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WOODY VEGETATION OF A DISJUNCT BUR OAK (*QUERCUS MACROCARPA*) FOREST IN EAST-CENTRAL NEBRASKA

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ABSTRACT

Woody plant composition was assessed for three tree-size classes in two ravines of Oak Glen Wildlife Management Area, a disjunct oak forest in Seward County, Nebraska, using Importance Values (IV) obtained by the Point-Quarter method. Bur oak (*Quercus macrocarpa* Michx.) dominated the large-size class (>30 cm dbh) (IV = 258) but elms (*Ulmus americana* L. and *U. rubra* Muhl.) (IV = 130) dominated the forest in one ravine in the medium-size class (10–30cm dbh) and elm and hackberry (*Celtis occidentalis* L.) (IV = 114 and 27 respectively) dominated the small-size class (<10cm dbh). Bur oak in the small-size was low in abundance (IV = 9) and was absent from one of the study transects. These data on tree-size distribution in the extant forest suggests that the forest is likely to succeed from one presently dominated by bur oak, which appears to have characterized the presettlement forest, to one dominated primarily by elm or hackberry. Current management is likely to encourage a continuation of this succession.

† † †

Upland forests or savannas, dominated by bur oak (*Quercus macrocarpa* Michx.), occurred within the tallgrass prairie region of the North American Midwest prior to European settlement (Weaver, 1965; Nuzzo, 1986; Rozmajzl, 1988) although the time of origination of these stands is in question. While some of these stands persist today, quantitative evaluations of woody plant composition and its relationship to vegetation dynamics (Bragg, 1974; Briggs and Gibson, 1992) are limited. This study was designed to provide one such evaluation using an extant, disjunct forest embedded within the tallgrass or bluestem (*Andropogon-Panicum-Sorghastrum*) prairie region (Küchler, 1964). A second objective of the study was to estimate the presettlement, woody composition of the stand using both historical records and the size structure of current woody vegetation. This information was intended to provide a description of an oak forest for future reference as well as to suggest any future changes in stand composition, presuming that the existing environmental conditions and present management continue.

METHODS AND MATERIALS

Study site

The study was conducted at the Oak Glen Wildlife Management Area, managed by the Nebraska Game and Parks Commission, located 2.6 km north of Garland in Seward County, Nebraska (Sections 28-29 and 32-33, Township 12N, Range 4E). The site is on a large moraine remaining from the last glacial retreat at the end of the Kansan glaciation of the Pleistocene Epoch (Goll, 1961; Reed and Dreeszen, 1965; Stout et al., 1965, 1971). Runoff flows toward the north and is part of the Middle and Oak creek drainages. The valley floors are dominated by a silty alluvial soil consisting of frequently flooded bottomlands and deeply entrenched, meandering channels. The slopes above the valley floor, on which most of the sampling for this study was conducted, consist of rough broken land (till) with 31–75% slopes containing large gullies and overfalls in areas of active gully erosion with rocks and boulders on the surface in some places. Soils of the upper slopes are dominated by Steinauer clay loams, 12–31% slopes (Subgroup: Typic Udorthents, Soil Order: Entisol). These soils are underlain with a deposit of Greenhorn Limestone (Quandt, 1974).

The site, which includes approximately 74 ha of trees along generally east- and west-facing slopes, was acquired by the Nebraska Game and Parks Commission in March, 1983. Hilltops have been disturbed but contain some patches of native prairie. Land ownership documents, terracing on some hills and internal and old fences suggest different land management and grazing histories. Similarly, tree stumps in the South but not in the North ravine suggest differences in lumbering, and multiple-stemmed trees and trees showing scarred boles indicate both potential differences in management and the likelihood of fires occurring in the forest. Historical accounts of both fire and lumbering verify the occurrence of these practices in the region. A plant survey was conducted from 1983 to 1988 by Rolfsmeier (1988).

Field procedures

Tree and shrub species were evaluated for two aspects, one east-slope and one west-slope, in each of the two principal ravines of the area. The ravine referred to in this study as the "South Ravine" enters from Section 33 into Section 28; the "North Ravine" is located entirely within Section 29 (Beightol, 1986). Sampling was limited to approximately the same elevation within each ravine to avoid differences in composition due to topographic location. Data were collected using the Point-Quarter Method (Cottam and Curtis, 1956). A correction factor was used to compensate for missing data when necessary (Wardle and Petranka, 1981). Thirty points were evaluated along each transect except the west-facing, transect of the South Ravine (Transect 1). This transect started at the ecotone between an area dominated by eastern red cedar (*Juniperus virginiana* L.) and a grassland habitat, and ended as it entered into a marsh; only 27 points were evaluated. Evaluation points along all transects were approximately 20 m apart. This number of transects thoroughly covered the study area since the wooded ravines are relatively small.

At each of the 30 points, the three closest trees in each of three size classes were recorded in each of the four quarters, a total of 12 trees for each point. Tree-size classes used were: "small" = <10 cm diameter-at-breast-height (dbh), "medium" = 10–30 cm dbh, and "large" = >30 cm dbh. These three size classes were analyzed separately. A number of trees had multiple stems but only the stem closest to the center point was recorded. This and other features, such as trees with large scars at the base of the bole, were noted when included in the sample. Importance values (IV) were used to compare transects. These are dimensionless values calculated for each species from Point-Quarter field data by summing a species' relative density, relative dominance, and relative frequency.

The three size classes used were selected to approximate relative tree ages for assessing potential changes in vegetative composition. While tree dbh is only poorly correlated to age, there was enough uniformity in the soil conditions that growth rates were most likely similar. For example, Rozmajzl (1988) noted that, in bur oak greater than 30 cm dbh in eastern Nebraska, all trees aged to presettlement dates exceeded 50 cm dbh. In addition, Gehring and Bragg (1992) noted that, in eastern red cedar, crown diameter, another measure of tree-size, increased significantly with tree-age ($r = 0.52$; $P < 0.01$). Moreover, site-index curves for several species of oak (Sander, 1977), elm (Geyer and Lynch, 1990b), black walnut (*Juglans nigra* L.) (Geyer and Lynch, 1987), hackberry (Lynch and Geyer, 1988), and green ash (*Fraxinus pennsylvanica* L.) (Geyer and Lynch, 1990a), all indicate a relationship between age and height, yet another measure of tree-size. Given these relationships and the need for only general precision, using tree dbh as an indirect measure of *relative* tree-age was considered reasonable and time-efficient.

In addition to field sampling, the 1857 General Land Office Survey records that included the study site were reviewed to assess potential presettlement vegetation. These records typically include observations on vegetation that occurs along, and near, section lines established during the ground survey. Since the study area includes parts of four section lines, the information from the General Land Office Survey is considered to provide a reasonable amount of information on which to base site-specific presettlement vegetation. The descriptions given in the 1857 GLO survey are considered to represent pristine conditions since it was conducted prior to settlement of the area in 1864.

RESULTS AND DISCUSSION

Presettlement vegetation

Evidence suggesting a presettlement oak forest comes from existing trees, from historical accounts provided by early settlers, and from the GLO survey. The largest trees found during this study are primarily bur oaks that are scattered throughout the forest. These trees are characterized by non-overlapping canopies and low, branching growth form, both characteristics typical of trees developing in a more open community than exists today. An open habitat would be conducive to bur oak regeneration since this species requires such conditions for germination (Cottam, 1949). Moreover, given the high frequency of fires in the tallgrass prairie (i.e. see Anderson, 1990), such a habitat would have been subject to frequent burning, thereby remaining savanna-like (i.e. see summary by Rozmajzl, 1988). Further, bur oak's thick bark gives it a high degree of fire-resistance (Lawson et al., 1980) and it could persist under such conditions. In combination, these observations suggest that the presettlement forest of the study site may once have resembled a savanna-type community dominated by bur oak and, perhaps, maintained by recurrent fires.

The general description of the 10 × 10 km township that includes the study site, as documented in the 1857 General Land Office survey, provides further informa-

Table I. Importance values by species, ravine, and aspect (west- or east-facing slopes). Numbers in parentheses indicate transect number.

Species by DBH Size Class	Importance Value by Ravine and Aspect			
	North Ravine		South Ravine	
	West Slope (4)	East Slope (3)	West Slope (1)	East Slope (2)
> 30 CM DBH				
Quercus macrocarpa Michx. (bur oak)	285	295	240	213
Celtis occidentalis L. (hackberry)	11	5	4	33
Ulmus spp. (*U. americana* L. and *U. rubra* Mulh.) (elm)	0	0	21	20
Fraxinus pennsylvanica Marsh. (green ash)	4	0	18	13
Juniperus virginiana L. (eastern red cedar)	0	0	17	18
Morus alba L. (white mulberry)	0	0	0	3
10–30 CM DBH:				
Quercus macrocarpa Michx. (bur oak)	244	172	105	69
Ulmus spp. (*U. americana* L. and *U. rubra* Mulh.) (elm)	29	74	135	125
Celtis occidentalis L. (hackberry)	7	15	19	56
Fraxinus pennsylvanica Marsh. (green ash)	4	4	17	36
Juniperus virginiana L. (eastern red cedar)	16	28	0	3
Morus alba L. (white mulberry)	0	7	0	0
Juglans nigra L. (black walnut)	0	0	24	11
<10 CM DBH:				
Ulmus spp. (*U. americana* L. and *U. rubra* Mulh.) (elm)	70	88	147	149
Celtis occidentalis L. (hackberry)	14	9	37	46
Fraxinus pennsylvanica Marsh. (green ash)	3	8	9	8
Juniperus virginiana L. (eastern red cedar)	17	23	9	2
Quercus macrocarpa Michx. (bur oak)	0	13	12	11
Juglans nigra L. (black walnut)	0	0	4	4
Prunus americana Marsh. (wild plum)	0	2	0	6
Cornus drummondii C.A. Mey. (rough-leaved dogwood)	136	121	63	53
Xanthoxylum americanum P. Mill. (prickly ash)	60	36	19	21

tion on the presettlement forest of the study site. At the time of the survey, timbered streams were found along the section lines that cross the study area as well as those section lines within 1.6 km of the study area. Trees mentioned included bur oak, cottonwood (*Populus* L.), hickory (*Carya* Nutt.), and ash (*Fraxinus* Marsh.). One bur oak, with a dbh of 60 cm, is recorded near the study area, suggesting a tree that was greater than 140 years old in 1857 based on the relationship between large trees and tree-age of Rozmajzl (1988). Extending this information back in time, one conclusion is that this tree, and probably others, had been present at the site since at least the early 1700s.

Historical accounts provided by the early settlers also indicate that trees were present in the area prior to settlement. In 1864, the area that includes the present study site was known as Oak Groves (Olney, 1887). Timber found in the ravines of the area, however, was cut for firewood for the salt works in Lancaster County. The forest of the study site, therefore, are most likely to be primarily second growth forest developed from the local seed bank, from young trees present at the time of the initial disturbance, or from resprouting stumps or roots of felled trees.

Present vegetative composition

Bur oak dominated the >30 cm dbh (large) size class in all transects (average IV = 258) with hackberry, elm, ash, and eastern red cedar (average IV = 13, 10, 9, and 9 respectively) of considerably less importance (Table I). These results also are reflected in absolute density values (Fig. 1). This similarity among transects for the large-size class is also shown in Beta

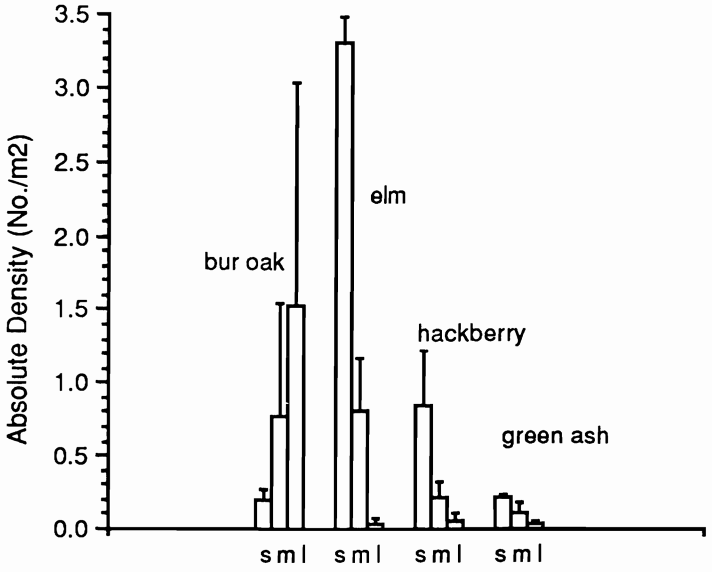

Figure 1. Average absolute density, by size class, of dominant trees of the study site. Vertical lines depict the Standard Error of the mean. s = small-size (<10cm dbh), m = medium-size (10–30cm dbh), l = large-size (>30cm dbh).

Diversity (between-habitat) comparisons in which a greater similarity occurred among comparisons between the large trees than among transect pairs of other size classes (Table II).

In contrast to bur oak domination of the large-size class, dominant trees for the two smaller size classes differed between ravines and aspects, perhaps reflecting different management histories. For trees 10–30 cm dbh (medium-size class), bur oak dominated only in the North Ravine (average IV = 208) whereas elm dominated this size class in the South Ravine (average IV = 130) although the IV of bur oak was second highest (average IV = 87). In the <10 cm dbh size class, elm had the highest importance value (average IV = 114) of all tree species for all transects although it was higher in the South (average IV = 148) than in the North Ravine (average IV = 79). Hackberry was second highest (average IV = 12 in the North and 42 in the South Ravine). High values for prickly ash (*Xanthoxylum americanum* P. Mill.) and rough-leaved dogwood (*Cornus drummondii* C.A. Mey.) in the North Ravine reflect the substantial number of large clearings along the transect that allowed sunlight to reach the forest floor. In such openings, these species grew in dense, tall stands giving inflated importance values. Aikman (1929), however, also describes this type of understory growth in a bur oak forest although forests in the 1920s are more likely to have represented earlier stages of ecological succession such as might have been a response to a decline in natural fires. The large number of clearings in the North Ravine also explains why the values for the two smaller size-classes of eastern red cedar are highest in this transect. Differences in importance value distribution between the two smaller size-classes and the large-size class suggest a difference in the factors affecting tree establishment and ecosystem maintenance. More recent forest development appears to be affected by different conditions than those affecting the forest represented by trees in the large-size class.

As with historical references to differing managements, different species importance values for certain transects suggest that the woody plant composition of the ravines differ from each other. For example, for bur oak, the highest value in each of the three size classes

Table II. Beta diversity values based on Percent Similarity (Whittaker, 1975). High values represent high degree of similarity. SR = South Ravine, NR = North Ravine, East/West indicates aspect of slope.

	Tree Size Class		
Transect Comparison	**<10cm dbh**	**10–30cm dbh**	**>30cm dbh**
SR West × SR East	0.9395*	0.8047	0.8904
SR West × NR East	0.6941	0.6607	0.8153*
SR West × NR West	0.5925	0.4851	0.8278*
SR East × NR East	0.6526	0.5474	0.7244*
SR East × NR West	0.5452	0.3718	0.7590*
NR East × NR West	0.8523	0.7619	0.9643*

* = greatest similarity among size classes for the comparison indicated

is recorded only in North Ravine while hackberry, elm, ash, and black walnut attain their highest importance values in all size classes in the South Ravine (Table I). Hackberry was particularly uniquely distributed, being the only species to have its highest importance values dominate all size classes in both the same ravine and the same, east-facing, aspect. This distribution is influenced by a stand of hackberry trees growing in an area of more flat and more mesic habitat through which the transect passed. Of the 12 hackberries sampled in the large-size class along this transect, ten were recorded from this stand. In contrast, among the other common trees (species with importance values greater than 10 in at least one transect), only eastern red cedar has maximum importance values in a size class in both ravines. This distribution is consistent with the invasive tendency of eastern red cedar (Bragg, 1974) and is suggestive of its potential to replace or alter existing or developing stands of native trees.

Potential vegetation dynamics

Assuming that relative tree-age is reflected by the size class used, the results of this study suggest that the extant forest will change substantially in future years. This change is most apparent in the difference in both importance values and density of bur oak and elm. While bur oak is the dominant and most densely occurring tree species in the present forest, both its importance and density decline in each successively smaller size class (Fig. 1, Table I). This trend suggests that current oak establishment is not adequate to replace the existing population. For example, the few small oaks observed were found in well-lit areas, such as in clearings or near the edge of the forest, and not within it, where they would be expected to occur if bur oak were regenerating under its own canopy (personal observation). Elm, hackberry, and to a lesser extent, ash, however, appear to be increasing in both importance and density (Fig. 1, Table I). Elm, for example, was not mentioned in the historical accounts by GLO surveyors and may, therefore, be a relatively recent addition to the forest composition.

The presettlement forest at the Oak Glen Wildlife Management Area appears to have been more open and savanna-like whereas the extant forest is more fully canopied. Further, under present management, it seems likely that bur oak will ultimately be replaced as a dominant by other, more shade tolerant species, like elm, hackberry, or ash, except that elm necrosis may diminish the role of elm as a dominant in any future forest. Additional study is needed to assess management practices that could retain bur oak as a dominant species in the Oak Glen Wildlife Management Area, if that is to be the desired objective.

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