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THE EFFECT OF SLOPE ASPECT AND POSITION ON THE COMPOSITION AND SIZE OF WOODY VEGETATION IN THE KANSAS TALL-GRASS PRAIRIE

by

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B.G.S., Kansas University, 1976

A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Division of Biology

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1980

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Introduction

The Flint Hills of Kansas lie on the western, more xeric border of the broad ecotonal region between the Eastern Deciduous Forest and the grasslands of the Great Plains. A bluestem or tall-grass prairie is the predominant vegetation form. Woody vegetation is restricted by fire and limited water availability to flood plains and the steep-sided ravines and limestone outcroppings characteristic of the rolling topography.

Numerous studies have discussed the greater water supply for plants on north-facing slopes in northern latitudes (Albertson and Weaver 1945, Benson et al. 1967, Birdsell and Hamrick 1978, Cooper 1960, Costello 1931, Kormondy 1969, Potzger 1939, Shelford 1963, Shul'gin 1957, and Weaver, Hanson, and Aikman 1925). Tree species numbers and basal area per individual are maximized for lower positions (Costello 1931) of north-facing slopes (Birdsell and Hamrick 1978, Kormondy 1973, and Potzger 1939). However, the relationship of tree height to slope aspect and position has not been studied extensively. This paper describes and analyzes the effect of slope aspect and position on the composition and height of the canopy layer of woody vegetation in ravines of the Flint Hills of Kansas.

Materials and Methods

A baseline study of the woody vegetation on the Dewey Ranch addition to the Konza Prairie Research Natural Area was conducted during the summer of 1977. The data in this paper were taken from two ravines on the southeast ¼ of Section 32, Township 10S, Range 8E, of Riley County, Kansas, approximately ten kilometers south of Kansas State University at Manhattan. The only level area in the steep sided ravines was the 305 meter wide dry streambed at the bottom of the opposing slopes. Four transects were randomly located across the width of the ravines in areas where soil characteristics would be similar for corresponding plot locations on opposing slopes. Five-meter-long plots were placed along the length of each transect. Percent of rock and grass cover, amount of and direction of slope, and position on the transect were recorded for each plot location. Slope position was described three ways: distance from the nearest prairie area, distance from the bottom of the slope (stream), and relative elevation as the number of plots downslope from the uppermost plot on the uppermost transect. As vertical distance and slope distance were not perfectly correlated, limestone outcroppings were used as benchmarks in the latter designation.

Plot width varied for three size categories of woody vegetation -- ground layer, tall shrub layer, and tree layer. Woody plants less than two meters in height were designated as the ground layer and were sampled with one by five meter plots, the transect line being the longer axis. Within a plot, density and height were recorded in categories for each species, with nomenclature following Barkley (1977) and Anderson and Owensby (1969). The tall shrub layer, consisting of individuals greater than two meters in height and less than 100 millimeters in diameter, was given similar treatment except that plot width was increased to two meters and stem counts were enumerated.

Each stem greater than 100 millimeters in diameter (tree layer) was listed separately. Tree layer plots were five by ten meters with the transect line the mid-line for the shorter dimension. Species, diameter at breast height (1.37 meters above ground) to the nearest millimeter, and height to the nearest meter were recorded for each stem. The largest stems from the top, middle, and bottom portions of a north-facing slope were cored with a Swedish increment borer to obtain maximum ages for differing slope positions. Cores were taken on the uphill side at a height of 0.5 meters above ground. Heights, diameters, and ages of the cored stems were ranked, and then compared using Spearman's rank correlation coefficient, $r_s = 1 - \frac{6\Sigma d^2}{n(n^2-1)}$, where d is the difference in ranking and n is the number of ranked pairs (Snedecor and Cochran 1967).

For each species represented in the tree layer an importance value was calculated by summing values for relative frequency, relative density, and relative dominance. Relative frequency was calculated as a percentage of plot occurrence. The number of plots on which each species occurred as tree layer stems was divided by the total for all tree layer species. Relative density was calculated as a percentage of the total number of tree layer stems, and relative dominance as a percentage of the total basal area of tree layer stems.

For each plot location the dependent variables average height and average diameter per stem were computed for the dominant species, Quercus muhlenbergii. A pooled correlation matrix of these dependent variables and the independent environmental parameters determined by each plot's location on the transect was computed using the Statistical Analysis System (SAS). Analyses of covariance for the dependent variables' stem height and average diameter were computed using a program furnished by the Statistical Laboratory of Kansas State University. Another such program was used to create a model of the dependent variable tree height with respect to the continuous independent variable distance from the stream and the discrete independent variable slope aspect.

Aerial photos made in 1939, 1943, and 1969 were evaluated to determine the change in the extent of woody vegetation in the study ravines from the period immediately following the "Great Drought" of the 1930's to more recent times.

Results and Discussion

Of the 24 woody species present, 6 were represented in the tree layer (Table 1). *Quercus muhlenbergii* was by far the dominant tree layer species, with an importance value of 209.7 out of a possible 300 (Table 2). By comparison, the importance value of *Quercus macrocarpa* was 48.3 and the remaining four tree layer species (*Cercis canadensis*, *Juglans nigra*, *Ostrya virginiana*, and *Ulmus americana*) possessed a combined importance value of 51.1.

O. virginiana and *J. nigra* appeared as tree layer stems on only two and one plots, respectively. Only occasional stems of *C. canadensis* exceeded the size required to be classified as a member of the tree layer (100 millimeters DBH). The average diameter of the eleven *C. canadensis* tree layer stems was 128 millimeters. Only one stem at 219 millimeters diameter, exceeded 134 millimeters in diameter.

There are indications that *U. americana* has been severely restricted in eastern Kansas following the introduction of Dutch Elm Disease (Birdsell and Hamrick 1978) which was first confirmed in Riley County in 1963 (Willis 1970). Although numerous seedlings and sprouts were present in the study ravines (Table 1), most of the larger specimens were either dead or dying. 57.7% of the basal area of *U. americana* was accounted for by a single dead individual. Within the last 75 years there has been regular light logging as well as periods of much heavier logging of *J. nigra* in the region. Such logging is not uncommon for Kansas, which as recently as 1963 ranked second only to Indiana in the production of walnut veneer logs (Deneke and Funsch 1970). However, logging likely did not occur in the study ravines due to the steep slopes involved. In addition to potential specific selection pressures against U. americana and J. nigra, extensive herbicide spraying within the last 20 years has adversely affected most of the woody vegetation in the study ravines. Although 41% of the stems were recorded as dead (Appendix B) most of these deaths were in the five years preceeding the gathering of field data (personal correspondence).

White man's settlement of the Flint Hills began in the 1840's. Since then, intentional burning of the grassland has been needed to limit the woody vegetation to amounts approximating presettlement conditions (Bragg 1971). The oldest trees sampled sprouted circa 1880 (Table 3). Stems on the upper slopes sprouted after 1921 except for one individual from 1902. Although a comparison of aerial photos made in 1939, 1943, and 1969 reveals little change in woodland extent during the last 40 years, it is possible that these ravines did not support a significant woodland prior to white man's arrival. Historical effects such as changes in fire frequency and the above selection pressures against woody vegetation may have modified the vegetation from that of presettlement time. Therefore, this study will be limited to the characteristics of the present day woodland. Although this study does not attempt to determine the date or manner of woodland origination in the study ravines, historical effects must be taken into consideration in any examinations of today's woodland.

Cercis canadensis, Quercus muhlenbergii and Ulmus americana were found throughout the ravines near Manhattan. Of a total of 32 Quercus macrocarpa tree layer stems, one was on a plot adjacent to the bottom of the south-facing slope, one was 30 meters from the bottom of the north-facing slope, and the remainder were within 20 meters of the bottoms of north-facing slopes. The plot containing the single tree layer Juglans nigra and the two plots on which the eight tree layer individuals of Ostrya virginiana occurred were on the lower 30 meters of north-facing slopes. Also, several plots containing ground layer and tall shrub layer O. virginiana were on this lower portion of a north facing slope (Table 1). Thus all six of the tree layer species were present in the lower 30 meters of north-facing slopes, and three of the six species were restricted to either this portion of the transects or to one plot on a south-facing slope adjacent to the streambed. Other studies had similar findings regarding species numbers for both slope aspect (Birdsell and Hamrick 1978, Potzger 1939) and slope position (Costello 1931).

In northeastern Kansas sharp ecotones exist between the oak-hickory and tallgrass-prairie vegetations. Before the arrival of white settlers in the 1850's, these two types of vegetation appeared in an interdigitating pattern that was determined by various environmental factors (Fitch and McGregor 1956). Kuchler (1974) notes that forest islands in the prairie "decrease from east to west in extent, height, number of species, and in significance in the vegetational pattern of the landscape. Toward the west, they are often restricted to valley sides of varying steepness, especially on north-facing slopes." A comparison of two forest islands restricted to ravines reveals that near Manhattan, Kansas (average annual precipitation 80 centimeters) 6 tree layer species were present in a sample of 240 stems. To the east, in a similar ravine near Lawrence, Kansas (average annual precipitation 89 centimeters) 11 tree layer species were present in a sample of 74 individuals. Thus the species numbers decreased by 44% with a precipitation decrease of 10% even though the sample increased considerably.

The diversity of forest-type vegetation in eastern Kansas has been linked by species richness to a set of environmental parameters regulating the number of species which can exist in a given area (Birdsell and Hamrick 1978). An important limiting factor in Kansas is water availability (Weaver et. al. 1925). In northern latitudes north-facing slopes are cooler and moister (Benson et. al. 1967, Cooper 1960, Kormondy 1969, Potzger 1939, and Shul'gin 1957), and are better for tree growth and development (Albertson and Weaver 1945, Birdsell and Hamrick 1978, Costello 1931, Shelfor 1963, and Weaver et al. 1925). In this study, species numbers fit the generally accepted concept of decreasing species richness with a decrease in precipitation effectiveness.

The height of the dominant species, Quercus muhlenbergii, decreased as distance from the stream increased (Fig. 2). Stems were tallest on the lower portions of north-facing slopes. The following computer model of Quercus muhlenbergii height was developed using slope aspect and distance from the stream as independent variables:

$$QH = 6.59 + .63\ SA - .048\ DS, \text{ where}$$

QH is the height in meters of Quercus muhlenbergii

SA is the slope aspect, with values of

-1 for south-facing plots, and

+1 for north-facing plots, and

DS is the distance from the stream in meters.

Thus stems are calculated as being 1.26 meters taller on north-facing slope plots than on corresponding south-facing slope plots.

There is an increase in fire protection for lower slope positions as well as a potential increase in moisture due to run-off from upslope. Individuals were older on lower slope positions (Table 3), and rank order correlations were significant at the 1% level for age with both tree heights(r_s = .638) and diameter (r_s = .821). Relative elevation, a measurement of slope position calibrated from limestone layers of the topography, was significant in analysis of covariance with both tree height (p < .0193) and average diameter (p < .0373)(Table 4). Thus both age and tree size were increased for lower slope positions.

Even though tree heights may increase due to competition for sunlight when stems are crowded, the correlation between tree height and number of stems per plot was quite low (r = -.0452) (Table 5). Natural thinning typically produces negative correlations between tree height and stem densities, going from young stands with high stem densities and short individuals to old stands with low stem densities and tall individuals. However, although the correlation is negative (*r* = .0452) it was clearly not significant, so that perhaps the effects of crowding and natural thinning are canceling each other. As there is no clear relationship between tree height and stem densities, it is possible that some factor might be influencing tree height other than size increases normally associated with age.

When slope position was measured in terms of relative elevation, it was significant in analysis of covariance with both tree height and average diameter. However, when slope position was measured as distance from the stream, it was a good predictor for the dependent variable tree height ($p < .0001$) but not for average diameter ($p < .4540$) (Table 4), although diameter and tree height were significantly correlated ($r = .5105$) (Table 5). Thus individuals further from the stream had a shorter and bushier growth form, with such growth forms commonly associated with drier climatic conditions. Therefore, some factor inherent to distance from the stream but not to relative elevation appears to be causing drier conditions. Just as micro-climatic differences due to slope aspect influence the vegetation, perhaps the angle of the opposing slopes is sufficient to create a more protected and more humid micro-climate near the streambed which would be more favorable to tree height growth than to increases in diameter.

In this study tree layer individuals extended 35% further up the north-facing slopes than the south-facing slopes (Fig. 3). Costello (1931), faced with similar variations, found that evaporation was the same for identical vegetational associations regardless of slope aspect or position and concluded that "These differences, as well as the treelessness of the west-facing bluffs, appear to result from the high rate of evaporation caused by prevailing winds during the growing season." The prevailing surface winds in this study area are from the south, so that the south-facing slopes would be more exposed to their drying effects than the north-facing slopes (USDA 1975). Costello noted that for "a north-facing slope...development of vegetation was much the same as that on the Nebraska (east-facing) side of the river" so that his conclusion that wind is responsible for drier conditions on the west-facing bluffs can be applied to the south-facing slopes of this study.

Wind is clearly involved in evaporation, but there has not been documentation separating the effect of wind from that of other contributing factors. Also, while there have been numerous studies of tree diameters, few if any have investigated tree height. The author feels these areas deserve study, and presents here a potential relationship between tree height, wind, and woodland extent.

In summary, both species numbers and height of the dominant species, Quercus muhlenbergii, were maximized on the lower portions of north-facing slopes. Distance from the stream influenced Q. muhlenbergii height, but not diameter. Species numbers were greater at a moister site to the east than at the present study site. Water availability inherent to slope aspect and position is held to be primarily responsible for the observed variations in species numbers and tree height. However, greater woodland extent on north-facing slopes indicates that wind might also be involved as a limiting envirnonmental factor.

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TABLE 1: Occurrence of woody plants by size class and slope aspect.

Species	Number of plots on which species occurred					
	Ground layer (<2m tall)		Tall shrub layer (>2m tall and <100 mm DBH)		Tree layer (>100mm DBH) (Numbers of individuals are given in parenthesis)	
	South-facing slopes	North facing slopes	South-facing slopes	North-facing slopes	South-facing slopes	North-facing slopes
Ceanothus ovatus (inland ceanothus)	6	4				
Celastrus scandens (American bittersweet)	14	4				
Celtis occidentalis (common hackberry)	2	1				
Cercis canadensis (eastern redbud)	21	27	6	7	3(3)	6(8)
Cornus drummondii (roughleaf dogwood)	35	42	22	26		
Juglans nigra (black walnut)					0(0)	1(1)
Juniperus virginiana (redcedar)	1	5				
Morus alba (white mulberry)	0	1				
Ostrya virginiana (American hophornbeam)	0	8	0	2	0(0)	2(8)
Parthenocissus quinquefolia (Virginia creeper)	3	8				
Populus deltoides (eastern cottonwood)	1	0				
Quercus macrocarpa (bur oak)	1	0	0	1	1(2)	11(30)

TABLE 1: Continued

Species	Number of plots on which species occurred					
	Ground layer (<2m tall)		Tall shrub layer (>sm tall and <100mm DBH)		Tree layer (>100mm DBH) (Numbers of individuals are given in parenthesis)	
	South-facing slopes	North-facing slopes	South-facing slopes	North-facing slopes	South-facing slopes	North-facing slopes
Quercus muhlenbergii (chinquapin oak)	16	23	10	19	29(90)	34(92)
Ribes missouriense (Missouri gooseberry)	0	7				
Rhus aromatica var. *serotina* (aromatic sumac)	3	1				
Rhus glabra (smooth sumac)	4	4	0	1		
Rosa arkansana (Arkansas rose)	1	16				
Smilax hispida (bristly greenbrier)	1	3	0	1 (vine)		
Symphoricarpos orbiculatus (buckbrush)	25	21				
Tilia americana (American linden)			0	1		
Toxicodendron radicans (poison ivy)	4	9				
Ulmus americana (American elm)	15	19	1	0	3(3)	2(3)
Vitis riparia (riverbank grape)	1	2				
Zanthoxylum americanum (common pricklyash)	2	1				
Totals	156	206	39	58	36(98)	56(142)

TABLE 2: Importance values for canopy layer species.

Species	Relative frequency[1]	Relative density[2]	Relative dominance[3]	Importance value[4]
Quercus muhlenbergii	68.5	75.6	65.6	209.7
Quercus macrocarpa	13.0	13.4	21.9	48.3
Cercis canadensis	9.8	4.6	2.3	17.1
Ulmus americana	5.4	2.5	6.8	14.7
Ostrya virginiana	2.2	3.4	1.4	7.0
Juglans nigra	1.1	.4	1.5	3.0
Totals	100.0	99.9	99.9	299.8

[1]Percent of total sum (92 plots) of tree species plot occurrence.

[2]Percent of total number (240 stems) of tree species stems.

[3]Percent of total basal area ($5.5 \times 10^6 mm^2$) for all species.

[4]Summation of relative frequency, relative density, and relative dominance.

TABLE 3: Ring count ages of selected *Quercus muhlenbergii* individuals from a north-facing slope.

Slope Position	Year sprouted	Age[1] (1980)	Diameter, mm	Height m
Upper Near Prairie	1902	78	40.4	7
	1921	59	19.8	3 1/2
	1922	58	13.0	3
	1929	51	14.1	3
	1939	41	12.1	3
	1939	41	16.9	4
	1941	39	16.2	3
Middle	1881	99	24.1	6
	1883	97	30.4	9
	1895	85	30.0	9
	1907	73	17.0	5
	1917	63	17.8	6
Lower Near Stream	1879	101	28.1	8
	1881	99	17.7	6
	1884	96	18.5	7
	1886	94	26.5	8 1/2
	1892	88	32.8	9
	1894	86	16.8	6
	1921	59	2618	7
	1929	51	16.0	5

[1]Three years were added to ring counts to allow for growth to level of core sample. Cores were taken 0.5 meters above ground on uphill side of stem.

TABLE 4: Analysis of covariance with size characteristics of *Quercus muhlenbergii* as the dependent variables: (1) height and (2) diameter. Values are given as probabilities of greater than F values.

Independent Variables	Dependent Variables: Average Height Per Plot	Dependent Variables: Average Diameter Per Plot
Slope aspect	.0001	.0070
Relative elevation	.0032	.0373
Distance from stream	.0001	.4540
Distance from prairie	.1593	.9162
Percent rock cover	.1303	.7831
Percent grass cover	.1315	.2243
Degree of slope	.2913	.0591

TABLE 5: Pooled correlation matrix for plots containing *Quercus muhlenbergii* north- and south-facing plot values are pooled[1] unless the probability of the values having the same correlation is 7.0% or less.

Variables	Relative Elevation	Distance From Stream	Distance From Prairie	Percent Rock Cover	Percent Grass Cover	Degrees of Slope	Average Diameter	Height
Distance from stream	.0093							
Distance from prairie	.5381	-.4444						
Percent rock cover	.0206	-.3439	-.0177					
Percent grass cover	.1927	.5534	-.1340	-.2930				
Degrees of slope	-.1505	-.1506[2] -.6576[3] .0174[4]	.3367	.2397	-.1425[2] -.5591[3] .0664[4]			
Average diameter	.2643	-.3490	.3271	.1758	-.2686	.3434		
Average height	.2027	-.6803	.1027[2] .5266[3] .0704[4]	.1679	-.4310	.0463[2] .5123[3] .0514[4]	.5105	
Stems per plot	.1252	-.2163[2] .3892[3] .0184[4]	.2099[2] -.2638[3] .0694[4]	.2086[2] -.2646[3] .0694[4]	.0843	-.2323	-.0453 .0543	-.0452

[1]Critical values for correlation coefficients to be significantly different from zero are ±.25 at the 5% level and ±.325 at the 1% level.

[2]Correlation value for south-facing plots.

[3]Correlation value for north-facing plots.

[4]Probability of north- and south-facing values having the same correlation.

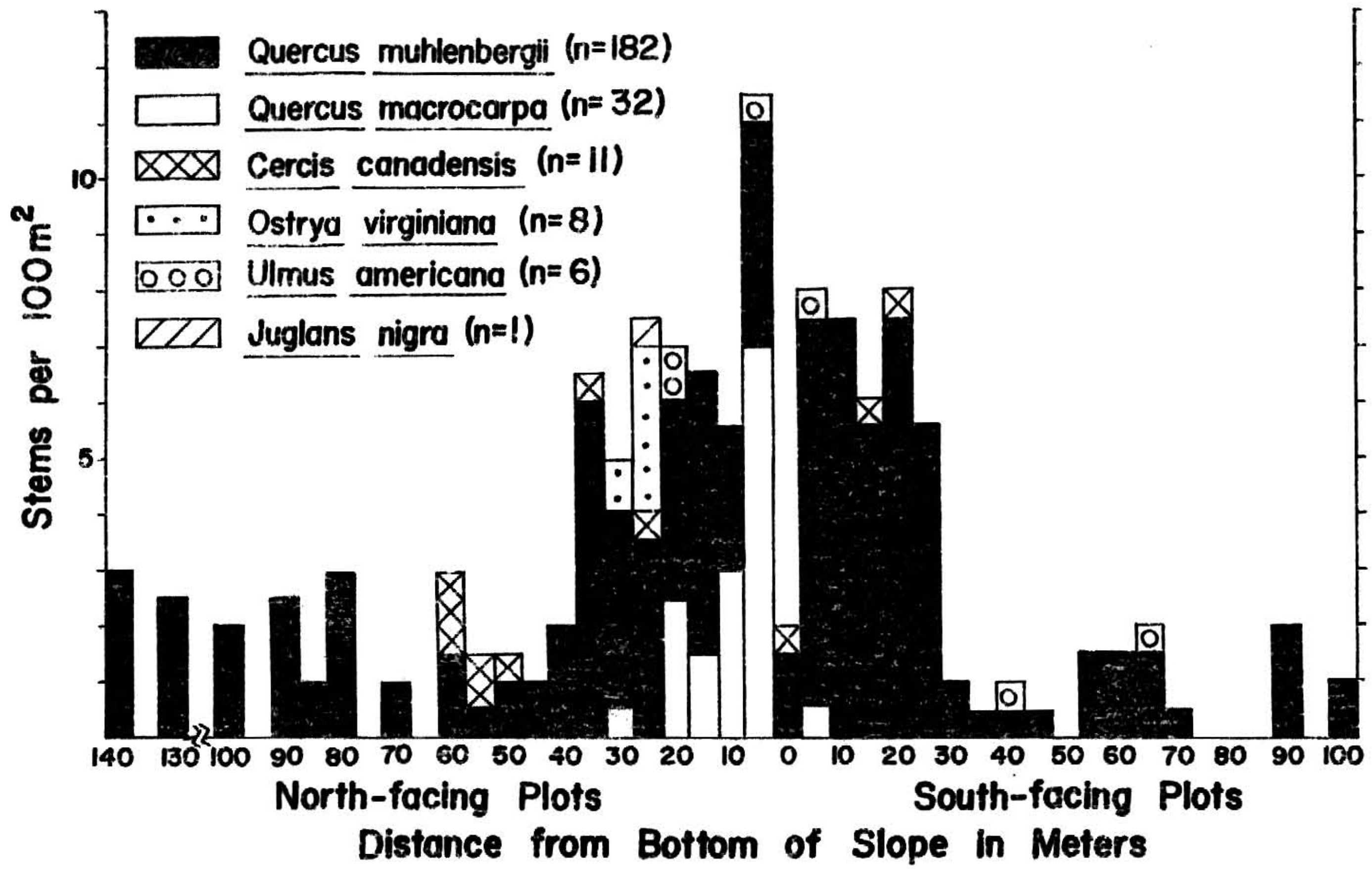

Figure 1: Tree stem density in relation to slope aspect and position.

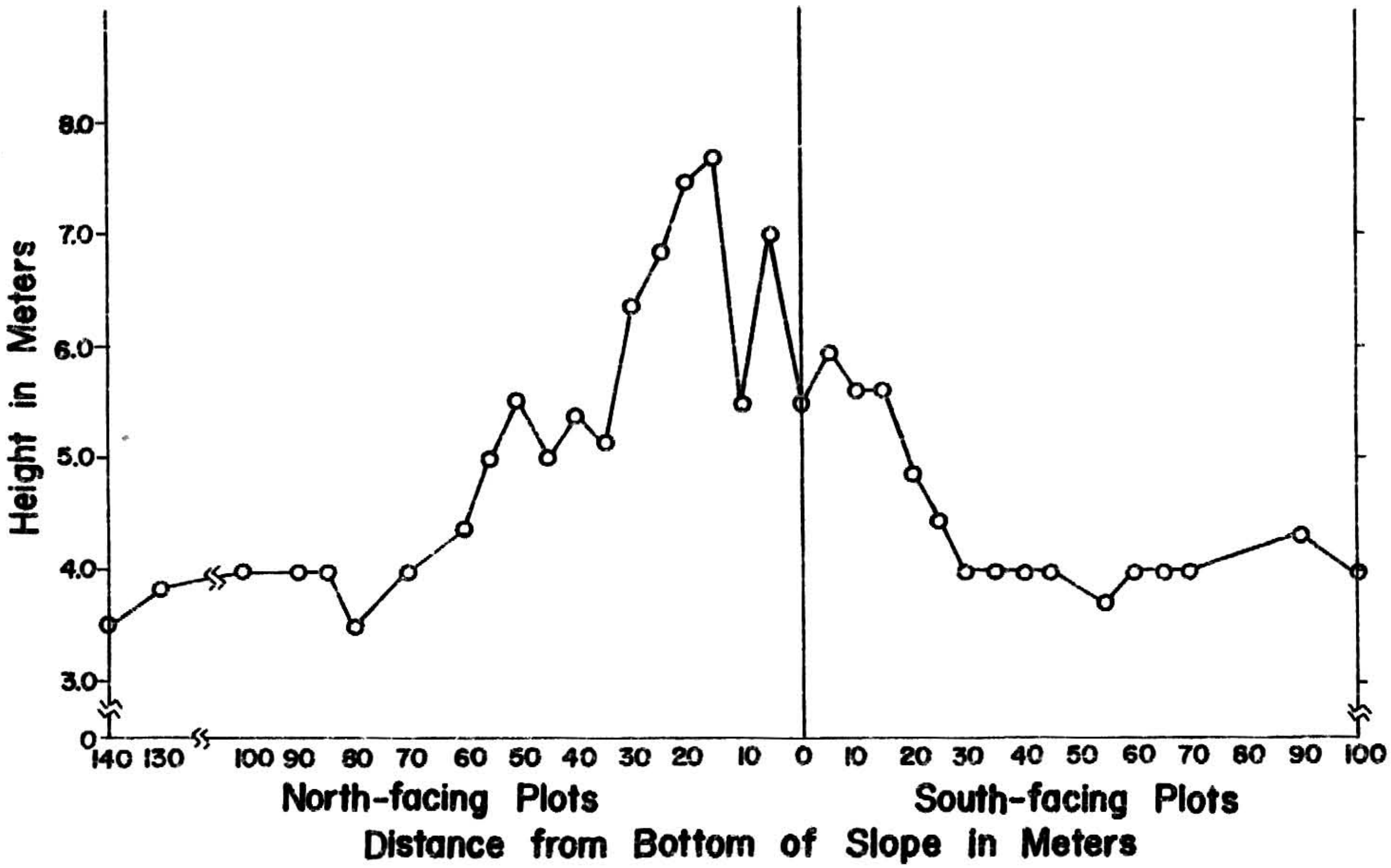

Figure 2: Average height of _Quercus muhlenbergii_ in relation to slope aspect and position.

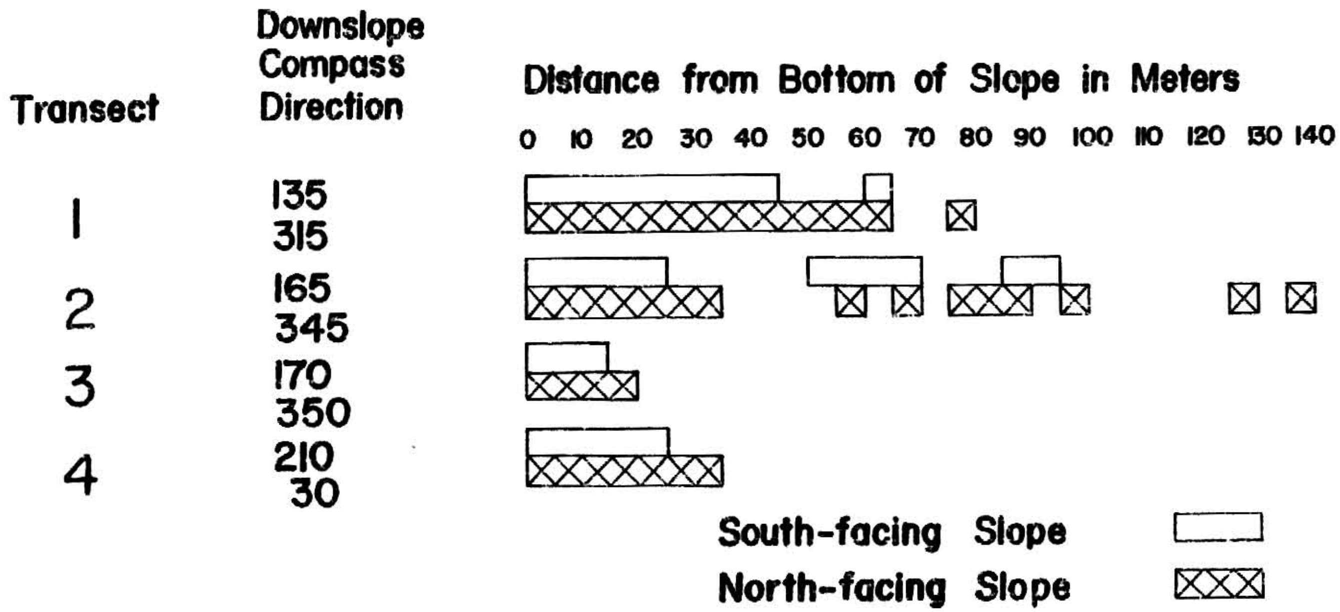

Figure 3: Extent of tree layer individuals up north- and south-facing slopes on four transects.

Appendix A: Literature Review

Species richness has been found to relate proportionally to temperature, and biomass to actual evapotranspiration, on a macroclimatic basis (Odum 1969). Within the ecotonal region from the Eastern Deciduous Forest of extreme eastern Kansas to the prairie of western Kansas, the potential species richness of the forest canopy decreases in a westerly direction. This decrease is primarily due to range limitations of certain species which occur exclusively in the eastern thrid of the state (Stephens 1969). Species diversity of the forest canopy in eastern Kansas, as measured by the Shannon-Weiner Index of Species Diversity, has been found more dependent on species richness than on the relative abundance of each species, indicating that there are environmental parameters regulating the number of species that can exist in a given area (Birdsell and Hamrick 1978).

In Kansas there is a westerly decrease in average annual precipitation and Thornewaite's Precipitation-Evaporation Index with an important limiting factor in Kansas being water availability (Weaver, Hanson, and Aikman 1925). For northern latitudes north-facing slopes have been documented to be cooler and moister than corresponding south-facing slopes. In a study in Michigan during the 1957 growing season, the air temperatures at a height of 50 centimeters above the ground were $2\frac{1}{2}^{o}C$ higher for the south-facing than for the north-facing slope (Cooper 1960). Soil temperatures at depths of two centimeters and twenty centimeters displayed similar variations.

In a study by John Cantlon on Suchetunk Mountain in New Jersey, the air and soil temperatures were 3.5-6.0^{O}F greater on the south-facing slopes than on the north-facing slopes (Kormondy 1969). As a result of this increase in temperature, the south-facing slope possessed a larger vapor pressure deficit. The vegetation on the south-facing slope would more rapidly transpire the limited amount of moisture available. It has been calculated that the soil temperatures of a field sloping 1^{O} to the south are the rough equivalent of a level field 100 kiolmeters to the south (Shul'gin 1957).

North-facing slopes have been shown to contain more moisture than south-facing slopes. Potzger (1939) found that for an Indiana ridge the evaporation for the 1934 season resulted in 61% greater loss for the south-facing slope than for the north-facing slope with surface soil having 30%, and soil at six inches depth 28%, more moisture on the north-facing than on the sough-facing slope. The percent moisture (by weight) in Cooper's (1931) Michigan study was as much as 12.7% greater for the north-facing slope at depths of two centimeters and twenty centimeters demonstrating the greater moisture supply of north-facing slopes during periods of water stress.

Slope aspects other than north- and south-facing have also been shown to influence vegetational patterns. In a study of east- and west-facing bluffs along the Missouri River near Nebraska City, Nebraska, the development of vegetation on the north-facing slopes adjacent to west-facing slopes was much the same as on the east-facing slopes across the river (Costello 1931). The largest extremes have been found to be northeast- and southwest-facing slopes (Benson et al. 1967). Causes of the increased evaporation on south-and west-facing clopes have included mention of both the warmer afternoon sun and prevailing winds during the growing season.

These micro-climatic variations inherent to slope aspect influence vegetational patterns in a manner similar to that of macro-climate. Numerous studies during the Great Drought of the 1930's demonstrated the greater tolerance of vegetation on north-facing slopes (Albertson and Weaver 1945, Shelford 1963). The north-facing slopes were better able to maintain a moisture supply during times of high water stress than were corresponding south-facing slopes.

Tree species composition and basal area per individual have been found to respond to slope aspect (Birdsell and Hamrick 1978, Kormondy 1973, Potzger 1939) and slope position (Costello 1931), with both maximized for lower portions of north-facing slopes. Thus the micro-climatic variations due to slope aspect and position are reflected by corresponding variations in tree layer vegetation.

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Appencix B: Data for tree layer stems

Tree Number[1]	Species	Tree diameter, mm	Tree height, m	Spray damage[2]	Sprouting[3]	Plot number	Downslope compass direction	Number of plots from stream[4]	Number of plots from prairie[4]	Degrees of slope	Percent grass cover	Percent rock cover	Relative elevation[5]
1	*Ulmus Americana*	183	4	3	4	1	135	13	0	25	75	25	3
	Ground layer only					2	135	12	0	25	95	5	4
	Ground layer only					3	135	11	0	25	95	50	5
	Ground layer only					4	135	10	1	25	25	25	6

[1]Letters refer to stems from the same root system.

[2]1 = 0% damage
2 = 5% to 25% damage
3 = 25% to 75% damage
4 = 75% to 95% damage
5 = 100% damage to tree

[3]Sprouting in 1977:
1 = From ends of branches
2 = From sides of branches
3 = From main trunk only
4 = From root system only

[4]Plots are five meters in length

[5]Number of 5-meter-long plots below the top plot of the uppermost transect.

Tree number[1]		Tree diameter, mm	Tree height, m	Spray damage[2]	Sprouting[3]	Plot number	Compass direction	Distance from stream[4]	Distance from prairie[4]	Degrees of slope	Percent grass cover	Percent rock cover	Relative elevation[5]
2	Quercus muhlenbergii	122	4	2	2	5	135	9	2	25	5	5	7
3	Quercus muhlenbergii	101	4	4	3	6	135	8	3	30	5	25	8
4	Ulmus americana	178	4	2	3								
5	Quercus muhlenbergii	110	4	3	3	7	135	7	4	30	25	5	9
6	Quercus muhlenbergii	152	4	3	3	8	135	6	5	30	5	50	10
7	Quercus muhlenbergii	153	4	4	2								
8	Quercus muhlenbergii	113	4	5		9	135	5	6	35	5	50	11
9	Quercus muhlenbergii	100	4	3	3								
10	Quercus muhlenbergii	102	4	5									
11	Quercus muhlenbergii	118	4	5		10	135	4	7	30	5	25	12
12	Quercus muhlenbergii	114	4	5									
13a	Quercus muhlenbergii	138	5	5									
13b	Quercus muhlenbergii	163	5	5									
14a	Quercus muhlenbergii	131	5	5		11	135	3	8	25	0	5	13
14b	Quercus muhlenbergii	156	5	5									
15	Quercus muhlenbergii	172	6	5									
16	Quercus muhlenbergii	129	5	5		12	135	2	9	30	5	25	14
17	Quercus muhlenbergii	166	5	3	3								
18	Quercus muhlenbergii	183	6	5		13	135	1	10	30	0	50	15
19	Quercus muhlenbergii	189	6	2	2								
20	Quercus muhlenbergii	132	5	5		14	135	0	11	20	5	75	16
21	Quercus muhlenbergii	188	6	2	2	15	315	1	12	35	5	50	16
22	Quercus muhlenbergii	155	6	5									
23	Quercus muhlenbergii	147	4	4	2	16	315	2	11	30	5	50	15
	Ground layer only					17	315	3	10	25	5	5	14

Tree number[1]	Species	Tree diameter, mm	Tree height, m	Spray damage[2]	Sprouting[3]	Plot number	Compass direction	Distance from stream[4]	Distance from prairie[4]	Degrees of slope	Percent grass cover	Percent rock cover	Relative elevation[5]
24	*Quercus muhlenbergii*	192	8	5		18	315	4	9	25	5	5	13
25	*Quercus muhlenbergii*	199	8	5									
26	*Ulmus americana*	288	5	4	3								
27	*Ulmus americana*	203	6	2	2								
28	*Quercus muhlenbergii*	211	8	5		19	315	5	8	20	5	5	12
29	*Quercus muhlenbergii*	212	8	2	4								
30	*Quercus muhlenbergii*	204	6	5		20	315	6	7	25	5	25	11
31	*Quercus muhlenbergii*	201	8	5									
32	*Quercus muhlenbergii*	168	6	5									
33	*Quercus muhlenbergii*	200	8	5									
34	*Cercis canadensis*	123	3	4	3	21	315	7	6	30	0	50	10
35	*Quercus muhlenbergii*	181	5	3	3								
36	*Quercus muhlenbergii*	145	5	2	2								
37	*Quercus muhlenbergii*	162	5	5	4	22	315	8	5	20	5	5	9
38	*Quercus muhlenbergii*	181	5	5									
39	*Quercus muhlenbergii*	150	5	5									
40	*Quercus muhlenbergii*	217	6	5									
41a	*Quercus muhlenbergii*	149	5	5		23	315	9	4	20	5	25	8
41b	*Quercus muhlenbergii*	116	5	5									
42	*Quercus muhlenbergii*	247	6	4	2	24	315	10	3	25	5	25	7
43	*Quercus muhlenbergii*	136	5	5									
44	*Cercis canadensis*	121	5	4	4								
45	*Cercis canadensis*	125	5	5	4	25	315	11	2	20	5	25	6
46	*Cercis canadensis*	219	6	5	4								
47	*Quercus muhlenbergii*	119	5	3	4								
48a	*Quercus muhlenbergii*	129	4	5		26	315	12	1	25	5	25	5
48b	*Quercus muhlenbergii*	131	4	5									
49	*Cercis canadensis*	134	4	3	3								
50	*Quercus muhlenbergii*	113	5	3	4								
	Ground layer only					27	315	13	0	25	95	25	4

Tree number[1]	Species	Tree diameter, mm	Tree height, m	Spray damage[2]	Sprouting[3]	Plot number	Compass direction	Distance from stream[4]	Distance from prairie[4]	Degrees of slope	Percent grass cover	Percent rock cover	Relative elevation[5]
	Ground layer only					28	315	14	0	25	100	5	3
	Ground layer only					29	315	15	0	20	95	25	2
51	*Quercus muhlenbergii*	182	3	2	2	30	315	16	0	10	75	5	1
	No woody vegetation					31	170	7	0	15	100	50	3
	No woody vegetation					32	170	6	0	15	100	25	4
	Ground and shrub layers only					33	170	5	1	15	50	25	5
	Ground and shrub layers only					34	170	4	2	15	25	5	6
52	*Quercus muhlenbergii*	108	5	3	3	35	170	3	3	15	5	5	7
53a	*Quercus muhlenbergii*	109	5	5									
53b	*Quercus muhlenbergii*	168	5	5									
53c	*Quercus muhlenbergii*	157	5	5									
54	*Quercus muhlenbergii*	111	5	5		36	170	2	4	15	5	50	8
55	*Quercus muhlenbergii*	139	6	2	3								
56a	*Quercus muhlenbergii*	127	6	2	3								
56b	*Quercus muhlenbergii*	131	6	2	2								
57a	*Quercus muhlenbergii*	117	6	5									
57b	*Quercus muhlenbergii*	125	6	5									
57c	*Quercus muhlenbergii*	134	6	5									
58a	*Quercus muhlenbergii*	118	6	2	2	37	170	1	5	20	5	75	9
58b	*Quercus muhlenbergii*	134	5	2	2								
59	*Quercus muhlenbergii*	132	6	5									
60a	*Quercus muhlenbergii*	105	6	2	3								
60b	*Quercus muhlenbergii*	111	6	2	3								
60c	*Quercus muhlenbergii*	111	6	2	3								
61	*Cercis canadensis*	132	6	2	3	38	170	0	6	5	5	75	10
62a	*Quercus muhlenbergii*	120	6	2	3								
62b	*Quercus muhlenbergii*	107	6	2	3								

Tree number[1]	Species	Tree diameter, mm	Tree height, m	Spray damage[2]	Sprouting[3]	Plot number	Compass direction	Distance from stream[4]	Distance from prairie[4]	Degrees of slope	Percent grass cover	Rereent rock cover	Relative elevation[5]
63a	*Quercus macrocarpa*	162	8	3	3	39	350	1	7	15	5	50	10
63b	*Quercus macrocarpa*	203	6	3	3								
63c	*Quercus macrocarpa*	178	6	2	3								
63d	*Quercus macrocarpa*	102	5	2	3								
63e	*Quercus macrocarpa*	109	5	2	3								
64	*Quercus macrocarpa*	209	8	2	3								
65a	*Quercus macrocarpa*	174	6	3	3								
65b	*Quercus macrocarpa*	139	6	2	3								
66a	*Quercus muhlenbergii*	110	6	5	4	40	350	2	5	10	25	5	9
66b	*Quercus muhlenbergii*	118	6	5	4								
67a	*Quercus macrocarpa*	133	6	2	3								
67b	*Quercus macrocarpa*	102	6	2	3								
68	*Quercus macrocarpa*	151	8	2	3								
69a	*Quercus muhlenbergii*	150	6	5		41	350	3	4	15	5	5	8
69b	*Quercus muhlenbergii*	158	6	5									
69c	*Quercus muhlenbergii*	132	6	5									
69d	*Quercus muhlenbergii*	137	6	5									
69e	*Quercus muhlenbergii*	133	6	5									
70a	*Quercus macrocarpa*	139	6	2	4								
70b	*Quercus macrocarpa*	148	6	2	4								
71a	*Quercus macrocarpa*	197	6	2	3	42	350	4	3	15	5	5	7
71b	*Quercus macrocarpa*	161	6	2	3								
71c	*Quercus macrocarpa*	119	5	3	3								
72a	*Quercus macrocarpa*	130	6	2	3								
72b	*Quercus macrocarpa*	191	5	2	3								
73	*Quercus muhlenbergii*	104	6	3	3								
	Ground and shrub layer only					43	350	5	2	15	50	5	6
	Ground and shrub layer only					44	350	6	1	15	50	5	5
	Ground layer only					45	350	7	1	15	75	5	4
	Ground layer only					46	350	8	0	10	75	5	3
	Ground layer only					47	350	9	0	10	95	25	2

Tree number[1]	Species	Tree diameter, mm	Tree height, m	Spray damage[2]	Sprouting[3]	Plot number	Compass direction	Distance from stream[4]	Distance from prairie[4]	Degrees of slope	Percent grass cover	Percent rock cover	Relative elevation[5]
	Ground layer only					48	165	20	0	20	75	25	25
74a	*Quercus muhlenbergii*	128	4	3	3	49	165	19	1	20	50	25	27
74b	*Quercus muhlenbergii*	134	4	3	3								
75a	*Quercus muhlenbergii*	118	4	2	2	50	165	18	2	15	5	5	29
75b	*Quercus muhlenbergii*	108	4	3	2								
76	*Quercus muhlenbergii*	126	5	2	2								
77	*Quercus muhlenbergii*	106	4	2	2								
	Ground and shrub layers only					51	165	17	3	15	25	5	31
	Ground and shrub layers only					52	165	16	4	15	5	5	33
	Ground layer only					53	165	15	5	10	95	5	35
78	*Quercus muhlenbergii*	114	4	3	3	54	165	14	6	10	50	25	37
79a	*Quercus muhlenbergii*	105	4	5		55	165	13	7	10	75	25	39
79b	*Quercus muhlenbergii*	119	4	5									
80	*Quercus muhlenbergii*	128	4	4	3								
81a	*Quercus muhlenbergii*	113	4	2	2	56	165	12	8	20	50	25	40
81b	*Quercus muhlenbergii*	109	4	2	2								
81c	*Quercus muhlenbergii*	103	4	2	2								
82a	*Quercus muhlenbergii*	133	4	5		57	165	11	9	20	75	25	41
82b	*Quercus muhlenbergii*	130	4	5									
83	*Quercus muhlenbergii*	110	3	5									
	Ground layer only					58	165	10	10	20	25	25	42
	Ground layer only					59	165	9	11	20	95	25	43
	Ground and shrub layers only					60	165	8	12	15	75	5	44
	Ground layer only					61	165	7	13	20	50	25	45

Tree number[1]	Species	Tree diameter, mm	Tree height, m	Spray damage[2]	Sprouting[3]	Plot number	Compass direction	Distance from stream[4]	Distance from prairie[4]	Degrees of slope	Percent grass cover	Percent rock cover	Relative elevation[5]
	Ground and shrub layers only					62	165	6	14	25	25	50	46
84a	*Quercus muhlenbergii*	144	6	3	3	63	165	5	15	35	50	25	47
84b	*Quercus muhlenbergii*	165	6	3	3								
85	*Quercus muhlenbergii*	149	5	5									
86	*Quercus muhlenbergii*	160	5	5									
87	*Quercus muhlenbergii*	157	4	5		64	165	4	16	30	5	25	48
88a	*Quercus muhlenbergii*	164	6	2	2								
88b	*Quercus muhlenbergii*	152	3	2	4								
89	*Quercus muhlenbergii*	117	5	5									
90a	*Quercus muhlenbergii*	199	7	5									
90b	*Quercus muhlenbergii*	254	7	5									
91	*Quercus muhlenbergii*	100	4	5	4								
92	*Quercus muhlenbergii*	102	4	5		65	165	3	17	15	0	5	49
93	*Quercus muhlenbergii*	117	5	5									
94a	*Quercus muhlenbergii*	103	4	3	4	66	165	2	18	8	5	5	50
94b	*Quercus muhlenbergii*	150	4	3	4								
95a	*Quercus muhlenbergii*	117	4	5									
95b	*Quercus muhlenbergii*	158	5	5									
96	*Quercus muhlenbergii*	203	8	5		67	165	1	19	40	5	50	51
97a	*Quercus muhlenbergii*	206	6	5									
97b	*Quercus muhlenbergii*	199	5	5									
98	*Ulmus americana*	111	6	5									
99a	*Quercus muhlenbergii*	291	7	2	3								
99b	*Quercus muhlenbergii*	224	3	5									
	Ground layer only					68	165	0	20	0	0	95	52
	No woody vegetation.					69	345	32	0	15	100	25	20
	Ground and shrub layers only					70	345	31	1	10	50	5	21
	Ground and shrub layers only					71	345	30	2	5	5	5	22
	Ground and shrub layers only					72	345	29	3	5	0	0	23

Tree number[1]	Species	Tree diameter, mm	Tree height, m	Spray damage[2]	Sprouting[3]	Plot number	Compass direction	Distance from stream[4]	Distance from prairie[4]	Degrees of slope	Percent grass cover	Percent rock cover	Relative elevation[5]
100	*Quercus muhlenbergii*	111	4	2	2	73	345	28	4	5	5	0	24
101	*Quercus muhlenbergii*	100	3	2	2								
102	*Quercus muhlenbergii*	153	4	3	2								
103	*Quercus muhlenbergii*	179	4	3	2								
104	*Quercus muhlenbergii*	132	3	4	3								
105	*Quercus muhlenbergii*	125	3	4	3								
	Ground and shrub layers only					74	345	27	4	5	5	0	25
106	*Quercus muhlenbergii*	114	3	5		75	345	26	3	5	25	0	26
107a	*Quercus muhlenbergii*	114	4	3	2								
107b	*Quercus muhlenbergii*	178	4	3	2								
107c	*Quercus muhlenbergii*	188	4	3	2								
107d	*Quercus muhlenbergii*	218	4	3	2								
	Ground and shrub layers only					76	345	25	2	5	50	0	27
	Shrub layer only					77	345	24	1	5	75	0	28
	No woody vegetation					78	345	23	0	5	100	0	29
	No woody vegetation					79	345	22	0	5	100	0	30
	Ground and shrub layers only					80	345	21	0	5	100	0	31
108	*Quercus muhlenbergii*	129	4	3	2	81	345	20	1	5	75	5	32
109a	*Quercus muhlenbergii*	140	4	3	2								
109b	*Quercus muhlenbergii*	159	4	3	2								
110	*Quercus muhlenbergii*	100	4	2	2								
	Ground and shrub layer only					82	345	19	2	5	25	0	33
111a	*Quercus muhlenbergii*	133	5	2	2	83	345	18	3	5	50	0	34
111b	*Quercus muhlenbergii*	123	4	2	2								
111c	*Quercus muhlenbergii*	113	4	2	2								
112	*Quercus muhlenbergii*	137	4	2	2								
113	*Quercus muhlenbergii*	101	3	2	2								

Tree number[1]	Species	Tree diameter, mm	Tree height, m	Spray damage[2]	Sprouting[3]	Plot number	Compass direction	Distance from stream[4]	Distance from prairie[4]	Degrees of slope	Percent grass cover	Percent rock cover	Relative elevation[5]
114	*Quercus muhlenbergii*	103	4	5	4	84	345	17	4	5	25	0	35
115	*Quercus muhlenbergii*	109	4	4	4								
116	*Quercus macrocarpa*	219	6	2	3	85	345	16	5	5	25	0	36
117	*Quercus muhlenbergii*	126	4	2	3								
118a	*Quercus muhlenbergii*	121	4	2	4								
118b	*Quercus muhlenbergii*	129	4	2	4								
	Ground and shrub layers only					86	345	15	6	5	5	0	37
119a	*Quercus muhlenbergii*	124	4	2	2	87	345	14	7	5	5	75	38
119b	*Quercus muhlenbergii*	112	4	2	3								
	Ground and shrub layers only					88	345	13	8	20	5	50	39
120a	*Cercis canadensis*	102	4	4	3	89	345	12	9	20	5	75	40
120b	*Cercis canadensis*	104	4	2	3								
	Ground and shrub layers only					90	345	11	10	20	5	25	41
	Ground and shrub layers only					91	345	10	11	20	5	50	42
	Ground and shrub layers only					92	345	9	12	20	5	25	43
	Gound and shrub layers only					93	345	8	13	20	50	5	44
121a	*Quercus muhlenbergii*	234	6	5		95	345	7	14	20	5	25	45
121b	*Quercus muhlenbergii*	231	6	5									
121c	*Quercus muhlenbergii*	178	6	5									
122	*Ostrya virginiana*	106	6	5		95	345	6	15	25	5	50	46
123	*Ostrya virginiana*	101	6	5									
124	*Quercus macrocarpa*	186	7	5									
125a	*Ostrya virginiana*	106	6	5		96	345	5	16	30	25	50	47
125b	*Ostrya virginiana*	131	6	5									
125c	*Ostrya virginiana*	128	6	5									
126	*Quercus muhlenbergii*	152	7	5									
127	*Quercus muhlenbergii*	192	6	5									

Tree number[1]	Species	Tree diameter, mm	Tree height, m	Spray damage[2]	Sprouting[3]	Plot number	Compass direction	Distance from stream[4]	Distance from prairie[4]	Degrees of slope	Percent grass cover	Percent rock cover	Relative elevation[5]
128	*Ostrya virginiana*	103	4	3	4								
129	*Ostrya virginiana*	113	5	2	4								
130	*Ostrya virginiana*	101	4	4	4								
131a	*Quercus muhlenbergii*	248	8	3	3	97	345	4	17	25	5	25	48
131b	*Quercus muhlenbergii*	222	8	3	3								
132	*Quercus muhlenbergii*	175	7	3	3								
133a	*Quercus muhlenbergii*	170	8	2	2	98	345	3	18	20	25	5	49
133b	*Quercus muhlenbergii*	147	8	2	2								
134	*Quercus muhlenbergii*	182	8	2	2								
135	*Quercus macrocarpa*	189	7	2	3	99	345	2	19	15	25	5	50
136	*Quercus muhlenbergii*	122	6	2	2								
137	*Quercus muhlenbergii*	100	6	5									
138	*Quercus macrocarpa*	342	10	2	3	100	345	1	20	20	5	5	51
139	*Quercus macrocarpa*	257	10	1									
140	*Quercus muhlenbergii*	215	8	5									
141	*Quercus muhlenbergii*	198	8	4	2								
142	*Quercus macrocarpa*	246	8	2	2								
143	*Ulmus americana*	522	12	5									
	Ground layer only					101	210	6	0	15	75	25	38
144	*Quercus muhlenbergii*	288	3	5		102	210	5	1	5	5	95	39
145a	*Quercus muhlenbergii*	199	4	4	2								
145b	*Quercus muhlenbergii*	161	4	3	2								
146a	*Quercus muhlenbergii*	181	4	2	2								
146b	*Quercus muhlenbergii*	188	4	2	2								
147	*Cercis canadensis*	128	5	4	2	103	210	4	2	25	5	25	40
148a	*Quercus muhlenbergii*	186	5	2	2								
148b	*Quercus muhlenbergii*	147	4	5									
148c	*Quercus muhlenbergii*	159	5	2	2								
149	*Quercus muhlenbergii*	142	5	3	3								
150	*Quercus muhlenbergii*	204	8	5		104	210	3	3	25	0	50	41
151	*Quercus muhlenbergii*	193	7	5									
152	*Cercis canadensis*	123	7	2	4								

Tree diameter[1]		Tree diameter, mm	Tree height, m	Spray damage[2]	Sprouting[3]	Plot number	Compass direction	Distance from stream[4]	Distance from prairie[4]	Degrees of slope	Percent grass cover	Percent rock cover	Relative elevation[5]
153	Quercus muhlenbergii	123	7	3	3	105	210	2	4	10	5	5	42
154	Quercus muhlenbergii	258	7	5									
155	Quercus macrocarpa	378	10	3	3	106	210	1	5	8	5	0	43
156	Quercus macrocarpa	322	10	5									
	Ground and shrub layers only					107	210	0	6	2	5	50	44
157	Quercus macrocarpa	153	8	2	3	108	30	1	7	15	5	0	44
158	Quercus macrocarpa	175	8	2	2								
159	Quercus macrocarpa	399	10	2	3								
160a	Quercus macrocarpa	102	5	2	2	109	30	2	6	15	5	25	43
160b	Quercus macrocarpa	466	12	2	3								
161a	Quercus macrocarpa?	226	10	5	4	110	30	3	5	20	5	50	42
161b	Quercus muhlenbergii?	162											
162	Quercus muhlenbergii	141	8	5	4								
163	Quercus muhlenbergii	158	8	3	3	111	30	4	4	25	0	50	41
164	Cercis canadensis	100	6	3	3	112	30	5	3	25	5	50	40
165a	Quercus muhlenbergii	171	6	3	3								
165b	Quercus muhlenbergii	139	6	5									
165c	Quercus muhlenbergii	138	6	5									
166	Juglans nigra	329	10	3	3								
167	Quercus muhlenbergii	287	7	2	2	113	30	6	2	10	5	50	39
168	Quercus muhlenbergii	136	5	3	4								
169	Quercus muhlenbergii	134	6	4	4								
170a	Quercus muhlenbergii	125	4	5		114	30	7	1	30	5	50	37
170b	Quercus muhlenbergii	127	4	5									
171	Quercus muhlenbergii	126	4	5									
172	Quercus muhlenbergii	113	4	2	2								
173a	Quercus muhlenbergii	165	5	2	3								
173b	Quercus muhlenbergii	161	6	3	3								
173c	Quercus muhlenbergii	149	5	3	3								
	Ground layer only					115	30	8	0	30	5	95	35

THE EFFECT OF SLOPE ASPECT AND POSITION ON THE COMPOSITION AND SIZE OF WOODY VEGETATION IN THE KANSAS TALL-GRASS PRAIRIE

by

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B.G.S., Kansas University, 1976

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Division of Biology

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1980

Abstract

Line transects were used to evaluate the canopy layer of woody vegetation on north- and south-facing slopes of several ravines in the Flint Hills near Manhattan, Kansas. Three tree layer species, *Cercis canadensis*, *Quercus muhlenbergii* and *Ulmus americana*, were found throughout the ravines. Three additional species, *Juglans nigra*, *Ostrya virginiana*, and *Quercus macrocarpa*, were largely restricted to the lower 30 meters of the north-facing slopes, thus increasing species numbers for that portion of the transects. Species numbers were greater at a moister site near Lawrence, Kansas (11) than at the Manhattan site (6). The dominant species, *Q. muhlenbergii*, was tallest on lower portions of north-facing slopes. For corresponding slope positions, a linear model gave stem heights 1.26 meters taller for north-facing than for south-facing plots, with a maximum height of 7.22 meters at the stream. The tallest recorded average height per plot was 9.0 meters and was 15 meters up a north-facing slope. Tree layer individuals extended 35% further up the north-facing slopes than the south-facing slopes. Variations in water availability inherent to slope aspect and position are held to be the primary cause of these vegetational patterns.