILIA AMERICANA - (QUERCUS RUBRA) FOREST ALLIANCE
(I.B.2.N.a.8)

SYSTEM NAME: CENTRAL TEMPERATE PRAIRIE DRY OAK FOREST AND WOODLAND SYSTEM

Element Summary

The Central Temperate Prairie Dry Oak Forest and Woodland System is found primarily within the Central Tallgrass and Flint Hills/Osage Plains Ecoregions, extending from Kansas and Nebraska eastward into Missouri, Iowa and Illinois. It is distinct from other forested systems within the region by the relatively drier soils and the predominance of oak species. Forest cover can range from fairly dense to less than 25% where it can often reach a more savannah like situation. Those areas with less than 10% tree cover should be considered part of a grassland prairie system. Fire resistant oak species, in particular bur oak (*Quercus macrocarpa*) and/or black oak (*Quercus velutina*), dominate this system. *Carya* spp. and oak species such as *Quercus alba* and *Quercus rubra*, which are more typical of oak-hickory forests within the Central Hardwoods Division surrounding the eastern 2/3 of the Central Temperate Prairie region, may also be contained within examples of this system. Depending on the percent cover of the trees species, the understory can range from more mesic species such as *Zanthoxylem americanum*, *Maianthemum stellatum*, and *Urtica dioica* to mixture of woodland and grassland species including *Andropogon geradii*, *Panicum virgatum*, and *Spartina pectinata*. This system is can occur on uplands within the prairie matrix and near a floodplain. Soils are typically well-drained Mollisols that range from loamy to sandy in texture. Fire, along with drought, constitutes the main natural processes for this type and likely maintained a more open canopy structure with an understory dominated by grassland species. Fire suppression may account for the more closed oak forest examples of this system with the more mesic understory. It likely has allowed for other associates such as *Celtis occidentalis*, *Ostrya virginiana*, and *Juglans nigra* to become more prevalent, especially in upland areas along floodplains. This system is found primarily within the "corn belt" of the United States and those few remaining examples of this system are likely under considerable pressure due to conversion to agriculture and pastureland.

Environment Summary

This system can occur on uplands within a prairie matrix and/or in upland areas near a floodplain. It is found primarily on well-drained Mollisols ranging from loamy to sandy in texture.

Vegetation Summary

This system is dominated by fire-resistant oak species such as particular bur oak (*Quercus macrocarpa*) and/or black oak (*Quercus velutina*). *Carya* spp. and oak species such as *Quercus alba* and *Quercus rubra* may also be associated with this system. Canopy cover can range from 10 to over 70%. Mesic understory species such as *Zanthoxylem americanum*, *Maianthemum stellatum*, and *Urtica dioica* can occur in examples of this system that have a more closed canopy. Examples with a more open canopy typically have an understory of grassland species including *Andropogon geradii*, *Panicum virgatum*, and *Spartina pectinata*.

Dynamic Processes Summary
Drought and fire are the primary dynamic processes influencing this system. Fire suppression within this system may account for the examples with a more closed canopy and the invasion of more mesic species such as *Celtis occidentalis*, *Ostrya virginiana*, and *Juglans nigra*, especially in upland areas adjacent to floodplains. Conversion to agriculture and pastureland are the most immediate threats to this system.

Element Range
This system is found throughout the Central Temperate Prairie Region ranging from eastern Kansas and western Missouri to western Illinois. It may range as far northern as west-central Minnesota and eastern South Dakota.

Component Alliances in Original Kansas Vegetation Map

QUERCUS ALBA - (QUERCUS RUBRA, CARYA SPP.) FOREST ALLIANCE *(I.B.2.N.a.27)*

QUERCUS MACROCARPA WOODLAND ALLIANCE *(II.B.2.N.a.20)*

SYSTEM NAME: FLINT HILLS TEMPERATE PRAIRIE SYSTEM

Element Summary

The Flint Hills Temperate Prairie System is found primarily within the Flint Hills of Kansas and the Osage Plains of Oklahoma. It is distinguished from the Central Temperate Prairie System by having more species with western geographic affinities and the presence of a thin soil layer over limestone beds, although some areas of deeper soils are found within the region, especially on lower slopes. Because of the presence of limestone close to the surface and the rolling topography, this area is relatively unsuitable for agriculture and therefore contains the one of the largest remaining, relatively intact pieces of tallgrass prairie. The vegetation in this system is typified by tallgrass species such as big bluestem (*Andropogon gerardii*), switchgrass *(Panicum virgatum*), little bluestem (*Schizachrium scoparium*) and Indian grass (*Sorghastrum nutans*) forming a dense cover. A moderate to high density of forb species such as *Solidago rigida*, *Liatris punctata*, *Symphyotrichum ericoides, Lespedeza capitata,* and *Viola pedatifolia* also occur. Areas of deeper soil, especially lower slopes along draws, slopes and terraces, can include *Baptisia alba var. macrophylla*, *Liastris pycnostachya*, and *Vernonia missurica*. Shrub and tree species are relatively infrequent and if present, constitute less than 10% cover in the area. Fire and grazing constitute the major dynamic processes for this region. Although many of the native common plant species still occur, grazing does impact this region. Poor grazing practices can lead to soil erosion and invasion by cool season grasses such as smooth brome *(Bromus inermis*).

Environment Summary

This system is typified by the thin soil layer over limestone beds, although areas of deeper soils are possible along lower slopes, draws, and terraces. The topography is rolling and mostly unsuitable for agriculture.

Vegetation Summary

Tallgrass species such as big bluestem (*Andropogon gerardii*), switchgrass *(Panicum virgatum*), little bluestem (*Schizachrium scoparium*) and Indian grass (*Sorghastrum nutans*) predominate this system and often form a dense cover. Forb species such as *Solidago rigida*, *Liatris punctata*, *Symphyotrichum ericoides, Lespedeza capitata,* and *Viola pedatifolia* can also occur. In those areas of deeper soils, *Baptisia alba var. macrophylla*, *Liastris pycnostachya*, and *Vernonia missurica* can also occur. Tree and shrub species are relatively infrequent and constitute less than 10% cover.

Dynamic Processes Summary

Fire and grazing are the prevalent dynamic processes in examples of this system. Overgrazing can lead to soil erosion and invasion of cool season grasses. Fire suppression can lead to increased cover of woody species.

Element Range

This system is found primarily within the Flint Hills and Osage Plain regions of the Central Temperate Prairie Division.

Component Alliances in Original Kansas Vegetation Map

SCHIZACHYRIUM SCOPARIUM - BOUTELOUA CURTIPENDULA HERBACEOUS ALLIANCE *(V.A.5.N.c.20)*

ANDROPOGON GERARDII - (SORGHASTRUM NUTANS) HERBACEOUS ALLIANCE *(V.A.5.N.a.2)*

SCHIZACHYRIUM SCOPARIUM - SORGHASTRUM NUTANS HERBACEOUS ALLIANCE *(V.A.5.N.a.8)*

SYSTEM NAME: GREAT PLAINS CLOSED DEPRESSION SYSTEM

Element Summary

Communities associated with the playa lakes in the southern areas of this province and the rainwater basins in Nebraska characterize this system. They are primarily upland depressional basins. This hydric system is typified by the presence of an impermeable layer such as a dense clay, hydric soil and is usually recharged by rainwater and nearby run-off. They are rarely linked to outside groundwater sources and do not have an extensive watershed. Ponds and lakes associated with this system can experience periodic drawdowns during drier seasons and years, and are often replenished by spring rains. *Eleocharis* spp., *Hordeum jubatum*, along with common forbs such as *Coreopsis tinctoria*, *Aster subulatus*, and *Polygonum bicorne* are common vegetation in the wetter and deeper depression, while *Pascopyrum smithii* and *Buchloe dactyloides* are more common in shallow depressions in rangeland. Species richness can vary considerably among individual examples of this system and is especially influenced by adjacent landuse, which is often agriculture, which may provide nutrient and herbicide run-off. Dynamic processes that affect these depressions are hydrological changes, grazing, and conversion to agricultural use.

Environment Summary

This system is typified by upland depressional basins with an impermeable layer such as dense clay, hydric soils. Rainwater and run-off primarily recharge this system and it is rarely linked to outside groundwater sources.

Vegetation Summary

Species richness varies considerably among individual examples of this system. Commonly, *Eleocharis* spp., *Hordeum jubatum*, along with *Coreopsis tinctoria*, *Aster subulatus*, and *Polygonum bicorne* are found in the wetter and deeper depression. Shallower depressions in rangelands commonly contain *Pascopyrum smithii* and *Buchloe dactyloides*.

Dynamic Processes Summary

Hydrological changes, grazing and conversion to agriculture are the primary processes influencing this system.

Element Range

This system can be found throughout the eastern Great Plains Division, however, it is most prevalent in the central Great Plains states of Nebraska, Kansas and Oklahoma.

Component Alliances in Original Kansas Vegetation Map

SPARTINA PECTINATA TEMPORARILY FLOODED HERBACEOUS ALLIANCE *(V.A.5.N.j.11)*

HETERANTHERA LIMOSA PERMANENTLY FLOODED HERBACEOUS ALLIANCE *(V.C.2.N.a.4)*

POLYGONUM SPP. - ECHINOCHLOA SPP. TEMPORARILY FLOODED HERBACEOUS ALLIANCE *(V.A.5.N.j.12)*

ELEOCHARIS PALUSTRIS TEMPORARILY FLOODED HERBACEOUS ALLIANCE *(V.A.5.N.j.6)*

PASCOPYRUM SMITHII INTERMITTENTLY FLOODED HERBACEOUS ALLIANCE *(V.A.5.N.i.1)*

SYSTEM NAME: GREAT PLAINS OPEN FRESHWATER DEPRESSION SYSTEM

Element Summary

This system is composed of lowland depressions and also occurs along lake borders that have more open basins and a permanent water source through most of the year except during exceptional drought years. These areas are distinct from the Great Plains Closed Depression System by having a large watershed and/or significant connection to the groundwater table. Some of the specific communities will also be found in the floodplain system and should not be considered a separate system in that case. These types should also not be considered a separate system if they are occurring in lowland areas of the prairie matrix only because of an exceptional wet year. A variety of species are part of this system, including cattails (*Typha* spp.) and bulrush (*Schoenoplectus* spp.). These types can also drift into stream margins that are more permanently wet and linked directly to basin via groundwater flow from/into the pond or lake.

Environment Summary

This system is found within lowland depressions and along lakes that have more permanent water sources throughout the year. These areas typically have a large watershed and are connected to the groundwater sources. Examples may also drift into stream margins that are more permanently wet and linked to a basin via groundwater flow from/into a pond or lake. Those areas that are found within larger prairie matrix that are only lowland or wet because of an exceptional wet year are not part of this system.

Vegetation Summary

Many species can be associated with this system with cattails (*Typha* species) and bulrush (*Schoenoplectus* species) being common.

Dynamic Processes Summary

Hydrology is the primary process influencing this system. Grazing and conversion to agriculture can significantly impact the hydrology and species composition of this system.

Element Range

This system can occur throughout the Great Plains Division.

Component Alliances in Original Kansas Vegetation Map

TYPHA SPP. - (SCHOENOPLECTUS SPP., JUNCUS SPP.) SEASONALLY FLOODED HERBACEOUS ALLIANCE *(V.A.5.N.k.33)*

TYPHA (ANGUSTIFOLIA, LATIFOLIA) - (SCHOENOPLECTUS SPP.) SEMIPERMANENTLY FLOODED HERBACEOUS ALLIANCE *(V.A.5.N.l.9)*

SPARTINA PECTINATA TEMPORARILY FLOODED HERBACEOUS ALLIANCE *(V.A.5.N.j.11)*

POLYGONUM SPP. - ECHINOCHLOA SPP. TEMPORARILY FLOODED HERBACEOUS ALLIANCE *(V.A.5.N.j.12)*

ELEOCHARIS PALUSTRIS TEMPORARILY FLOODED HERBACEOUS ALLIANCE *(V.A.5.N.j.6)*

SYSTEM NAME: GREAT PLAINS SALINE DEPRESSION SYSTEM

Element Summary

This system is very similar to the Open and Closed Freshwater Depression Systems. However, strongly saline soils cause both the shallow lakes and depressions and the surrounding areas to be more brackish. Salt encrustations can occur on the surface in some examples of this system, and the soils are severely affected and have poor structure. Species that typify this system salt tolerant and halophytic species such as inland saltgrass, (*Distichlis spicata),* alkali sacaton, (*Sporobolus ariodes*) and foxtail barley (*Hordeum jubatum*). During exceptionally wet years, an increase in precipitation can dilute the salt concentration in the soils of some of examples of this system which may allow for less salt tolerant species to occur. Communities found within this system may also occur in floodplains, but probably should not be considered a separate system unless they transition to areas outside the immediate floodplain.

Environment Summary

This system is distinctive from the freshwater depression systems by brackish nature caused by strongly saline soils. Salt encrustations could occur near the surface in some examples of this system.

Vegetation Summary

Salt tolerant and halophytic species such as inland saltgrass, (*Distichlis spicata),* alkali sacaton, (*Sporobolus ariodes*) and foxtail barley (*Hordeum jubatum*) typify system.

Dynamic Processes Summary

Hydrology processes primarily drive this system. Increases in precipitation and/or runoff can dilute the salt concentration and allow for less salt tolerant species to occur. Conversion to agriculture and pastureland can also impact this system, especially when it alters the hydrology of the system.

Element Range

This system can occur throughout the Great Plains, but is likely more prevalent in the south-central portions of the Division.

Component Alliances in Original Kansas Vegetation Map

TYPHA (ANGUSTIFOLIA, LATIFOLIA) - (SCHOENOPLECTUS SPP.) SEMIPERMANENTLY FLOODED HERBACEOUS ALLIANCE *(V.A.5.N.l.9)*

DISTICHLIS SPICATA - (HORDEUM JUBATUM) TEMPORARILY FLOODED HERBACEOUS ALLIANCE *(V.A.5.N.j.5)*

SCHOENOPLECTUS PUNGENS SEMIPERMANENTLY FLOODED HERBACEOUS ALLIANCE (V.A.5.N.l.6)

SYSTEM NAME: GREAT PLAINS FLOODPLAIN SYSTEM

Element Summary

This system is found in the floodplains of medium and large rivers of the Great Plains. Alluvial soils and periodic, intermediate flooding (every 5-25 years) typify this system. Dominate communities within this system range from floodplain forests to wet meadows to gravel/sand flats, however they are linked by underlying soils and the flooding regime. Dominant species include cottonwood (*Populus deltoides*), and willows (*Salix* spp.). Grass cover underneath the trees is an important part of this system and is a mix of tallgrass species, including switchgrass (*Panicum virgatum*) and big bluestem (*Andropogon gerardii*). Tamarisk (*Tamarix* spp.) and less desirable grasses and forbs can invade degraded areas within the floodplains, especially in the western portion of the province. These areas are often subjected to heavy grazing and/or agriculture and can be heavily degraded. Another factor is that groundwater depletion and lack of fire have created additional species changes. In most cases, the majority of the wet meadow and prairie communities may be extremely degraded or extirpated from the system

Environment Summary

This system is found primarily along floodplains of medium and large rivers. Soils are primarily alluvial and range from sandy to dense clays.

Vegetation Summary

Dominant woody species occuring within this system include cottonwood (*Populus deltoides*), and willows (*Salix* spp.). Understory species constitute an important component of this system and include a mixture of tallgrass prairie species such as including switchgrass (*Panicum virgatum*) and big bluestem (*Andropogon gerardii*). Sparsely vegetated areas such as gravel and sand flats are also included within this system.

Dynamic Processes Summary

Periodic and intermediate flooding (i.e. every 5-25 years) constitutes the major process influencing this system. Grazing and conversion to agriculture can significantly impact this system and can lead to the degradation or extirpation of the majority of prairie and wet meadow communities from this system.

Element Range

This system is found throughout the Great Plains Division along major river floodplains.

Component Alliances in Original Kansas Vegetation Map

SPOROBOLUS AIROIDES HERBACEOUS ALLIANCE *(V.A.5.N.d.4)*

SPARTINA PECTINATA TEMPORARILY FLOODED HERBACEOUS ALLIANCE *(V.A.5.N.j.11)*

POPULUS DELTOIDES TEMPORARILY FLOODED FOREST ALLIANCE *(I.B.2.N.d.15)*

POPULUS DELTOIDES TEMPORARILY FLOODED WOODLAND ALLIANCE *(II.B.2.N.b.4)*

TYPHA SPP. - (SCHOENOPLECTUS SPP., JUNCUS SPP.) SEASONALLY FLOODED HERBACEOUS ALLIANCE *(V.A.5.N.k.33)*

QUERCUS MACROCARPA WOODLAND ALLIANCE *(II.B.2.N.a.20)*

FRAXINUS PENNSYLVANICA - ULMUS AMERICANA - CELTIS (OCCIDENTALIS, LAEVIGATA) TEMPORARILY FLOODED FOREST ALLIANCE *(I.B.2.N.d.11)*

TYPHA (ANGUSTIFOLIA, LATIFOLIA) - (SCHOENOPLECTUS SPP.) SEMIPERMANENTLY FLOODED HERBACEOUS ALLIANCE (V.A.5.N.l.9)

SCHOENOPLECTUS PUNGENS SEMIPERMANENTLY FLOODED HERBACEOUS ALLIANCE *(V.A.5.N.l.6)*

SALIX (EXIGUA, INTERIOR) TEMPORARILY FLOODED SHRUBLAND ALLIANCE *(III.B.2.N.d.6)*

SYSTEM NAME: GREAT PLAINS WOODED DRAW AND RAVINE SYSTEM

Element Summary

This system is typically found associated with permanent or ephemeral streams and small rivers and may occur on steep northern slopes or within canyon bottoms that do not experience periodic flooding although soil moisture and topography allow greater than normal moisture conditions compared to the surrounding areas. Ash species (*Fraxinus* spp.) and elm (*Ulmus rubra* and *U. americana)* typically dominate this system, although in some areas of the western Great Plains steppe province, *Juniperus* spp. can dominate the canopy. In south-central portions of the Great Plains, bur oak (*Quercus macrocarpa*) can also be present. More information from the broader division and from the Rocky Mountain division will be needed to determine if those areas dominated by ash and elm should be separated from areas dominated by Rocky Mountain juniper (*Juniperus scopulorum*). Those areas dominated by *Juniperus* are typically found in the Badlands and the western portions of ND and NE, and should probably be described based on data from the Great Plains Steppe or Rocky Mountain division. However, *Juniperus* can occur in stands with elm and ash in NE and ND. This system was often subjected to heavy grazing and trampling by both domestic animals and wildlife and can be heavily degraded in some areas. In addition, exotic species such as Siberian elm (*Ulmus pumila)* and Russian olive (*Elaeagnus angustifolia*) can invade these systems.

Environment Summary

This system is associated with permanent or ephermeral streams and small rivers. It also can occur on steep northern slopes or within canyon bottoms that do not experience periodic flooding. Soils are primarily wet to mesic and more dissected topography allow for greater than normal moisture conditions This system is most often associated with smaller rivers and/or temporary streams.

Vegetation Summary

Species composition of this system can vary across the range of this system. Ash species (*Fraxinus* spp.) and elm species (*Ulmus* spp.) typically dominate this system. In some western areas of the Great Plains Division, *Juniperus* spp. can dominate, and in the south-central portion of the division, bur oak (*Quercus macrocarpa*) can also be important. Exotic species such as Siberian elm (*Ulmus pumila)* and Russian olive (*Elaeagnus angustifolia*) can be present in degraded examples of this system.

Dynamic Processes Summary

Fire can influence this system; however grazing is the most prevalent dynamic process influencing this system. Overgrazing can heavily degrade this system and allow for the invasion of exotic species.

Element Range

This system is found throughout the Great Plains Division.

Component Alliances in Original Kansas Vegetation Map

FRAXINUS PENNSYLVANICA - ULMUS AMERICANA - CELTIS (OCCIDENTALIS, LAEVIGATA) TEMPORARILY FLOODED FOREST ALLIANCE *(I.B.2.N.d.11)*

SYSTEM NAME: GREAT PLAINS DRY BUR OAK FOREST AND WOODLAND SYSTEM

Element Summary

This system is dominated by bur oak (*Quercus macrocarpa*) and is found in upland areas throughout the Great Plains. Other species such as American basswood (*Tilia americana*), eastern red cedar (*Juniperus virginiana*), and ash species (*Fraxinus* spp.) may be present. The herbaceous layer can vary from sparsely to moderately vegetated. Historically, higher cover of grass species occurred as these stands were more open due to more frequent fires. Stands of bur oak can also be included within the Southern Great Plains Mixedgrass Prairie System, however that system would only include small patches or single trees protected by fire. Any stands of bur oak or more substantial woodlands should be included within this system. Few of good examples of this system likely remain because of past timber harvesting and heavy grazing.

Environment Summary

This system is found in upland areas throughout the Division. Soils are predominately dry to mesic.

Vegetation Summary

This system is typified by the predominance of bur oak (*Quercus macrocarpa*) constituting at least 10% of the vegetation cover in any given example of this system. Other species such as American basswood (*Tilia americana*), eastern red cedar (*Juniperus virginiana*), and ash species (*Fraxinus* spp.) may be also present. Understory vegetation can range from sparsely vegetated to more dense and usually exemplifies the surrounding prairie grassland vegetation.

Dynamic Processes Summary

This system is primarily driven by fire. Fire suppression within this system can lead to more closed canopies and a decrease in the cover of grass species in the understory. Grazing, conversion to agriculture, and past timber harvesting can impact this system. Overgrazing can also lead to a decrease in understory species, and timber harvesting can completely eliminate examples of this system.

Element Range

This system is found throughout the Great Plains Division.

Component Alliances in Original Kansas Vegetation Map

QUERCUS MACROCARPA WOODLAND ALLIANCE *(II.B.2.N.a.20)*

SYSTEM NAME: GREAT PLAINS SANDHILL SHRUBLAND SYSTEM

Element Summary

The Great Plains Sandhill Shrubland System is found mostly throughout the western half of the Great Plains Division ranging from the Nebraska Sandhill region south to central Texas, although some examples may reach as far north as the Badlands of South Dakota. The climate is semi-arid to arid for much of the region in which this system occurs. This system is found on somewhat excessively to excessively well-drained, deep sandy soils that are often associated with dune systems and ancient floodplains. In some areas, this system may actually occur as a result of overgrazing in the Great Plains Tallgrass System or the Great Plains Sand Prairie System. This system is characterized by a sparse to moderately dense woody layer dominated by *Artemisia filifolia.* Associated species can vary with geography, precipitation, disturbance and soil texture. Several graminoid species such as *Andropogon hallii*, *Schizachyrium scoparium*, *Sporobolus cryptandrus*, *Calamovilfa gigantea*, and *Bouteloua* spp. can be connected with this system. Other shrub species may also be present including *Yucca glauca*, *Prosopis grandulosa*, *Rhus trilobata*, and *Prunus augustifolia*. In the southern range of this system, *Quercus havadii* may also be present and represents one succession pathway that develops over time following a disturbance. *Quercus havadii* is able to resprout following a fire and thus may persist for long periods of time once established. Fire and grazing are the most important dynamic processes for this type, although drought stress can impact this system significantly in some areas. Overgrazing can lead to decreasing dominance of some of the grass species such as *Andropogon hallii*, *Calamovilfa gigantea*, and *Schizachyrium scoparium*.

Environment Summary

This system is found primarily in semi-arid to arid areas of the Great Plains Division. It occurs on somewhat excessively to excessively well-drained and deep sandy soils. This system is often found associated with dune systems and/or ancient floodplains.

Vegetation Summary

This system is distinguished by a sparse to a moderately dense shrub layer dominated by sand sagebrush (*Artemisia filifolia*). Graminoid species such as *Andropogon hallii*, *Schizachyrium scoparium*, *Sporobolus cryptandrus*, *Calamovilfa gigantea*, and *Bouteloua* spp. can also be found within this system. Other shrub species such as *Yucca glauca*, *Prosopis grandulosa*, *Rhus trilobata*, and *Prunus augustifolia* may be present. *Quercus havadii* may also be present in the southern extent of this system.

Dynamic Processes Summary

Fire and grazing constitute the most important processes impacting this system. Drought stress can also influence this system in some areas.

Element Range

This system is found primarily within the south-central areas of the Great Plains Division ranging from the Nebraska Sandhills south into central Texas. However, examples of this system can be found as far north as the Badlands in South Dakota.

Component Alliances in Original Kansas Vegetation Map

ARTEMISIA FILIFOLIA SHRUBLAND ALLIANCE (III.A.4.N.a.4)

SYSTEM NAME: GREAT PLAINS TALLGRASS PRAIRIE SYSTEM

Element Summary

The Great Plains Tallgrass Prairie System can be found throughout the Great Plains Division. It is found primarily in areas where soil characteristics allow for mesic conditions more typical of the Temperate Prairie Division and thus are able to sustain tallgrass species. This system may be small patches interspersed within the Great Plains Mixedgrass System or Great Plains Shortgrass System and may also be associated with upland terraces above a floodplain system where these more mesic conditions persist. Soils are primarily loamy Mollisols that are moderately deep and rich. Those areas that contain more sandy soils should be considered part of the Great Plains Sand Prairie System. The Great Plains Tallgrass Prairie System is dominated primarily by big bluestem (*Andropogon geradii*), and may also include Indian grass (*Sorghastrum nutans)*, little bluestem (*Schizachyrium scoparium)*, western wheatgrass (*Pascopyrum smithii*), needle and threadgrass (*Hesperostipa spartea*), and prairie dropseed (*Sporobolus heterolepis*). *Andropogon geradii* often dominates the lowland regions, although *Pascopyrum smithii* can be prolific if conditions are favorable. Forbs in varying density may also be present. The primary dynamics for this system include fire, climate and grazing. Fire suppression in these areas has allowed for the invasion of woody species such as *Juniperous virginiana* and *Prunus* spp. and annual species such as *Bromus inermis.* Grazing also has contributed these changes and likewise led to a decrease of this system as overgrazing favors shortgrass and mixedgrass systems. Conversion to agriculture likewise has probably decreased the range of this system. Thus, this system likely only occurs in small patches and in scattered locations throughout the division. Large patch occurrences are mostly isolated to slopes and swales of rolling uplands where either grazing or cultivation are more problematic.

Environment Summary

This system is found primarily on loam, moderately deep, and rich Mollisols throughout the Great Plains Division. These soils tend to be more mesic and deep than the majority of soils within the Great Plains and are more typical of the Temperate Prairie Division.

Vegetation Summary

The mesic, deep soils allow for dominance by big bluestem (*Andropogon geradii*). Other species such as Indian grass (*Sorghastrum nutans)*, little bluestem (*Schizachyrium scoparium)*, western wheatgrass (*Pascopyrum smithii*), needle and threadgrass (*Hesperostipa spartea*), and prairie dropseed (*Sporobolus heterolepis*) can also be present. In more lowland areas, *Pascopyrum smithii* can become more prevalent. Fire suppression can lead to the invasion of these areas by woody species such as eastern redcedar (*Juniperous virginiana*) and *Prunus* spp.

Dynamic Processes Summary

Fire, climate and grazing constitute the primary dynamic processes impacting this system. Fire suppression can allow for the invasion of woody species such as *Juniperous virginiana* and *Prunus* spp. into the prairie matrix. Overgrazing tends to favor shortgrass

and mixedgrass species and can cause the conversion of this system to the Great Plains Shortgrass or Mixedgrass Systems. Also, invasion by annual species such as smooth brome (*Bromus inermis*) can become more severe as grazing pressure increases. Likewise, conversion to agriculture has degraded or extirpated many examples of this system.

Element Range

This system occurs throughout the Great Plains Division, however grazing and conversion to agriculture have likely decreased its natural range.

Component Alliances in Original Kansas Vegetation Map

ANDROPOGON GERARDII - (SORGHASTRUM NUTANS) HERBACEOUS ALLIANCE *(V.A.5.N.a.2)*

SYSTEM NAME: GREAT PLAINS SAND PRAIRIE SYSTEM

Element Summary

The sand prairies constitute a very unique system within the Great Plains. These sand prairies are often considered part of the tallgrass regions in the Great Plains, but can contain elements from both the Great Plains Shortgrass System and South-Central Great Plains Mixedgrass System. The largest expanse of sand prairies (approximately 5 million ha) can be found in the Sandhills of north central Nebraska and southwestern South Dakota. These areas are relatively intact. The primary use of the Great Plains Sand Prairie System has been grazing (not cultivation) and areas such as the Nebraska Sandhills can experience less degeneration than other prairie systems. Although greater than 90 percent of the Sandhills region is privately owned, the known fragility of the soils and the cautions used by ranchers to avoid poor grazing practices have allowed for fewer significant changes in the vegetation of the Sandhills compared to other grassland systems. The distribution, species richness and productivity of plant species within the sand prairie ecological system is controlled primarily by environmental conditions, in particular the temporal and spatial distribution of soil moisture and topography. Soils in the sand prairies can be relatively undeveloped and are highly permeable. Soil texture and drainage along with a species' rooting morphology, photosynthetic physiology, and mechanisms to avoid transpiration loss are highly important in determining the composition and distribution of communities/associations within the sand prairies. Another important aspect of soils in the sand prairies is their susceptibility to wind erosion. Blowouts and sand draws are some of the unique wind driven disturbances in the sand prairies, particularly the Nebraska Sandhills, which can profoundly impact vegetation composition and succession within this system. Graminoid species dominate the sand prairies, although relative dominance can change due to impacts of wind disturbance. Sand bluestem (*Andropogon hallii)* and prairie sandreed (*Calamovilfa longifolia)* are the most common species, but other grass and forb species such as *Hesperostipa comata, Carex inops* var. *heliophila,* and *Panicum virgatum* may be present. Patches of shin oak (*Quercus havardii*) can also occur within this system in the southern Great Plains. Fire and grazing constitute the other major dynamic processes that can influence this system.

Environment Summary

This tallgrass system is found primarily on sandy and sandy loam soils that can be relatively undeveloped and highly permeable as compared the to Great Plains Tallgrass Prairie System, which occurs on deeper loams. This system is usually found in areas with a rolling topography and can occur on ridges, midslopes and/or lowland areas within a region. It often occurs on moving sand dunes, especially within the Sandhill region of Nebraska and South Dakota.

Vegetation Summary

This system is distinguished by the dominance of Sand bluestem (*Andropogon hallii)* and prairie sandreed (*Calamovilfa longifolia)*. Other species such as *Hesperostipa comata,*

Carex inops var. *heliophila,* and *Panicum virgatum* may be present. In the southern range of this system, patches of shin oak (*Quercus havardii*) can also occur. *Penstemon haydenii* is endemic to the sand prairie system and of special conservation concern because of its probable decline due to grazing and fire suppression.

Dynamic Processes Summary

The distribution, species richness and productivity of plant species within the sand prairie ecological system is controlled primarily by environmental conditions, in particular the temporal and spatial distribution of soil moisture and topography. Another important aspect of the Great Plains Sand Prairie system is its susceptibility to wind erosion. Blowouts and sand draws are some of the unique wind driven disturbances in the sand prairies, particularly the Nebraska Sandhills, which can profoundly impact vegetation composition and succession within this system. Fire and grazing constitute the other major disturbances that can influence this system. Overgrazing, fire and trampling that leads to the removal of vegetation within those areas susceptible to blowouts can either instigate a blowout or perpetuate one already occurring. Overgrazing can also lead to significant erosion.

Element Range

The Great Plains Sand Prairie System is found throughout the Great Plains Division. The largest and most intact example of this system is found within the Sandhills region of Nebraska and South Dakota.

Component Alliances in Original Kansas Vegetation Map

ANDROPOGON HALLII HERBACEOUS ALLIANCE *(V.A.5.N.a.3)*

SYSTEM NAME: SOUTH-CENTRAL GREAT PLAINS MIXEDGRASS PRAIRIE SYSTEM

Element Summary

This mixedgrass prairie system ranges from South Dakota to northern Texas and is bordered by the shortgrass prairie on the western edge and the tallgrass prairie to the east. The loessial regions in west-central Kansas and central Nebraska, the Red Hills Region of south-central Kansas and northern Oklahoma are all located within this system. Because of its proximity to other ecoregions, the Great Plains Mixedgrass Prairie contain elements from both the shortgrass prairie (*see Great Plains Shortgrass Prairie System*) and the tallgrass prairie (*see Great Plains Tallgrass Prairie System*), which combine to form the mixedgrass prairie ecological system throughout its range. The distribution, species richness and productivity of plant species within the mixedgrass ecological system is controlled primarily by environmental conditions, in particular soil moisture and topography. Grazing and fire are important dynamic processes in this system. The relative dominance of the various grass and forb species within different associations in the system also can strongly depend on the degree of natural or human disturbance. This system can contain grass species such as side-oats grama (*Bouteloua curtipendula*), little bluestem (*Schizachyrium scoparium*), big bluestem (*Andropogon gerardii*), needle-and - thread (*Hesperostipa comata*), prairie dropseed (*Sporobolus heterolepis*) and blue grama (*Bouteloua gracilis*), although the majority of the associations within the region are dominated by western wheatgrass (*Pascopyrum smithii*) or little bluestem. Numerous forb and sedge species (*Carex spp*.) can also occur within the mixedgrass system in the Great Plains. Although forbs do not always significantly contribute to the canopy, they can be very important. Some dominant forb species include *Ambrosia psilostachya*, *Echinacea angustifolia*, *Lygodesmia juncea*. Oak species such as bur oak (*Quercus macrocarpa*) can occur also in areas protected from fire due to topographic position. This can cause an almost oak savannah situation in certain areas, although fire suppression may allow for a more closed canopy and expansion of bur oak beyond those sheltered areas. In those situations, further information will be needed to determine if those larger areas with a more closed canopy of bur oak should be considered part of the Great Plains Bur Oak Woodlands and Forests. Likewise, within the mixedgrass system, small seeps and fens may occur, especially during the wettest years. Although these are not considered a separate system, the suppression of fire within the region has enabled the invasion of both exotics and some shrub species such as eastern red cedar (*Juniperus americana)* and also allowed for the establishment of Ponderosa pine (*Pinus ponderosa)* in some northern areas.

Environment Summary

Differences in topography and soil characteristics also occur across the range of the mixedgrass system. This system is often characterized by rolling to extremely hilly landscapes with soils developed from loess, shale, limestone or sandstone parent material. Mollisol soils are most prevalent and range from silt loams and silty clay loams with sandy loams possible on the western edge of the range. The Red Hills region of Kansas and Oklahoma, which contains examples of this system, contain somewhat unique soil

characteristics and have developed from a diversity of sources including red shale, red clay, sandy shale, siltstone, or sandstone. These soils have developed a characteristic reddish color from the primary material. These soils can consist of silt, loam, or clay and can have textures ranging from a fine sandy loam to a more clayey surface.

Vegetation Summary

The South-Central Great Plains Mixedgrass Prairie System contains elements from both Great Plains Shortgrass Prairie System and Great Plains Tallgrass Prairie System. This system typically contains grass species such as side-oats grama (*Bouteloua curtipendula*), little bluestem (*Schizachyrium scoparium*), big bluestem (*Andropogon gerardii*), needle- and -thread (*Hesperostipa comata*), prairie dropseed (*Sporobolus heterolepis*) and blue grama (*Bouteloua gracilis*), although the majority of the associations within the region are dominated by western wheatgrass (*Pascopyrum smithii*) or little bluestem. Isolated patches of bur oak (*Quercus macrocarpa*) also can occur.

Dynamic Processes Summary

Fire and grazing are the primary processes occurring within the South-Central Great Plains Mixedgrass Ecological System. The diversity in this mixedgrass system likely reflects both the short- and long-term responses of the vegetation to these often-concurrent disturbance regimes. Fire suppression and overgrazing can lead to the invasion of this system by woody species such as (*Juniperus americana)* and Ponderosa pine (*Pinus ponderosa)*. Likewise, fire suppression may lead to a more closed canopy of bur oak.

Element Range

This system is found throughout the central and southern areas of the Great Plains ranging from southern South Dakota into northern Texas.

Component Alliances in Original Kansas Vegetation Map

SCHIZACHYRIUM SCOPARIUM - BOUTELOUA CURTIPENDULA HERBACEOUS ALLIANCE *(V.A.5.N.c.20)*

PASCOPYRUM SMITHII HERBACEOUS ALLIANCE *(V.A.5.N.c.27)*

SYSTEM NAME: GREAT PLAINS SHORTGRASS PRAIRIE SYSTEM

Element Summary

The Great Plains Shortgrass Prairie System is found primarily in the western half of the Great Plains Division east of the Rocky Mountains and ranges from the Nebraska Panhandle south into Texas and New Mexico, although some examples may reach as far north as southern Canada where it grades into the Northern Great Plains Mixedgrass System. This system occurs primarily on flat to rolling uplands with loamy, ustic soils ranging from sandy to clayey. In much of its range, this system forms the matrix system with grama grasses (*Bouteloua* spp.) dominating this system. Other associated graminoids may include buffalo grasses (*Buchloe dactyloides*), needle and thread grass (*Hesperostipa comata*), junegrass (*Koeleria cristata*), western wheatgrass (*Agropyron smithii*), and sand dropseed (*Sporobolus cryptandrus*). Although tallgrass and mixedgrass species may be present especially on more mesic soils, they are secondary in importance to the sod-forming short grasses. Shrub species such as sand sagebrush (*Artemsia filifolia*) and big sagebrush (*A. tridentata*) that dominate the Great Plains shrubland systems may also be present. Also, because this system spans a wide range, there can be some differences in the relative dominance of some species from north to south and from east to west. Large-scale processes such as climate, fire and grazing influence this system. In contrast to other prairie systems, fire is less important, especially in the western range of this system, because the often dry and xeric climate conditions can decrease the fuel load and thus the relative fire frequency within the Great Plains Shortgrass Prairie System. However, historically, fires that did occur were often very expansive. Currently, fire suppression and more extensive grazing in the region has likely decreased the fire frequency even more and it is unlikely that these processes could occur at a natural scale. The majority of the range for this system has been converted to agriculture or pastureland where irrigation has impacted the relative dominance of the graminoid species. Overgrazing can significantly impact this system and lead to an increase in prickly pear cactus (*Opuntia* spp), annual grass species, such as cheat grass (*Bromus* spp) and other undesirable species. Likewise, much of the central and western range has been impacted by the unsuccessful attempts to develop dryland cultivation during the Dust Bowl of the 1930s. This system in combination with the associated wetland systems represents one of the richest areas for mammals and birds. Endemic bird species to the shortgrass system may constitute one of the fastest declining bird populations.

Environment Summary

The Great Plains Shortgrass System is located on primarily flat to rolling uplands. Soils typically are loaming and ustic and range from sandy to clayey.

Vegetation Summary

This system spans a wide range and thus there can be some differences in the relative dominance of some species from north to south and from east to west. This system is primarily dominated by grama grasses (*Bouteloua* spp.) throughout its range with associated graminoid species such as buffalo grass (*Buchloe dactyloides*), needle and

thread grass (*Hesperostipa comata*), junegrass (*Koeleria cristata*), western wheatgrass (*Agropyron smithii*), and sand dropseed (*Sporobolus cryptandrus*). Shrub species such as sand sagebrush (*Artemsia filifolia*) and big sagebrush (*A. tridentata*) can be present.

Dynamic Processes Summary

Fire and grazing constitute the primary processes impacting this system. However, fire is less important in this system compared to other Great Plains Prairie Systems, especially in the western portion of its range. Overgrazing and fire suppression can lead to an increase in prickly pear cactus (*Opuntia* spp) and annual grass species, such as cheat grass (*Bromus* spp). Conversion to agriculture and pastureland with the subsequent irrigation has degraded and extirpated this system in some areas of its range.

Element Range

The Great Plains Shortgrass Prairie System is found primarily in the western half of the Great Plains Division east of the Rocky Mountains and ranges from the Nebraska Panhandle south into Texas and New Mexico, although some examples may reach as far north as southern Canada where it grades into the Northern Great Plains Mixedgrass System.

Component Alliances in Original Kansas Vegetation Map

BOUTELOUA GRACILIS HERBACEOUS ALLIANCE *(V.A.5.N.e.9)*

SYSTEMS FOUND WITHIN BOTH THE GREAT PLAINS AND TEMPERATE PRAIRIE DIVISIONS IN KANSAS

SYSTEM NAME: CROSS TIMBERS OAK FOREST AND WOODLAND SYSTEM

Element Summary

The Cross Timbers Oak Forest and Woodland System is primarily found within central Texas and Oklahoma with the northern extent reaching into southeastern Kansas. It is distinct from the surrounding prairie and coastal plain grassland regions by the higher density of tree species, although it can be intermixed with the Southern Temperate Prairie System. The area consists of irregular plains with primarily sandy to loamy Ustalf soils that range from shallow to moderately deep. Rainfall can be moderate, but somewhat erratic, therefore moisture is often limiting during part of the growing season. Short, stunted post oak (*Quercus stellata*) and blackjack oak (*Quercus marilandica*) characterize and dominate this system. Other species such as *Carya texana*, *Carya cordiformis*, *Quercus prinoides*, *and Quercus* spp. can also be present. The understory often contains species typical of the surrounding prairies, in particular, *Schizachyrium scoparium*. Shrubs such as *Rhus* spp. may also be present. Drought, grazing, and fire are the primary natural processes that affect this system. Overgrazing and conversion to agriculture, along with fire suppression, have led to the invasion of some areas by problematic brush species such as eastern red cedar (*Juniperus virginiana*) and Ashe juniper (*Juniperus ashei*) and mesquite (*Prosopis grandulosa*) further south in Texas and Oklahoma. It has also led to decreases in native grass cover allowing for annual grasses and forbs to invade.

Environment Summary

The Cross Timbers Oak Forest and Woodland System is located on irregular plains comprised of sandy to loamy ustalf soils. These soils range from shallow to moderately deep. Rainfall can be moderate, but sporatic, leading to periods of limiting moisture.

Vegetation Summary

This system is distinguished by the dominance of short, stunted post oak (*Quercus stellata*) and blackjack oak (*Quercus marilandica*). Other tree species such as *Carya texana*, *Carya cordiformis*, *Quercus prinoides*, *and Quercus* spp. can also be present. The understory often contains species typical of the surrounding prairies, in particular, *Schizachyrium scoparium*. Shrubs such as *Rhus* spp. may also be present.

Dynamic Processes Summary

Drought, grazing, and fire primarily influence this system. Overgrazing and conversion to agriculture have allowed for the invasion of eastern red cedar (*Juniperus virginiana*), Ashe juniper (*Juniperus ashei*) and mesquite (*Prosopis grandulosa*). Decreases in native grass cover associated with overgrazing can also lead to an increase in invasive annual grasses and forbs.

Element Range

The Cross Timbers Oak Forest and Woodland System is primarily found within central Texas and Oklahoma with the northern extent reaching into southeastern Kansas.

Component Alliances in Original Kansas Vegetation Map

QUERCUS STELLATA - QUERCUS MARILANDICA WOODLAND ALLIANCE *(II.B.2.N.a.25)*

QUERCUS STELLATA - QUERCUS MARILANDICA FOREST ALLIANCE *(I.B.2.N.a.40)*