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MICROCLIMATIC AND SOIL DIFFERENCES BETWEEN HILL PRAIRIES AND ADJACENT FORESTS IN EAST-CENTRAL ILLINOIS

John T. Reeves[1], U. Douglas Zimmerman, and John E. Ebinger

Department of Botany, Eastern Illinois University
Charleston, Illinois 61920

Abstract: -- The vascular flora and several soil and climatic factors were studied on three hill prairies in Coles County, Illinois. These studies indicate that the environment of the hill prairies is more xeric than the surrounding forest. The climatic variables of wind velocity, evaporation, relative humidity, light intensity, and air temperature on the prairie and in the forest were significantly different as were soil temperature and moisture. A total of 50 taxa were found on the hill prairies with Schizachyrium scoparium or Sorghastrum nutans dominating and accounting for nearly all of the basal cover.

INTRODUCTION

Most of the tall grass prairie of Illinois as described by Sampson (1921) and Transeau (1935) have been destroyed. Hill prairies, in contrast, have been relatively undisturbed. These prairies are grassland openings in the midst of a forest and are usually on a south or southwest facing slope. Other site characteristics are steep slopes with unstable soil conditions (Costello, 1931), small size, usually a few acres or less (Hanson, 1922), and very little disturbance (Evers, 1955).

In the present study three hill prairies located in Coles County, Illinois were examined during the growing season of 1976. These include the 1/3 acre Lakeview Prairie located in Lakeview Park southeast of Charleston, Illinois (Sect. 12, T12N, R9E), the 1/4 acre Five-Mile Prairie located 5 miles south of Charleston (Sect. 1, T11N, R9E), and the 1/4 acre Waterworks Prairie at the east edge of Charleston (Sect. 13, T12N, R9E). The objectives of the study were to document climatic and soil factors responsible for hill prairie maintenance, and to determine their floristic composition.

MATERIALS AND METHODS

Wind velocity, evaporation, relative humidity, light intensity, and air and soil temperature were monitored on bright, sunny days near the

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1. Current address: Department of Botany and Plant Pathology, Purdue University, West Lafayette, Indiana.

beginning of each month from April through October, excluding May. These data were collected from two stations, one located on the Waterworks Prairie and the other in an adjacent forest area. Evaporation was determined with Livingston white bulb atmometers (Livingston, 1935), and air temperature was measured with a probe thermometer that was shielded from direct sunlight. The above data were collected 14 cm above the soil surface at each station every hour. Light intensity was determined with a Western Illumination Meter (Model 756) equipped with a quartz filter. Wind velocity was measured with a three-cup anemometer (No. 1439, C. F. Casella & Co.,LTD), mounted on a portable platform 1 m above the ground. Readings were taken approximately one-half hour every hour. Relative humidity was determined with a hand-asperated psychrometer (Daubenmire, 1974) every hour during the day.

Soil temperatures were measured during the afternoon with a Western Mirroband thermometer at a depth of 13.5 cm. Soil texture data were obtained for the forests and prairies at all three study sites. Six 30 cm soil cores were taken at each sampling site, two from the top of the slope, two from mid-slope, and two from near the bottom. The cores were mixed and texture determined by the Bouyoucos (1962) method, and Buckman and Brady (1960) was used for soil nomenclature. Soil moisture data were determined for the hill prairies and forests from four 30 cm cores collected from mid-slope each month from February through October. The cores were divided into three sections, 0-10 cm, 10-20 cm, and 20-30 cm. The four cores obtained for each depth were combined and soil moisture determined gravimetrically (Cape and Trickett, 1965).

All climate and soil data, with the exception of soil texture were analyzed with programs written by the ULCA Health Science Computing facility. Soil moisture data were analyzed with the BMD08V program (multiple way analysis of variance). All other environmental parameters were analyzed with the BMD02V program (analysis of variance for factorial design). Significance throughout the paper denotes statistical significance at the .05 confidence level.

Vegetation data were collected on the Five-Mile Prairie and the Waterworks Prairie using the line-intercept technique (Canfield, 1941). Samples for each area consisted of two randomly located lines positioned across the contours of the slope. From the data obtained the percent cover and the Importance Value (IV) for each species was determined. As used here, the IV is the sum of the relative density and relative dominance (Phillips, 1959). A species list was compiled for all three prairies by making collections every two weeks during the growing season. Nomenclature follows Mohlenbrock (1975) and the specimens are deposited in the Stover Herbarium of Eastern Illinois University (EIU).

RESULTS

Microclimate: The average light intensity differed significantly between forest and prairie during the growing season (Fig. 1). The light intensity on the prairie varied little, and averaged 6.3 X 10^4 lux during the study. Light intensity in the forest, in contrast, was much lower and more variable, averaging 1.6 X 10^4 lux. There was less differences between prairie and forest in April and October when the forest canopy

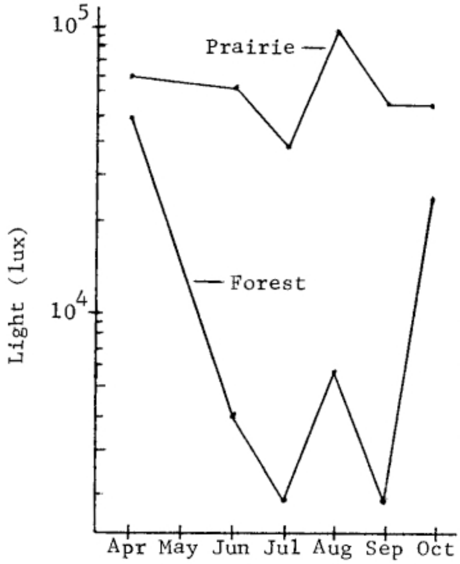

Fig. 1. Average daily light intensity during the growing season at the Waterworks sampling stations.

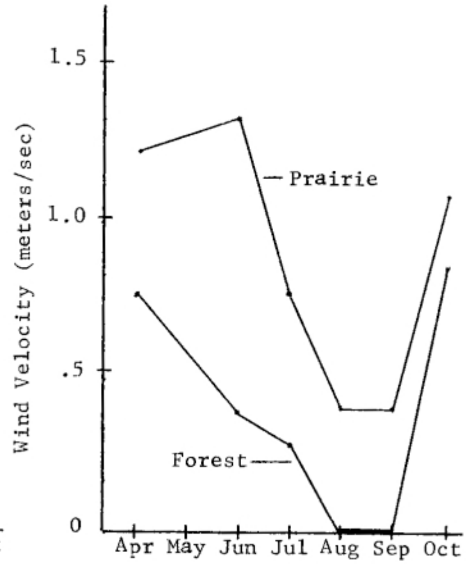

Fig. 2. Average daily wind velocity during the growing season at the Waterworks sampling stations.

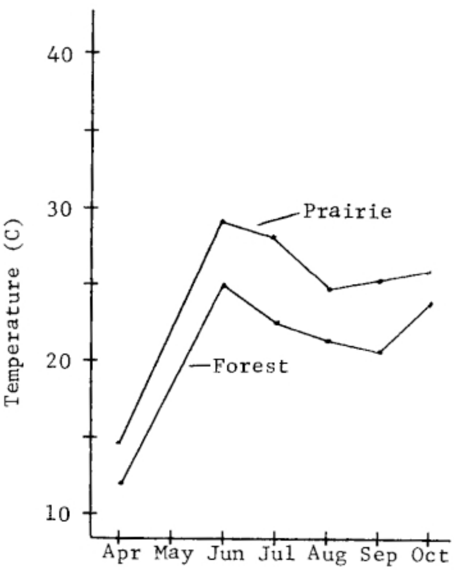

Fig. 3. Average daily air temperature during the growing season at the Waterworks sampling stations.

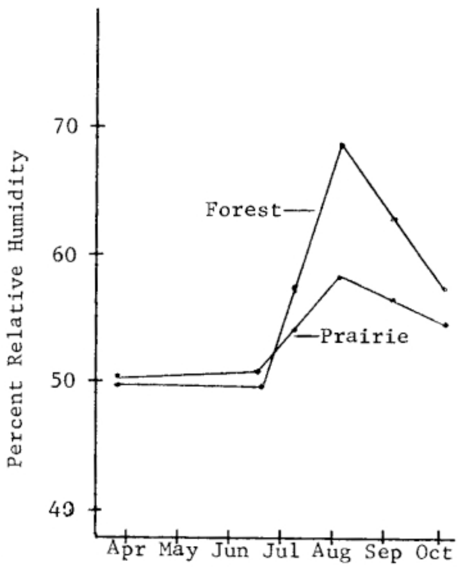

Fig. 4. Average daily relative humidity during the growing season at the Waterworks sampling stations.

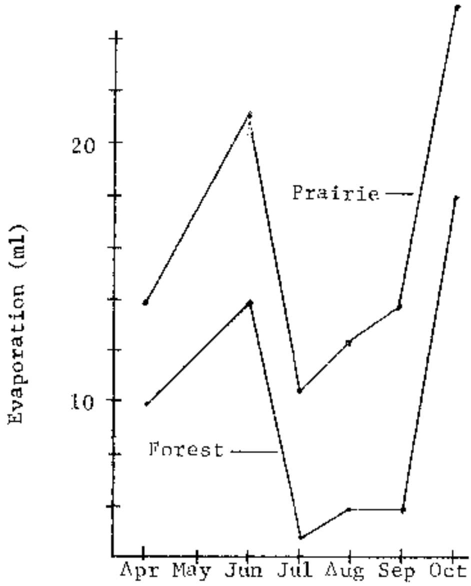

Fig. 5. Average daily evaporation during the growing season at the Waterworks sampling stations.

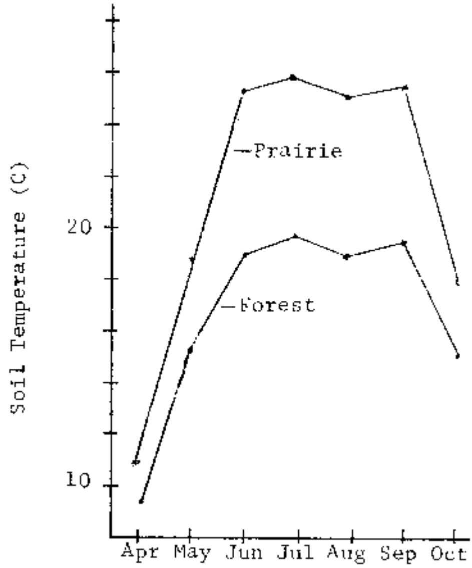

Fig. 6. Average daily soil temperature during the growing season at the Waterworks sampling stations.

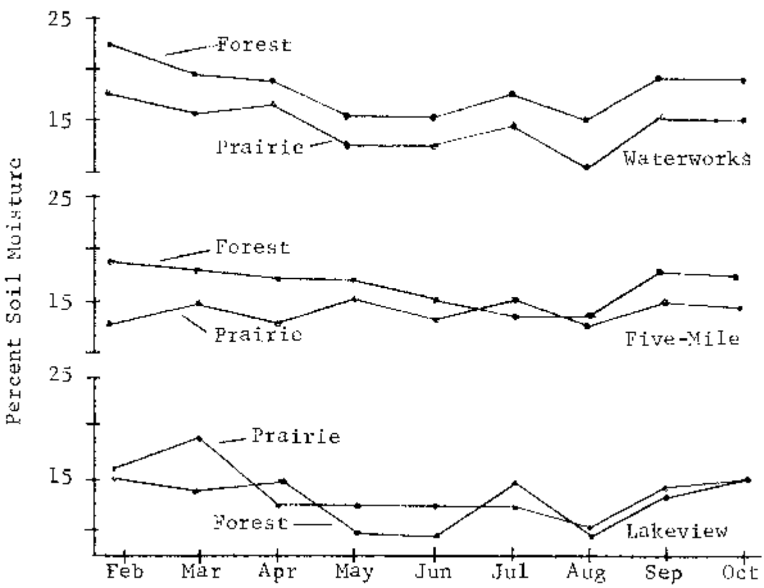

Fig. 7. Average soil moisture for February through October at the Waterworks, Five-Mile, and Lakeview sampling stations.

was more open, but the differences were still significant.

The average daily wind velocity was also significantly different in the prairie and forest throughout the growing season (Fig. 2). The prairie had higher wind velocities, but the forest canopy did not reduce the velocity as much as might be expected. The average wind velocity was 0.85 m/sec on the prairie and 0.39 m/sec in the forest.

The average air temperature also differed significantly between prairie and forest throughout the growing season (Fig. 3). The air temperature in the forest averaged 3.5° cooler than that of the prairie, and the differences were greater when the forest canopy was closed.

The average relative humidity of the prairie and forest did not have the pattern suggested by light and temperature. Differences in relative humidity during April and June were not significantly different (Fig. 4), but during the remaining months the differences were significant. During these four months the relative humidity averaged 53% on the prairie and 57% in the forest.

The total daily evaporation in the prairie and forest differed significantly throughout the growing season (Fig. 5). Although it varied greatly, the prairie had more evaporation (average of 17 ml/day) than the forest (average 10 ml/day). The rate of evaporation appeared to be more closely related to wind velocity (Fig. 2) than any of the other climatic variables.

Soil: Average soil temperature for forest and prairie differed significantly throughout the growing season (Fig. 6). The greatest difference occurred when the canopy was fully developed, however, during April and October when the forest canopy was more open there were still significant temperature differences. The daily average soil temperature was 4° C cooler in the forest, which averaged 16° C while the prairie averaged 20° C.

The Waterworks Prairie and Five-Mile Prairie soils had significantly lower soil moisture percentages than that of the adjacent forest, while the moisture level of the Lakeview Prairie soil was approximately the same as that of the forest (Fig. 7; Table 1). This anomaly can be explained when soil moisture (Table 1), and soil texture (Table 2) are compared. The Waterworks and Five-Mile Prairies and adjacent forests have soils of similar textures. The Lakeview Prairie, in contrast, has a loam soil, while the soil of the adjacent forest has less clay, more sand, and consequently lower water holding capacity.

Vegetation: The results of the quantitative analysis of the Waterworks and Five-Mile Prairies shows that each prairie has one dominant grass species (Table 3). On Five-Mile Prairie the dominant grass is little bluestem (Schizachyrium scoparium) with an IV of 156 and a basal cover of 30.2%, while on the Waterworks Prairie indian grass (Sorghastrum nutans) dominates with an IV of 143 and a basal cover of 21.2%. An important aspect indicated by the low cover values, besides the dominance of one grass species, is the large amount of bare soil (about 70%). This is probably the result of the steep slope, the heavy erosion, and the low soil moisture which tends to favor grasses.

Table 1. Average monthly soil moisture percentages for prairie and forest at each sampling location.

	WATERWORKS		FIVE-MILE		LAKEVIEW	
	Prairie	Forest	Prairie	Forest	Prairie	Forest
February	17.4	21.4	13.3	18.2	16.8	16.5
March	15.7	19.0	14.1	17.1	18.5	14.4
April	16.1	18.6	13.0	15.3	13.9	15.1
May	12.8	15.0	13.3	14.9	13.0	10.9
June	12.6	15.6	11.9	13.8	13.1	9.4
July	14.7	18.4	14.2	13.1	13.3	15.8
August	10.7	14.2	11.5	12.8	10.0	9.8
September	16.3	20.1	15.0	16.2	14.7	14.0
October	16.3	19.9	14.5	16.6	16.4	16.3
Average	14.7	18.0	13.3	15.3	14.4	13.6

Table 2. Soil particle size percentages and soil texture names for the prairie and forest soils at each sampling location.

Particle Size	WATERWORKS		FIVE-MILE		LAKEVIEW	
	Prairie	Forest	Prairie	Forest	Prairie	Forest
Sand	37	37	42	40	40	52
Silt	40	34	41	40	41	35
Clay	23	29	17	20	19	13
Soil Name	loam	clay loam	loam	loam	loam	sandy loam

Table 3. Relative values and percent basal cover for the dominant species on the Five-Mile and the Waterworks Prairies.

Species	Relative Density	Relative Dominance	Importance Value	% Basal Cover
FIVE-MILE PRAIRIE				
Schizachyrium scoparium	58.3	97.9	156.2	30.2
Monarda bradburiana	10.7	.4	11.1	.1
Solidago nemoralis	8.3	.4	8.7	.1
Brickellia eupatorioides	7.1	.4	7.5	.1
Others	15.6	.9	16.5	.3
Totals	100.0	100.0	200.0	30.8
WATERWORKS PRAIRIE				
Sorghastrum nutans	50.4	93.3	143.7	21.2
Euphorbia corollata	8.8	.8	9.6	.2
Carex muhlenbergii	5.9	2.9	8.8	.7
Silphium terebinthinaceum	6.6	.8	7.4	.2
Others	28.3	2.2	30.5	.4
Totals	100.0	100.0	200.0	22.7

A total of 50 species in 21 families were found on the three hill prairie (Table 4). These include 7 woody species, 5 grasses, and 38 forbs, of which about 1/4 are forest taxa. Of the prairie species, many are found on all three areas. Considerable difference in species composition exists, however, because the total number of taxa on a given area varies from 22 to 28.

Table 4. -- List of plant species found growing on one or more of the hill prairies studied in Coles County, Illinois.

ASCLEPIADACEAE
Asclepias purpurascens L.
Asclepias tuberosa L.
Asclepias verticillata L.
BORAGINACEAE
Lithospermum canescens (Michx.) Lehm.
COMPOSITAE
Antennaria plantaginifolia (L.) Richards.
Aster turbinellus Lindl.
Brickellia eupatorioides (L.) Shinners.
Chrysanthemum leucanthemum L.
Echinacea pallida (Nutt.) Nutt.
Erigeron strigosus Muhl.
Erigeron pulchellus Michx.
Helianthus divaricatus L.
Liatris aspera Michx.
Rudbeckia hirta L.
Silphium terebinthinaceum Jacq.
Solidago nemoralis Ait.
Solidago rigida L.
COMMELINACEAE
Tradescantia virginiana L.
CONVOLVULACEAE
Calystegia spithamaea (L.) Pursh.
CORNACEAE
Cornus florida L.
CYPERACEAE
Carex muhlenbergii Schk.
Carex pensylvanica Lam.
EBENACEAE
Diospyros virginiana L.
EUPHORBIACEAE
Euphorbia corollata L.
FAGACEAE
Quercus muhlenbergii Engelm.
Quercus velutina Lam.
GENTIANACEAE
Sabatia angularis (L.) Pursh.
IRIDACEAE
Sisyrinchium albidum Raf.
LABIATAE
Monarda bradburiana Beck.
Physostegia virginiana (L.) Benth.
Pycnanthemum pilosum Nutt.
LEGUMINOSAE
Cassia fasciculata Michx.
Desmodium rotundifolium DC.
Desmodium sessilifolium (Torr.) T. & G
Lespedeza virginica (L.) Britt.
Melilotus alba Desr.
POACEAE
Andropogon gerardii Vitman.
Elymus canadensis L.
Elymus hystrix L.
Schizachyrium scoparium (Michx.) Nash.
Sorghastrum nutans (L.) Nash.
RHAMNACEAE
Ceanothus americanus L.
ROSACEAE
Potentilla simplex Michx.
Rosa carolina L.
SAXIFRAGACEAE
Hydrangea arborescens L.
SCROPHULARIACEAE
Gerardia flava L.
Penstemon pallidus Small.
UMBELLIFERAE
Taenidia integerrima (L.) Drude.
Thaspium barbinode (Michx.) Nutt.
VIOLACEAE
Viola sororia Willd.

DISCUSSION

The present study indicates that a more xeric environment exists on the hill prairies than in the surrounding forests. This is primarily due to the rate of evaporation which is a direct response to wind velocity and light conditions on the prairie. The presence of the forest canopy during the growing season is undoubtedly a major factor causing these differences. In addition to the forest canopy the direction of the slope also appears to be an important factor in hill prairie maintenance. All of the prairies studied are situated on steep, south or southwest facing slopes.

Soil moisture and soil temperature differ significantly on the hill prairies and the surrounding forests, and are the result of microclimatic differences and not soil texture. Soil texture on both the forest and prairie areas is very similar (Table 2), and probably not important in creating the xeric conditions. The soil texture data of these hill prairies differs drastically from that of the western hill prairies. Kilburn and Warren (1963) found 78-85% sand in the soil of the western Illinois hill prairies. They believed that this high sand content favored the hill prairies maintenance. The lower amount of sand (37-52%) on the east-central Illinois hill prairies suggests that microclimatic conditions are the most important.

The hill prairies in east-central Illinois and those of western Illinois have similar basal cover values. On two prairies in western Illinois Evers (1955) found basal area or cover values to be 30.04 and 22.37%. The Five-Mile and Waterworks Prairies have values of 30.8 and 22.7% respectively. The Five-Mile Prairie is quite similar to the western hill prairies because it is dominated by little bluestem. The basal cover of 30.2% for little bluestem in this prairie compares closely to the 28.39% found on the Sampson Prairie sampled by Evers (1955) and the six western hill prairies studied by Kilburn and Warren (1963). When compared to the western Illinois hill prairies, however, a considerable difference is found in species composition. Nearly half of the east-central Illinois hill prairie species were absent from the western hill prairies. The number of taxa per unit area, however, corresponds rather well with the findings of Evers (1955) who reported 28 species on the Sampson Prairie and 35 on the Phegley Prairie.

In 1918, Vestal described and mapped a hill prairie located one mile east of the southern part of Charleston, Illinois. This is the same area that is now referred to as the Waterworks Prairie. In 1918 there were 10 different prairie areas located on the slope. Presently three areas exist and it is estimated that the extent of the prairie area has been reduced by at least 1/3 since 1918. This difference, as well as the number of forest species present, indicate that the hill prairies are not maintaining themselves, and will probably give way to forest. These changes are most likely due to slight changes in climate, the lack of fire, and shading by mature trees at the margins of the prairie areas. Another major difference noted between the present study and that of Vestal's (1918) is the change in the dominant grass. Vestal listed the dominant grass as little bluestem with big bluestem only nominally represented. Currently indian grass is the dominant grass and little bluestem is absent on the Waterworks Prairie. This change in dominance may indicate that the prairie has been disturbed (Weaver, 1968).

Though the climatological data indicates a more xeric environment on the hill prairies, the vegetation indicates that the prairie areas are being encroached upon by forest. This encroachment will probably continue at a relatively fast rate, unless the climate becomes dryer, or fire is introduced.

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