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Ecology Of East-Central Illinois Hill Prairies

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John Thomas Reeves

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ECOLOGY OF EAST-CENTRAL ILLINOIS HILL PRAIRIES

BY

JOHN THOMAS REEVES

B.S. in Biology, Southern Illinois University, 1974

ABSTRACT OF A THESIS

Submitted in partial fulfillment of the requirements
for the degree of Master of Science in Botany at the Graduate School
of Eastern Illinois University

CHARLESTON, ILLINOIS
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ABSTRACT

Several environmental factors (light, wind, air temperature, evaporation, relative humidity, soil temperature, soil texture, soil moisture, and soil pH) were monitored along with a quantitative and qualitative vegetation analysis of three East-Central Illinois hill prairies from March through October, 1975. The purpose was to determine which factor or combination of factors is responsible for maintaining hill prairies and to determine if these hill prairies had typical prairie vegetation.

The environment of the hill prairies proved to be more xeric than the surrounding forest. This was primarily attributed to the slopes which face south-southwest with very steep inclines. The south-southwest facing slopes allows the prairies to receive more direct afternoon sunlight and more wind due to the prevailing south-westerly winds which predominate in this area during the summer.

Even though the environmental variables seem to favor the more xeric prairie species, the vegetation data showed considerable encroachment by the forest onto the hill prairie. Thus indicating that the hill prairies are not being maintained.

There was a total of 52 species found on these hill prairies. These included 4 woody species, 7 grasses and 41 forbs. Twelve of these were herbaceous forest species. The dominant grasses were typical of hill prairies. These included *Andropogan scoparius* (Little Bluestem) and *Sorghastrum nutans* (Indian Grass).

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INTRODUCTION

Hill prairies of forest inclusions may be defined as grassland openings in the midst of a forest usually on the south, south-west facing slope. The term hill prairie was first used by Dr. Arthur G. Vestal from the University of Illinois in 1943 (Evers, 1955). Dr. Vestal defined the term as hill prairies on loess bluffs, mounds, steep rocky slopes, slopes of glacial drift or on steep slopes of almost any type (Evers, 1955). Other things that hill prairies have in common are steep slopes with unstable soil conditions (Costello, 1931), small size, usually less than one acre (Hanson, 1921) and they have been little disturbed by man (Evers, 1955).

Most of the tall grass prairies of the prairie peninsula in Illinois as described by Sampson (1921) and Transeau (1935) have been plowed under for agricultural purposes. The hill prairies have been left relatively undisturbed because of their steep slopes and unstable soils, which render them impractical for farming or grazing. Because of their near natural condition, hill prairies are ideal for ecological studies.

The purpose of this study was to quantify several environmental factors (light, wind, air temperature, evaporation, relative humidity, soil temperature, soil texture, soil moisture and soil pH) in an attempt to determine which one or combination of these is/are responsible for maintaining hill prairies and to use vegetation analyses to determine the amount of typical prairie vegetation found on these hill prairies.

HISTORICAL

There are few publications concerning hill prairies and most of these have been performed on loess bluff hill prairies along rivers. Shimek (1910, 1924) as noted by Evers (1955) describes the vegetation on loess bluffs in western Iowa and on the Iowa bluffs of the Mississippi River. Vestal (1918) notes the existence of hill prairies near Charleston, Illinois along the Embarras River. He presents some unproven theories concerning their existence. Hanson (1922) describes hill prairie inclusions in a deciduous forest climax on loess bluffs, along the Missouri River in Nebraska. His evaporation data and soil moisture data showed the hill prairie to be a much more xeric habitat than the surrounding forest. Costello (1931) compared the river bluff succession patterns on the Iowa and Nebraska sides of the Missouri River. The findings of his evaporation study were similar to the results of Hanson's (1922). A study by Vestal (1931) noted the existence of loess bluff hill prairies along the Mississippi River. Vestal and Bartholomew (1941) made a brief description of some loess bluff prairies along the Illinois River. Braun (1950) noted the widespread existence of bluff hill prairies along the Mississippi River in Wisconsin, Minnesota, Iowa and Illinois. A complete vegetation analysis was conducted by Evers

(1955) on several bluff prairies along the Mississippi and Illinois River Valleys. The study extended over the length of the state of Illinois and included 61 hill prairies with a combined area of more than 200 acres. Several methods were used to quantitatively analyze the vegetation and a complete annotated species list was made. A species description of the gravel-hill prairies of the Rock River Valley in Illinois was conducted by Fell and Fell (1956). They also associated several plants found on prairie with the type of soil present. Kilburn and Ford (1963) did a frequency distribution of hill prairie plant species on loess bluffs found along the Illinois River near Grafton, Illinois. The Kilburn and Warren (1963) study lead them to believe that the high sand content of hill prairie soils favors prairie vegetation. In another study on the same prairies, Bland and Kilburn (1966) suggested that there was a correlation between soil texture and vegetation composition.

It is known that prairies inhabit a dryer environment than forest (Odum, 1971). The overall climate for the Embarras River Valley is one that should support a deciduous forest and, with the minor exception of hill prairies, it does. Weaver and Clements (1938) described major vegetation climaxes as being controlled by climate. They believed that the major climate conditions would result in a major vegetation climax. However, Potzger (1939) suggests that Weaver and Clements' (1938) ideas do not account for the various subclimax types of vegetation which may exist as climaxes within the major climax. Potzger (1939) and Cooper (1961) point out that topography may influence the climate to the point that microclimates may exist. These microclimates may be so different from the major climate that they exhibit a different type of vegetation. Many studies have been done illustrating the existence of sub-climax vegetation. These are thought to result from the presence of microclimates (Weaver 1914, Shreve 1931, Potzger 1939, Daubenmire 1943, 1968, Canthon 1953, Johnson and Parker 1954, Mark 1958, Cooper 1961, Morgan and Sylvia 1972, Root and Habeck 1972).

Selection of which physical factors to be studied is a major problem when attempting to explain the long term existence of hill prairies in the midst of deciduous forests. Previous studies have indicated that those factors producing xeric conditions are most important. Daubenmire (1943, 1968) and Root and Habeck (1972) studied grass openings in forests of the Rocky Mountains in the north-western United States. Their data suggests that these grassland openings are maintained because of low soil moisture during the mid-summer which inhibits tree seedling survival. Hanson (1922) also suggested this as a possible reason why the forest cannot invade hill prairies. Soil moisture is effected by several factors including soil texture, soil temperature, air temperature, wind, light, relative humidity and evaporation.

Hanson (1922), Costello (1931) and Evers (1955) pointed out that it is the topography that is responsible for the above factors having a drying effect on the hill prairie soils. All of these hill prairies are located on slopes that face west or south-west and thus receiving more wind (due to the prevailing south-westerly winds) and solar radiation. These prevailing south-westerly winds led Evers (1955) to postulate that these winds are the main factor responsible for hill prairie maintenance. However, Evers (1955) as well as Hanson (1922) and Costello (1931) concluded that no single factor is responsible for the maintenance of hill prairies.

DESCRIPTION OF AREAS

The prairies used in this study were named Lakeview Prairie, Five-Mile Prairie and Water Works Prairie. All of these prairies were located on steep ridges and were a part of the Embarras River drainage system. All of the prairies had a Strawn-Lawson soil association as classified by the USDA in April, 1968. This association is characteristically found on steep slopes. It is a light colored well-drained soil on uplands which is usually adjacent to dark colored poorly-drained soils of the bottomlands.

The Lakeview Prairie is located in Charleston's Lakeview Park on the banks of Lake Charleston, T12N, R9E, Sect. 12. The prairie faces south-west and is on a steep slope. The prairie is about one eighth of an acre in size and has many characteristic prairie species. There did not appear to be a clear cut dominant grass. However, all three major prairie grass species, Little Bluestem (Andropogan scoparius), Big Bluestem (Andropogan gerardi) and Indian Grass Sorghartsum nutans) are well represented. The deciduous forest surrounding the prairie is dominated by White Oak (Quercus alba) on the ridge and Chestnut Oak (Quercus prinus) along the sides and bottom. The understory consists mostly of Dogwoods (Cornus florida) and Ironwoods (Ostrya virginiana). This prairie has been subjected to massive erosion; and as a result of this, it was used only for soil analysis and species composition studies.

The Five-Mile Prairie is located about six miles south-east of Charleston in T11N, R9E, Sect. 1, on a south-west facing slope. This prairie is about one quarter of an acre in size with a small strip of woods dividing it in half. The slope is variable but not nearly as steep as the other two prairies. The dominant grass is Little Bluestem and the prairie is surrounded predominantly by White Oaks on the ridge and Chestnut Oaks along the sides and bottom. The understory consists mostly of Dogwoods and Ironwoods. Because of its uniformity, soil analysis and vegetation analysis were done as well as a species composition.

The Water Works Prairie is located about one quarter of a mile off Route 130, south-east of Charleston near the city limits, T12N, R9E, Sect. 13. The prairie occupies the upper south and south-west facing slope with a small creek at the base of the slope. It is about one third of an acre in size with Indian Grass being the dominant grass. The forest around the prairie consists mainly of Red and White Oak on the upper sides and Chestnut Oaks on the lower sides. The understory consists mainly of Dogwood and Ironwood. Because of its size and uniformity, this prairie was chosen as the location of the weather stations. A soil analysis, vegetation analysis and a plant collection were also done on this prairie.

METHODS AND MATERIALS

Climate Analysis Methods

Five climate variables were monitored; these included: wind, evaporation, relative humidity, light, and air temperature. Data for these climate factors were collected from two stations located on the hill prairie and in the surrounding forest of the Water Works Prairie. The data were collected on bright sunny days preferably at the beginning of each month from April through October with the exception of May. May was omitted because it proved impossible for the author to get into the field. The October data collection day was delayed until the middle of the month due to cloudy-rainy weather. Data for the various climate factors were taken every hour on the hour from 10:00 a.m. to 4:00 p.m.

Analysis of the evaporation on the prairie and in the forest was determined by Livingston Atmometeres that were modified for this experiment. The porous bulb atmometer, as described by Livingston (1935), was modified by using a 100 ml graduated cylinder in place of the large jar or burette and by eliminating the glass equilizer tube. It was found that the small hole between the lip of the graduated cylinder and porous bulb was large enough to allow air passage and yet small enough so that no significant evaporation occurred through it within a 24 hour period. There were two atmometers constructed, one for the forest station and one for the prairie station. Both instruments were standardized in the laboratory for a 24 hour period of time with no significant difference in evaporation found between them. These instruments were mounted in the field on iron rods placed in the ground with the porous bulbs approximately 0.5 m above the soil surface.

Air temperatures were measured by using a standard fahrenheit probe thermometer which was shielded from direct sunlight. These data were collected 14 cm above the soil surface in the hill prairie and surrounding forests. The readings were taken after the thermometer had reached an equilibrium with the air.

Light readings were measured in foot candles by a Western Illumination Meter, Model 756 with quartz filter. The readings were later converted to lux. This instrument was standardized to the international foot candle. In order to minimize the biasing of readings, a standard procedure was employed. The wand was held approximately 1.5 m from the soil surface, directly parallel to the slope and perpendicular to the direction the slope faced. Six replicates were taken and averaged in both areas for each hour.

Wind was measured by a sensitive three-cup anemometer No. 1349 made by the C. F. Casella Co., LTD. The instrument was mounted on a portable platform supported by three expanding aluminum poles. The anemometer platform was approximately one meter from the ground. The instrument measures total meters of wind per unit time. Readings were taken for approximately one-half hour every hour. Calibration charts made for this particular instrument by the C. F. Casella Co. were used to convert these data to meters per second.

Relative humidity readings were taken by using a hand-aspirated psychrometer. The method used was described by Daubenmire (1974). The readings were then converted by relative humidity by using a table prepared by Marvin (1941).

Soil Analysis Methods

Four soil factors were analyzed. These were: soil temperature, soil pH, soil texture, and soil moisture.

Soil temperatures were taken only on the Water Works Prairie and forest. These data were collected on the climate sampling days in the afternoon. A Western Mirroband fahrenheit thermometer Model 2265 was used to take readings. This probe thermometer was placed 13.5 cm into the soil to take the readings. Six replicate readings were taken from six different locations in both the hill prairies and the forests.

Soil pH was analyzed at all three prairie and forest locations in July. Three 15 cm soil cores were taken from both the hill prairies and forests. Each core was analyzed by using a method described by Reed and Cumings (1945). There were two replicate readings made for each soil core.

Soil texture data were obtained for the forests and the hill prairies at all three locations during the month of July. The soil samples were obtained by taking six 30 cm soil cores and mixing them. These cores were taken at different locations within each sampling area; two from the top of the prairie, two from the middle region and two from the lower region. This insured an average soil from each sampling area. The texture analysis was done using a method described by Bouyoucos (1962). A soil texture diagram (Buckman and Brady, 1960) was used to determine soil names.

Soil moisture data were obtained for both hill prairies and forest for each of the three sampling areas. Four 30 cm cores were collected from each area from February through October. The cores were divided into three sections, 0-10 cm, 10-20 cm, 20-30 cm. The four cores were combined according to depths and the weigh-dry and reweigh method of analysis described in a review by Cape and Trickett (1965) was used.

Methods for Vegetation Analysis

Vegetation data were collected on the Five-Mile Prairie and the Water Works Prairie. Importance 200 values were obtained for both prairies by adding relative density and relative dominance values. All of these values were computed using methods described by Phillips (1959). Percent cover based on basal cover was also determined by methods described by Phillips (1959). The data were collected by using the line-intercept technique described by Canfield (1941). A sample for each area was taken by reading two lines. The first line was randomly located and the second was located 8 meters to the right of the first. Both lines ran from the top of the slope to the bottom. Two lines were run because it was determined that the size of the prairies were such that this amount of sampling would constitute an adequate sample.

A species list was compiled for all three hill prairies. Collections were made approximately every two weeks for the entire growing season. The collection was deposited in the Stover Herbarium located in the Life Science Building at Eastern Illinois University.

Statistical Analysis Methods

All climate and soil data, with the exception of soil texture data, were analyzed using an IBM 360 Computer (Model 50) at the Eastern Illinois University Computer Center. The following programs, which were utilized, were written by the UCLA Health Sciences Computing facility.

BMCO2V	Analysis of Variance for Factorial Design (Revised 2/71)
BMDO8V	Multiple Way Analysis of Variance (Revised 2/72)

Soil moisture data were analyzed using the BMDO8V program. Data were tested at the .05 and .01 confidence levels. See Table II for the number and kinds of variables used and the types of interactions between variables obtained from this program.

All the other environmental parameters were analyzed using the BMDO2V program. See Appendix for number and kinds of variables used for each parameter analyzed and the interaction involved.

RESULTS AND DISCUSSION

Climatological Analysis

The data collected in this study cannot be construed to be a definite indication of the climate, because there was only one sampling day per month. However, the sampling days were thought to be typical sunny days for each month involved. Therefore, the differences found between hill prairie and forest are sufficient to suggest several reasons why these hill prairies may be maintaining themselves.

There were significant differences found between the hill prairie and the forest for light, air temperature, soil temperature, relative humidity, wind and evaporation (Table I). These differences between the prairie and forest differed significantly over the six sampling months for all of the above factors except evaporation. Figures 1-6 indicate that the prairie received more light, had higher air temperatures and soil temperatures, received more wind, had a higher evaporation rate and had a lower relative humidity.

Air temperatures, soil temperatures and light data showed greater differences between the hill prairie and forest during the months of June, July, August and September. The forest canopy is the probable cause for these greater differences. The canopy acts as

TABLE I. Summary of analysis of variance for the physical factors (light, air temperature, soil temperature, relative humidity, wind speed, evaporation) showing degree of significance for each variable (Ecosystem, month, time).

	Light	Air Temperature	Soil Temperature	Relative Humidity	Wind Speed	Evaporation
Time[b] (1)	NS[a]	**	No test	**	NS	**
Month (2)	**[a]	*[a]	**	*	**	**
Ecosy (3)	**	**	**	**	**	**
12	NS	NS	No test	NS	NS	NS
13	NS	NS	No test	*	NS	**
23	**	**	**	*	**	NS

[a]Degree of Significance
- NS = Not significant
- * = Significant at .05 level
- ** = Significant at .01 level

[b]Source of Variation
1. Time - Time of day data was taken
2. Month - Time of year data was taken
3. Ecosystem
   - Prairie
   - Forest

12. First Order Interaction - Time with Month
13. First Order Interaction - Time with Ecosystem
23. First Order Interaction - Month with Ecosystem

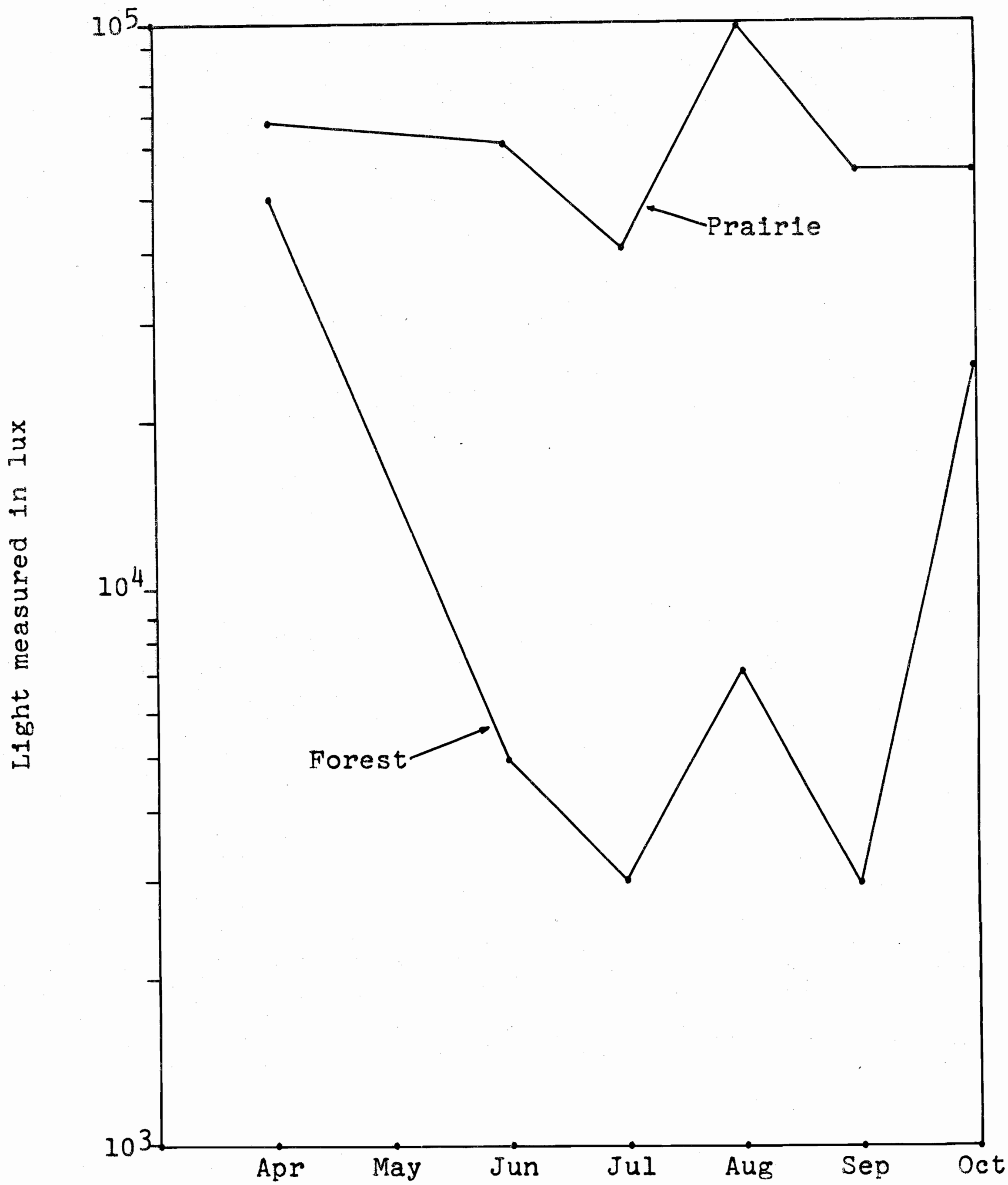

FIG. 1. Average light per day on the sampling day in each month during the growing season at the Water Works sampling station.

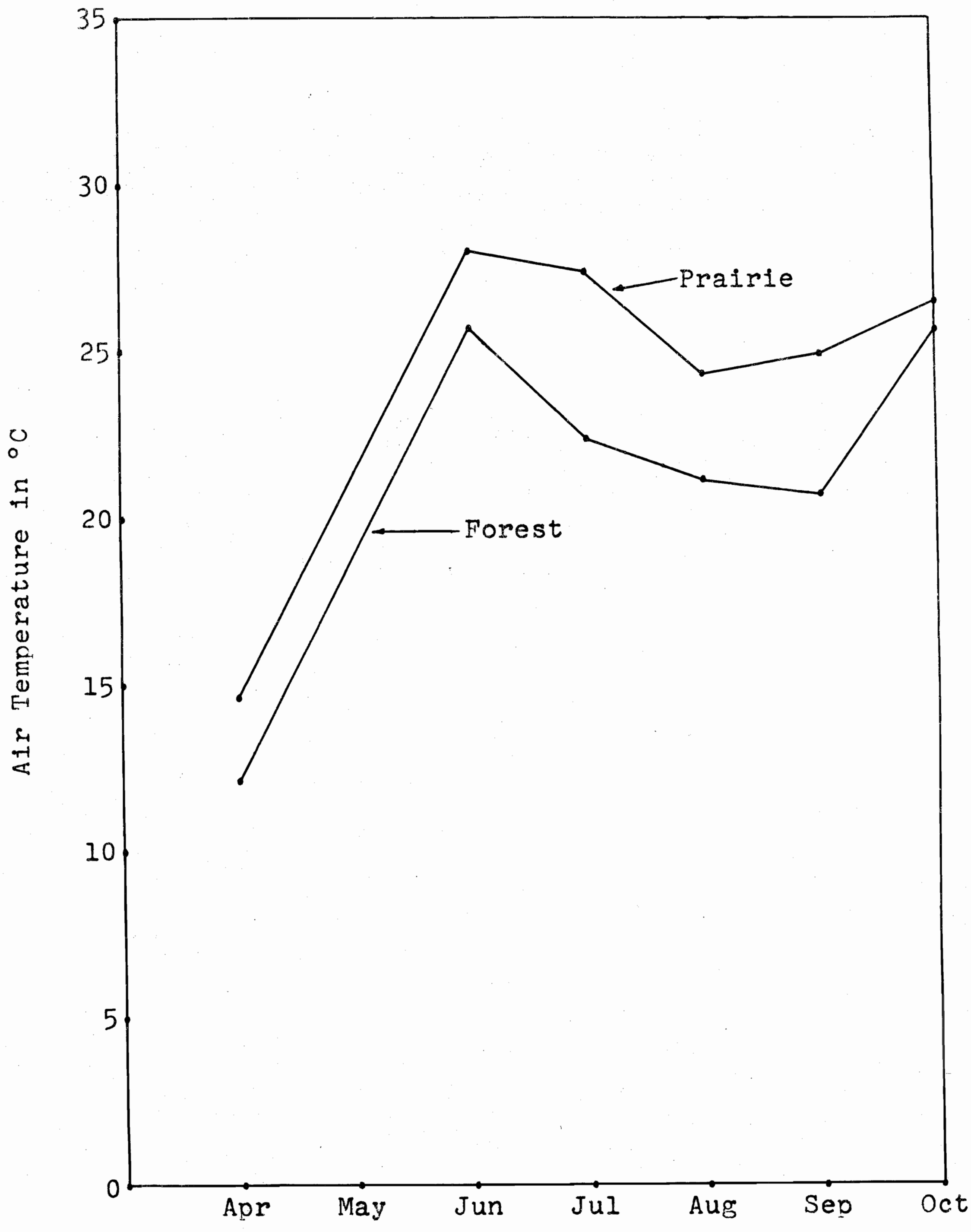

FIG. 2. Average air temperature per day on the sampling day in each month during the growing season at the Water Works sampling station.

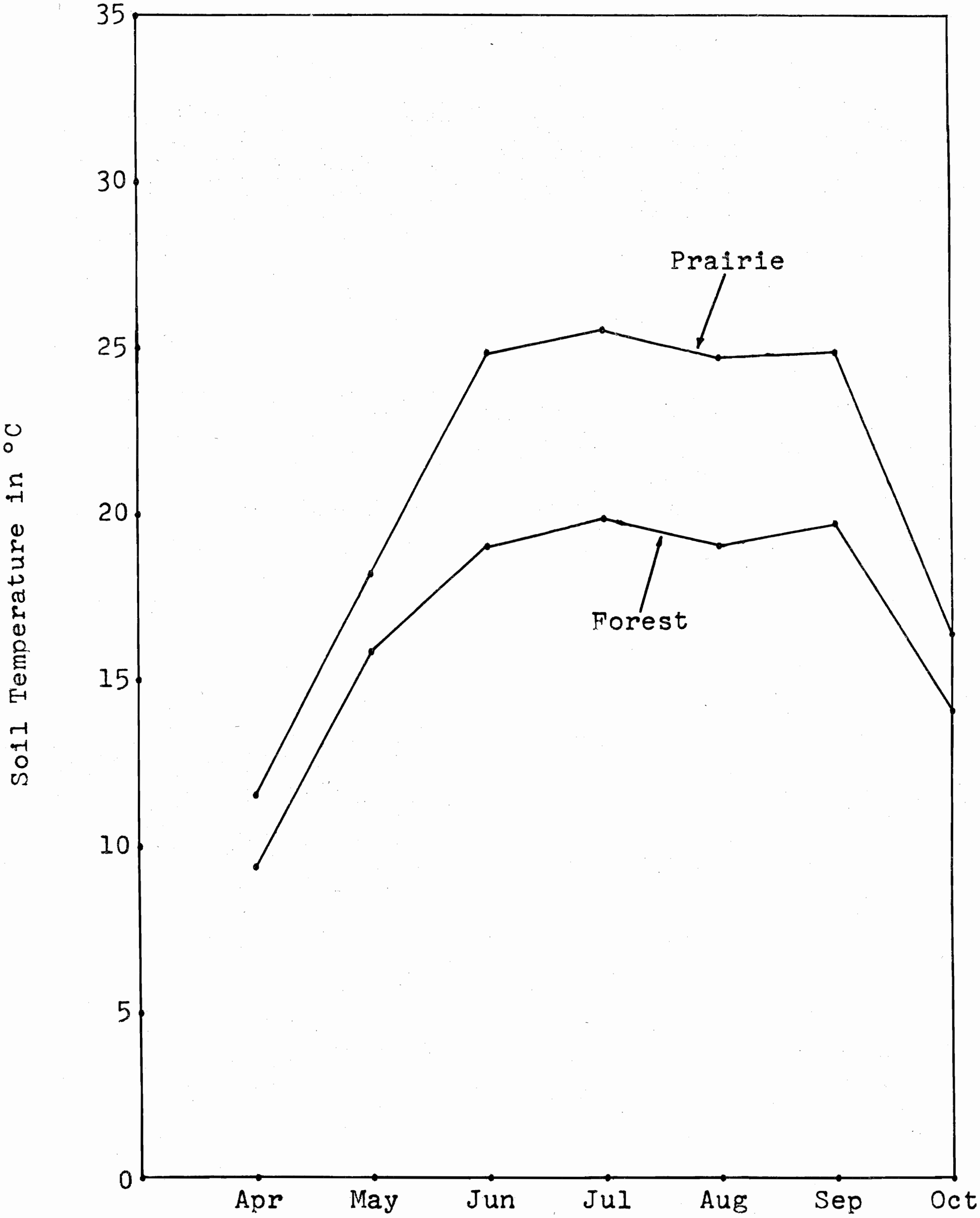

FIG. 3. Average soil temperature per day on the sampling day in each month during the growing season at the Water Works sampling station.

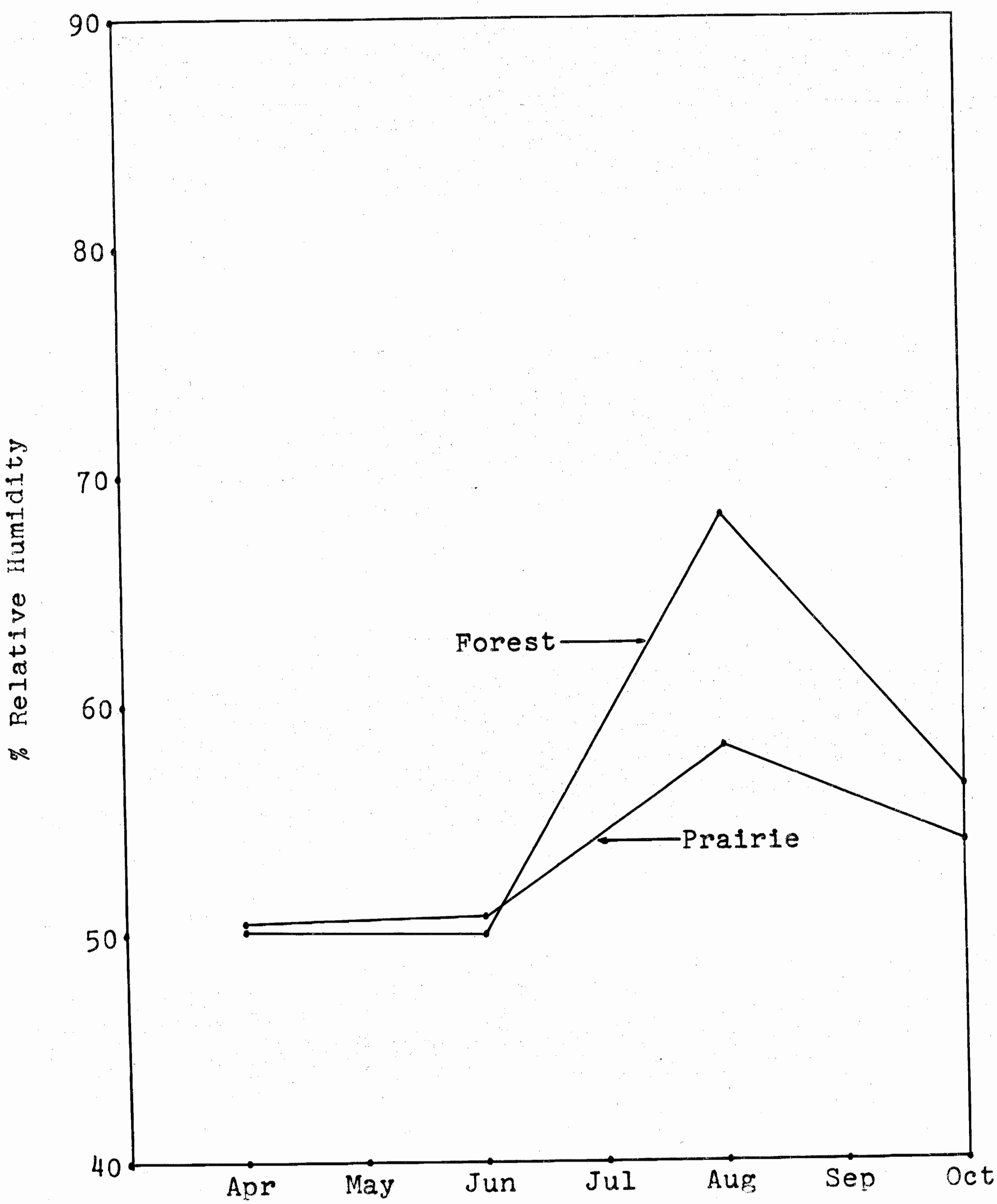

FIG. 4. Average relative humidity per day on the sampling day in each month during the growing season at the Water Works sampling station.

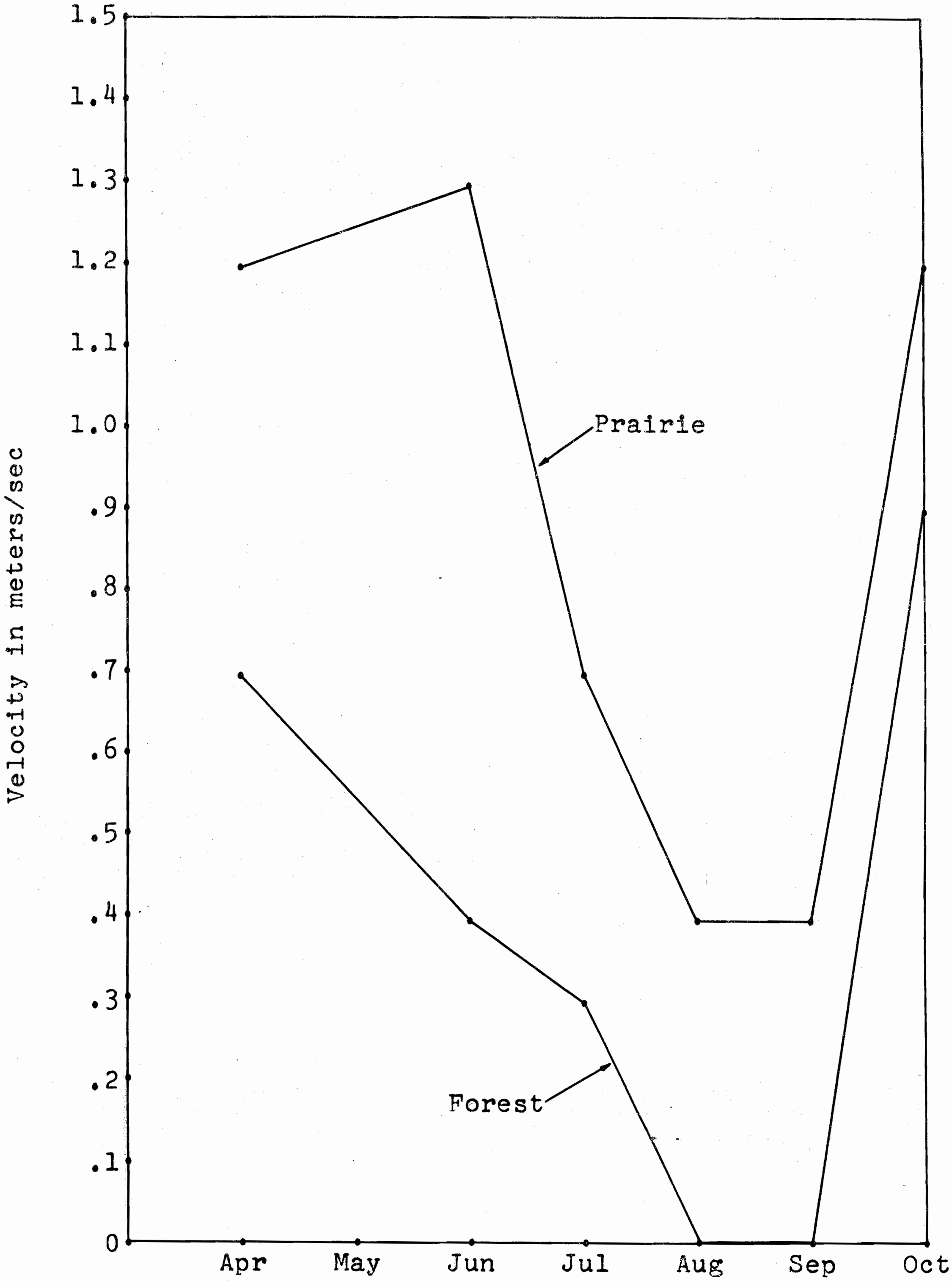

FIG. 5. Average wind velocity per day on the sampling day in each month during the growing season at the Water Works sampling station.

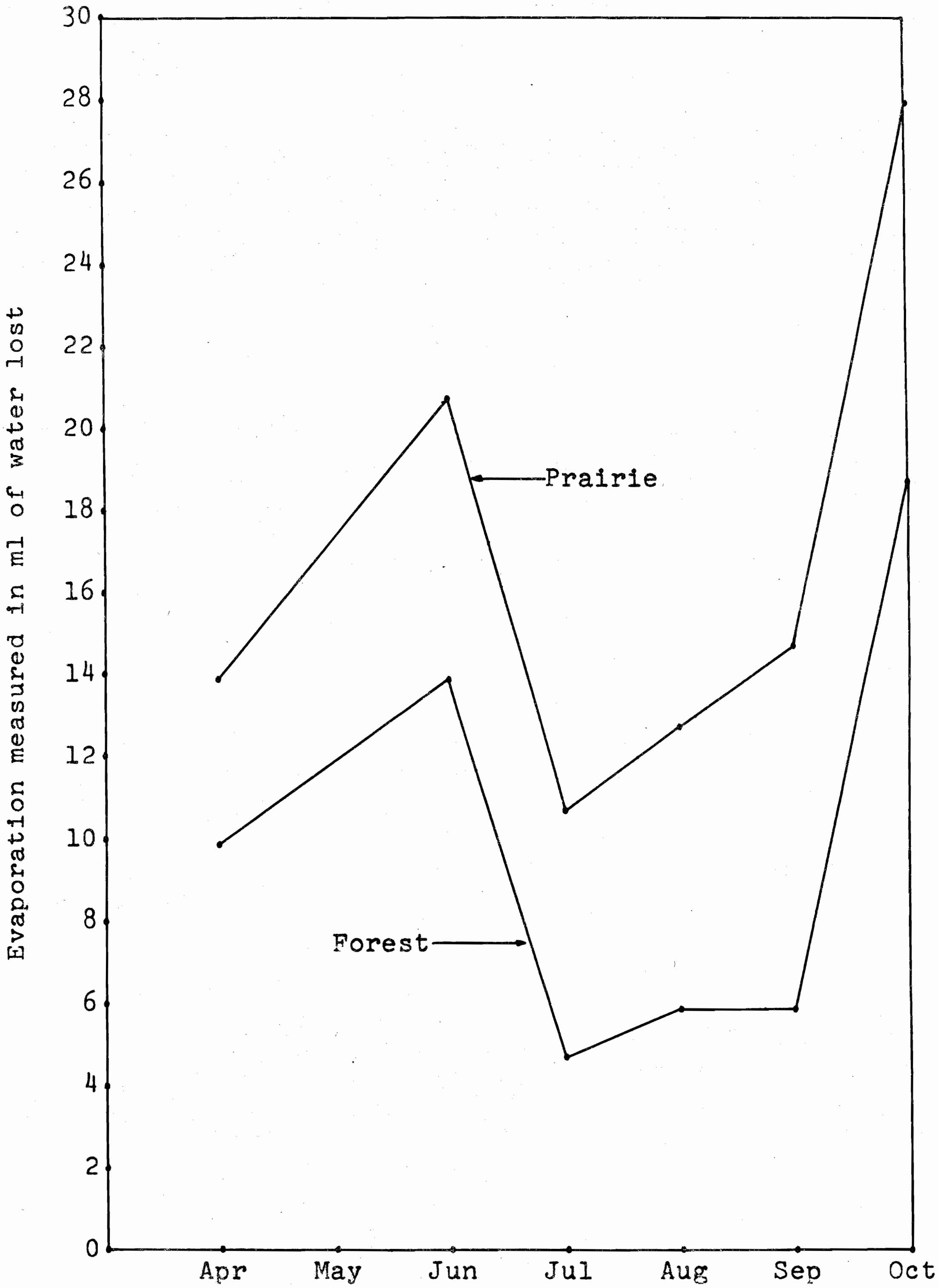

FIG. 6. Total evaporation per day on the sampling day in each month during the growing season at the Water Works sampling station.

a shield to incoming light or solar radiation. Thus, the amount of light reaching the forest floor is reduced and this lowers the air temperature. It is the lower air temperature and solar radiation of the forest that causes the soil temperature of the forest to be lower than those of the prairie soil. Even though there is a greater difference in light, air temperature and soil temperature during June, July, August, and September, there is still a considerable difference in April and October when the forest canopy is not a factor. It has been suggested that this difference may be due to topography (Hanson 1922, Costello 1931, Potzer 1939, Evers 1955 and Cooper 1961). Evers (1955) states, "South-west and west facing bluff slopes receive more nearly at right angles the rays of the hot afternoon (2:00 p.m.) summer sun, than do the other slopes". The hill prairie in question faces south-south-west, while the forest faces south-south-east. This admittedly is a small difference in slope direction, but it seems to be enough to allow the prairie to receive greater light intensities. As stated above, the greater the incoming solar radiation, the warmer the air temperature is, which in turn causes warmer soil temperatures.

The degree of difference in air temperature and soil temperature caused by light intensity is difficult to measure. Figures 1-3 show that there was a large difference in light intensity, for the months of June, July, August, and September while the difference in air temperature and soil temperature was not nearly so significant. Daubenmire (1974) points out that as light intensity decreases due to canopy cover, air temperature also decreases. He notes that it is hard to assess how much effect light intensity has on air temperatures and other environmental factors.

The relative humidity data was surprisingly variable (Figure 4). On the April sampling day the average relative humidity was about the same for both the hill prairie and the forest. This might be expected because there was no canopy covering the forest. However, in June when the forest canopy was a factor and the forest would be expected to have a higher relative humidity, just the opposite was recorded. August had typical or expected data with the prairie possessing a much lower relative humidity. The October sampling day also showed a lower relative humidity in the prairie than in the forest, even though the canopy was not a factor. An explanation for the atypical June data may be that it was just an atypical day. However, other factors such as air temperature, light and wind had typical data and therefore this is probably not the cause. A more likely possibility is the psychrometer used was not working properly.

The wind and evaporation data seem to correlate rather well (Figure 5-6) even though the difference in wind between the prairie and forest varied significantly over time and the evaporation data did not (Table I). It may be inferred from Figures 5-6 that evaporation on hill prairies is effected more by wind than the other factors. This has been suggested by Hanson (1922), Costello (1931) and Evers (1955). These researchers also believe that the south-south-west facing slopes of hill prairies allow for greater exposure to the prevailing south-westerly winds. Therefore, as was the case in incoming solar radiation, direction of slope is important in exposing hill prairies to more xeric conditions. It is also true that light, air temperature, and relative humidity also effect evaporation as has been noted by Weaver (1914), Shreve (1931), and Cooper (1961).

In summary of the above discussion, it was found that the climatological factors all indicate a more xeric environment on the hill prairie when compared to the surrounding forest. The major indicator of the dryer conditions on the prairie is the evaporation data. The graphs of the data indicate that the wind may be mainly responsible for the greater evaporation on the prairie. The graphs also indicate the canopy as being a major factor. However, in April and October when there was not a canopy there was still a significant difference in these climatological data, with the prairie having more xeric conditions. The significant differences found when the canopy was not a factor indicate the slope as the probable factor in determining the more xeric condition on the prairie. This has been suggested by several researchers (Vestal 1918, Hanson 1922, Costello 1931, Evers 1955) and this data seems to further substantiate their suggestion.

Soil Moisture and Texture Analysis

Soil moisture data were compared statistically by an analysis of variance (Table II). A significant difference in soil moisture between

TABLE II

SOIL MOISTURE: ANALYSIS OF VARIANCE

a. SOURCE OF VARIATION:

- A. ECOSYSTEM
  - Forest
  - Prairie
- B. SITE
  - Five-Mile Prairie and Forest
  - Lakeview Prairie and Forest
  - Waterworks Prairie and Forest
- C. TIME
  - Spring (February, March, April)
  - Summer (May, June, July)
  - Fall (August, September, October)
- D. DEPTH
  - 0-10 cm
  - 10-20 cm
  - 20-30 cm
- AB. FIRST ORDER INTERACTION
  - Ecosystem with site
- ABC. SECOND ORDER INTERACTION
  - Etc.

b. DEGREES OF FREEDOM

c. F-VALUES CALCULATED BY:

$$\frac{\text{VARIATION MEAN SQUARE}}{\text{RESIDUAL MEAN SQUARE}}$$

d. DEGREE OF SIGNIFICANCE

**. Significant at .01 level
*. Significant at .05 level
NS. Not significant at .05 level

TABLE II

SOIL MOISTURE: ANALYSIS OF VARIANCE

SOURCE[a]	D. F.[b]	MEAN SQUARES	F[c]
A	1	91.27739	14.796**
B	2	88.79987	14.394**
C	2	95.51186	15.482**
D	2	37.50435	6.079**
AB	2	61.16606	9.915**
AC	2	4.081201	0.662NS
BC	4	5.681904	0.921NS
AD	2	1.530853	0.248NS
BD	4	6.615223	1.072NS
CD	4	6.122330	0.992NS
ABC	4	3.947414	0.640NS
ADD	4	3.878345	0.629NS
ACD	4	2.865513	0.464NS
BCD	8	0.5233727	0.085NS
ABCD	8	2.791903	0.453NS
E(ABCD)	108	6.169254	

ecosystem (hill prairies and forests) was found. There was also a significant interaction between ecosystems and sites. This indicates that the soil moisture differences between the hill prairies and forests differed from site to site.

The significant differences for soil moisture data over time and at different soil depths, were variable and failed to show any worthwhile trends. However, these differences are probably due to precipitation. For example, if there had been considerable precipitation two days before the data were collected, then the soil moisture would naturally be higher than if it had precipitated ten days before data were obtained. Therefore, because of the lack of a trend among the different soil depths, the data for all depths were averaged for each month at each location. This allowed a comparison of the ecosystems for each site.

Figure 7 illustrates how the soil moisture differed between the prairie and forest. The Water Works Prairie had less soil moisture than the forest on each sampling day. The Five-Mile Prairie had less soil moisture on each sampling day except in July. However, the Lakeview Prairie had more soil moisture than the forest except on the sampling days of April and July.

It was expected that the prairie soils would have less soil moisture than the forest; this was the case at the Water Works location and the Five-Mile location. However, the Lakeview data contradicted this generally accepted trend. This can be explained when soil moisture

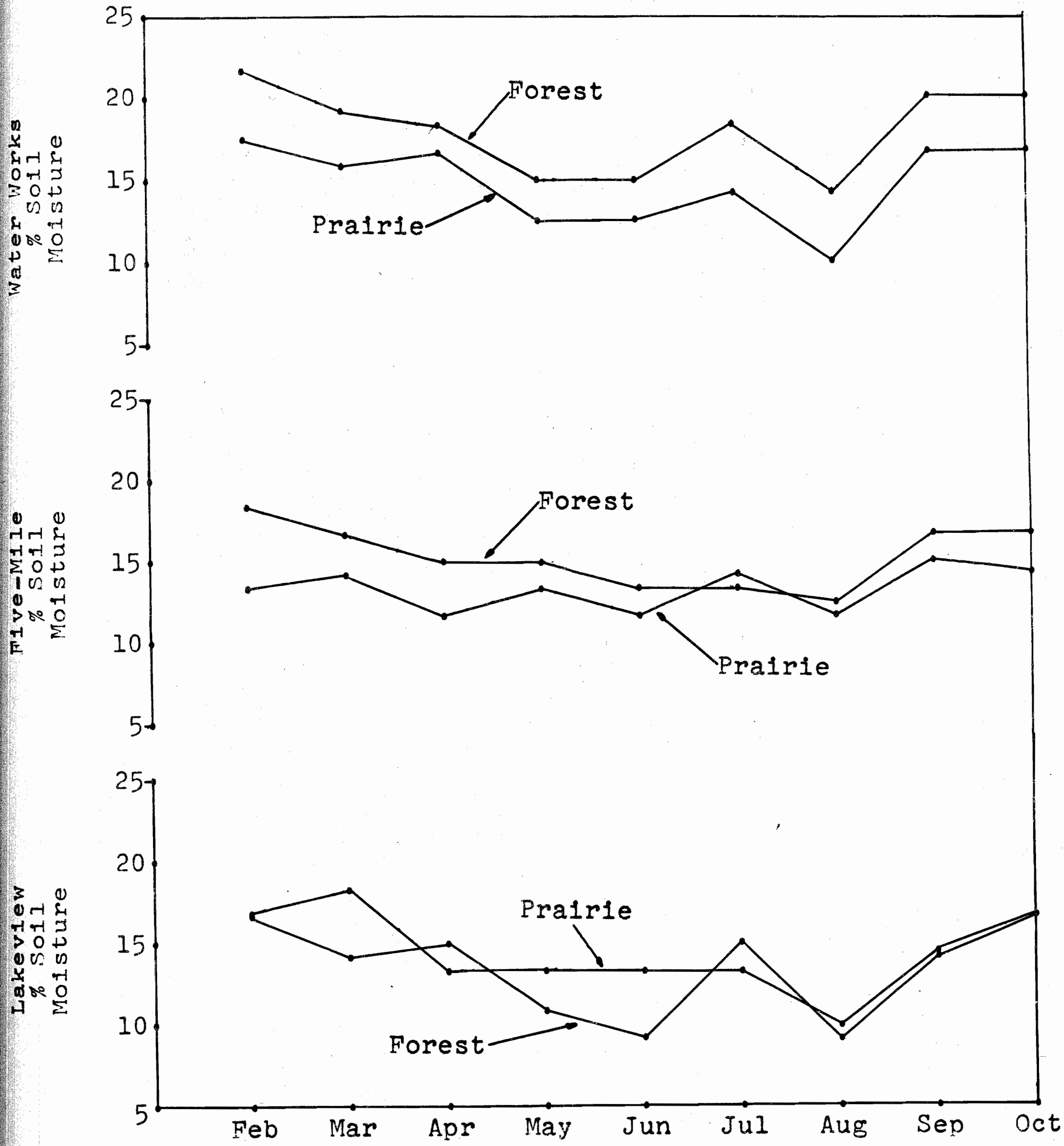

FIG. 7. Average soil moisture on the sampling day for the months of February through October at the Water Works, Five-Mile, and Lakeview sampling stations.

(Table III) and textural data (Table IV) are compared. Table III condenses the soil moisture data illustrated in Figure 7 so that comparisons between soil texture and soil moisture can be made more easily. The differences in soil moisture between prairie and forest may be at least partially explained by soil texture.

The Lakeview Prairie has a loam soil, while the forest has a sandy loam soil. The sandy loam soil contains less clay and more sand and therefore holds less water. This seems to explain why the prairie had more soil moisture. However, the months of April and July found the prairie with less soil moisture. This may have been due to atmospheric conditions and the time and amount of precipitation preceding the sampling day. If the latent precipitation had been small and several days before the data collecting day, the presumed dryer atmospheric conditions of the prairie would have caused the prairie soil to be dryer than the forest soil.

The Water Works Prairie has a loam soil while the forest has a clay loam soil. As the name implies, the clay loam soil contains more clay, thus, more water-holding capacity. The prairie has 6% more clay than the forest and this, at least in part, is responsible for the rather large soil moisture difference of about 3.3%. The Five-Mile Prairie and forest are both loam soils. However, the prairie had 3% less clay and 2% less soil moisture.

The soil texture data of these Eastern Illinois hill prairies differs drastically from that of Western Illinois hill prairies. Kilburn

TABLE III. *Average monthly soil moisture and total average soil moisture for both 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	12.0	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
Total Average	14.7	18.0	13.3	15.3	14.4	13.6

* All numbers are percentages.

TABLE IV. Soil textural names with percent soil particle composition are given for prairie and forest at each sampling site.

Soil Particles Size	LAKEVIEW Particle Composition (%)		WATERWORKS Particle Composition (%)		FIVE-MILE Particle Composition (%)	
	Prairie	Forest	Prairie	Forest	Prairie	Forest
Sand	40	52	37	37	42	40
Silt	41	35	40	34	41	40
Clay	19	13	23	29	17	20
Soil Name	Loam	Sandy loam	Loam	Clay loam	Loam	Loam

and Douglas (1963) found 78-85% sand in the soil on the Western Illinois hill prairies. They believed that this high sand content favors the hill prairies' existence. The much lower amounts of sand (37-52%) on the East-central Illinois hill prairies tends to indicate the importance of the atmospheric conditions in hill prairie maintenance.

It is difficult to assess how much effect soil texture has on soil moisture in this study. The soil moisture data appears to correlate rather well with the soil texture. However, it is probably not the major cause for hill prairie existence; if it were, one would expect a more consistent hill prairie-forest soil texture relationship. All the prairies have loam soil but the forests are all different and they differ in different ways. Also the Lakeview data shows a large difference in soil texture as does Water Works, but the difference in soil moisture is much smaller between the Lakeview prairie-forest than the Water Works prairie-forest. This difference is probably due to the dryer atmospheric conditions on the hill prairies.

In summary, there was a significant difference in soil moisture between the hill prairies and forests and between sites. These soil moisture data were compared with the soil texture data of these sites and a good correlation observed between these data. The location with smaller amounts of clay in the soil had proportionately less soil moisture. The importance of soil texture with respect to soil moisture in hill prairie maintenance was suggested by Kilburn and Douglas (1963) in a study of Western Illinois hill prairies. These Western Illinois hill prairies have much higher sand content when compared to the East-central Illinois hill prairies and this may indicate the importance of atmospheric conditions in maintaining the xeric environment that prairie vegetation needs.

Soil pH Analysis

The soil pH's for all three locations in both forest and prairie were between 7.0-7.6. These data were analyzed statistically and no significant differences were found for soil pH between the hill prairies and the forests (Table V). This analysis seems to eliminate the need for any further study of soil pH as a possible factor in hill prairie existence.

Vegetation Analysis

The quantitative vegetation analysis of the Water Works Prairie and Five-Mile Prairie showed that each prairie has one very dominant grass species. Even though the dominant species are different for each prairie, the quantitative results for the two prairies are quite similar.

The dominant grass on the Five-Mile Prairie is Little Bluestem (*Andropogan scoparius*). While the dominant on the Water Works Prairie is Indian Grass (*Sorghastrum nutans*). Little Bluestem has a relative density of 58.3% while Indian Grass has 50.4% (Table VI). The relative dominance and importance values are similar with Little Bluestem, having slightly more dominance and thus more importance

TABLE V

SOIL PH: ANALYSIS OF VARIANCE

SOURCE[a]	DF[b]	MEAN SQUARE	F[c]
1	1	.24500	3.2605NS
2	2	.00792	1.054NS
12	2	.00125	.0166NS

a. SOURCE OF VARIATION

1. ECOSYSTEM
   Forest
   Prairie
2. SITE
   Five Mile Prairie and Forest
   Lakeview Prairie and Forest
   Waterworks Prairie and Forest
12. FIRST ORDER INTERACTION
   Ecosystem with site

b. DEGREES OF FREEDOM

c. F-VALUES CALCULATED BY:

$$\frac{\text{VARIATION MEAN SQUARE}}{\text{WITHIN REPLICATES}}$$

TABLE VI. Vegetation composition analysis including relative density, relative dominance, importance 200 values and basal values for the dominant species on the Five-Mile Prairie and the Water Works Prairie.

Species	Relative Density	Relative Dominance	Importance 200 value	Percent Basal Cover
		Five-Mile Prairie		
Andropogon scoparius	58.3	97.9	156.2	30.2
Monardo bradburiana	10.7	.4	11.1	.1
Solidago nemoralis	8.3	.4	8.7	.1
Kuhnia eupatoriodes	7.1	.4	7.5	.1
Others	15.6	.8	16.5	.3
Total	100.0	100.0	200.0	30.8
		Water Works Prairie		
Sorghastrum nutans	50.4	93.3	143.7	21.2
Euphorbia corollata	8.8	.8	9.6	.2
Carex pennsylvania	5.9	2.9	8.8	.7
Silphium terebinthaceum	6.6	.8	7.4	.2
Others	28.3	2.2	30.5	.4
Total	100.0	100.0	200.0	22.7

than Indian Grass. The other grasses and forbs show very little importance (Table VI). The highest ranking forb in terms of importance is Monardo bradburiana found on Five-Mile Prairie, while the highest ranking forb on the Water Works Prairie is Euphorbia corollata (Table VI).

These East-central Illinois hill prairies and the Western Illinois hill prairies sampled by Evers (1955), have very similar basal coverage values. Evers (1955) found the basal areas or ground coverage values on the Sampson and Phegley prairies to be 30.04 and 22.37% respectively. This compares very closely to the values of 30.8 and 22.7% found for the Five-Mile and Water Works Prairies respectively.

The Five-Mile Prairie was quite similar to the Western Illinois hill prairies in that it was dominated by Little Bluestem. The basal coverage values of 30.2% (Table VI) for Little Bluestem on the Five-Mile Prairie compares closely to the 28.39% found on the Sampson prairie sampled by Evers (1955). The other grasses and forbs found on both prairies had negligible basal coverage values. These basal coverage values may be somewhat variable. Kilburn and Warren (1963) found coverage values for Little Bluestem ranging from 40.5-62%. However, they did not indicate if these values were crown coverage values or ground coverage values. If they are crown coverage values, they are smaller than 76% found for the Sampson prairie (Evers 1955), but if they are ground coverage values, they are considerably higher than Evers (1955) and these East-central Illinois hill prairies. An important phenomenon that these coverage values show, besides the dominance of one grass species, is the tremendous amount of bare ground. This may indicate rather poor growing conditions. The steep slope causing eroding soil and lack of soil moisture, which keep the grasses and other forbs from obtaining a better ground cover, may also keep the tree seedlings from becoming established. Thus, this may be a reason for the existence of these non-forested areas.

In summary of this quantitative data, there are a couple of trends that can be seen. The prairies are dominated by one grass and the basal area reveals a tremendous amount of bare ground. This bare ground may be due to poor growing conditions and may be partly responsible for these non-forested (hill prairies) existing. The Five-Mile Prairie is very similar with the Western Illinois hill prairies of Evers (1955) in that the Little Bluestem is the dominant grass and the coverage values are similar. The Water Works Prairie had similar coverage values. However, coverage data for an Indian Grass dominated prairie such as is found on the Water Works Prairie has not been reported. Evers (1955) does state the occurrence of a few Indian Grass dominated hill prairies in Western Illinois.

Species Analysis

There were 52 different species from 19 families collected on the three East-central Illinois hill prairies. These included 4 woody species, 7 grasses and 41 forbs (Table VII). When these data were broken down for each hill prairie, considerable differences in species

TABLE VII. Species list indicating growth forms (forb, grass, woody plant) for locality of Water Works, Five-Mile, Lakeview) hill prairies and associated species.

FOREST SPECIES Family and Species	Forbs	Grasses	Woody Plants	Water Works	Five-Mile	Lakeview
ASCLEPIADACEAE						
Asclepias purpurascens	X			X		
A. verticillata	X				X	
A. tuberosa	X					X
COMPOSITAE						
Erigeron pulchel lus	X					X
CORNACEAE						
Cornus florida			X	X	X	X
EBENACEAE						
Diospyros virginica			X			X
FAGACEAE						
Quercus muhlenbergii			X	X		X
Q. velutina			X		X	
GRAMINEAE						
Hystrix patulla		X				X
HYDRANGLACEAE						
Hydrangea arbaresens	X			X		
LEGUMINOSAE						
Desmodium globellum	X					X
D. marilandicum	X			X		
RHAMNACEAE						
Ceanothus americanus			X	X		X
SCROPHULARIACEAE						
Aureolaria flava	X				X	X
UMBELLIFERAE						
Thaspium barbinode	X				X	
VIOLACEAE						
Viola sororia	X					X
PRAIRIE SPECIES						
BORAGENACEAE						
Lithospermum canescens	X			X		
COMPOSITAE						
Antennaria plantaginitolia	X			X		X
Aster turbinellus	X			X	X	X

TABLE VII--continued

Family and Species	Forbs	Grasses	Woody Plants	Water Works	Five-Mile	Lakeview
Chrysanthemum leucanthemum	X			X		
Echinacea pallida	X					X
Erigeron annuus	X				X	X
E. pulchellus	X					X
Helianthus dwaricata	X				X	
Kuhnia eupatoriodes	X				X	
Liatris aspera	X			X		X
Rudbeckia hirta	X			X	X	X
Silphium terebinthinaceum	X			X		
S. nemoralis	X			X	X	X
Solidago ridgida	X			X		X
COMMELINACEAE						
Tradescantia virginica	X					X
CONVOLVULACEAE						
Convolvulus spithamaeus	X			X		
CYPERACEAE						
Carex muhlenbergii		X				X
C. pennsylvania		X		X		
EUPHORBIACEAE						
Euphorbia corollata	X			X	X	
GENTIANACEAE						
Sabatia angularis	X				X	
GRAMINEAE						
Andropogon furcatus		X		X		X
A. scoparius		X			X	X
Bromus commutatus		X		X		
Elymus canadensis		X			X	
Festuca elatior		X				X
Sorghastrum nutans		X		X		
IRIDACEAE						
Sisyrinchium albidum	X			X		
LABIATAE						
Monarda bradburiana	X			X	X	X
Physostegia verginiana	X			X		
Pycnanthemum pilosum	X				X	
LEGUMINOSAE						
Cassia fasciculata	X				X	
Desmodium globellum	X					X

TABLE VII--continued

Family and Species	Forbs	Grasses	Woody Plants	Water Works	Five-Mile	Lakeview
Lespedeza virginica	X			X		
Melilotus alba	X			X	X	
ROSACEAE						
Potentilla simplex	X			X	X	
Rosa carolina	X				X	
SCROPHULARIACEAE						
Penstemon digitalis	X					X
UMBELLIFERAE						
Taenidia integerrima	X			X		X

composition were found (Table VII). However, the relative numbers of species are about the same. The Lakeview Prairie had 21 forbs, 4 woody species and 3 grasses. The Five-Mile Prairie had 18 forbs, 2 woody species and 2 grasses, while the Water Works Prairie had 21 forbs, 2 woody species and 4 grasses. When this species list was compared to Ever's (1955) species list from the Western Illinois hill prairies, a considerable difference was found. Twenty-two out of the fifty-two species found on these East-central Illinois hill prairies were not found on the Western Illinois hill prairies. However, the number of species per prairie corresponds rather well with Ever's (1955) findings. He found the number of species in 1 acre of the Sampson and Phegley prairies to be 28 and 35 respectively. The 22, 27, and 28 species (Table VII) found on these East-central hill prairies can be considered reasonably close to Ever's figures due to the much smaller size of the East-central prairies.

A total of 12 herbaceous forest species and 2 weedy species were found on these East-central Illinois hill prairies (Table VII). The 2 weedy species were _Melilotus alba_ and _Festuca elatior_. Both of these species were introduced from Europe (Jones, 1963). The 12 herbaceous forest species is a conservative number because it only includes those forest species which Ever's (1955) did not list on the Western Illinois hill prairies. The 4 woody forest species (Table VII) found on the East-central Illinois hill prairies were also found on the Western Illinois hill prairies.

The most significant portion of data from the species list is the 12 herbaceous and 4 woody forest species found on the hill prairies of East-central Illinois. This may very well indicate that these hill prairies are not maintaining themselves and through succession are giving way to a forested condition. A paper by Vestal (1918) helps to support this belief. Vestal (1918) described and mapped a hill prairie area which was located one mile east from the southern part of Charleston, Illinois. After comparing topographic maps with Vestal's map, it was determined that the Water Works hill prairie area is the same one that Vestal (1918) mapped and described. This hill prairie has undergone several changes since 1918. In 1918, there were 10 different prairie vegetation sections located on the slope (Figure 8). Today, there are only 3 prairie sections (Figure 8). The total area occupied by prairie vegetation on this slope has been estimated to have been reduced by at least one third since 1918 and the prairie sections have moved to different positions on the slope. These different positions of the prairie vegetation on the slope can probably be explained by the oscilating of the area from prairie vegetation to forest and back to prairie due to the climate. Vestal (1918) noted by observation that the prairie had been encroached upon by the forest from 1911 to 1918. This encroachment by the forest probably continued until the 1930's drought (Weaver, 1954). During this drought, the forest probably receeded and a much larger part of the slope was covered by prairie vegetation. Finally, as the climate became more moist, the forest again began

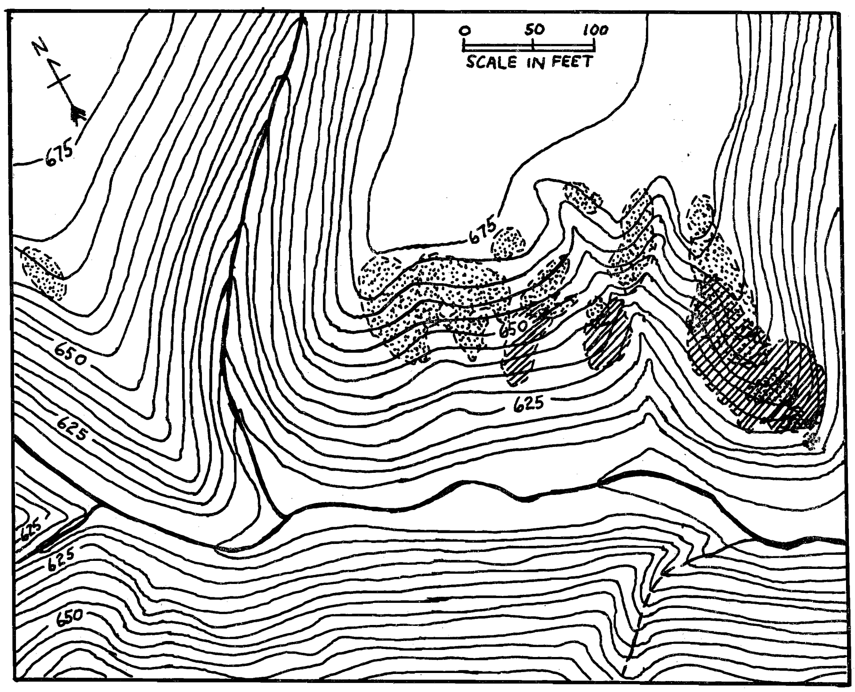

Figure 8. Map of a ravine area with prairie inclusions, near Charleston, Illinois. The stippled areas are those mapped by Vestal (1918). The cross-hatched areas are those mapped in 1975.

encroaching on the prairie. This encroachment by the forest probably has continued until the present time, leaving only 3 sections of prairie on this slope. The remaining prairie sections are facing south-west, which is the dryest slope.

Vestal (1918) also noted several long-lived Silphium terebinthinaceum plants in the prairie, which are indicative of long-term prairie existence. Presently, there are several Silphium terebinthinaceum plants on the prairie and 10-15 feet inward into the forest on the north-east side of the slope. The presence of Silphium terebinthinaceum in the forest along with the smaller tree sizes observed in the forest around the prairie, indicates rather strongly that the forest is presently overtaking the prairie.

In summary, four main factors are noted as indicating the apparent encroachment by the forest onto the prairie. These factors include: the many forest species found on the prairie; the apparent oscilation between prairie and forest due to climate; the presence of Silphium terebinthinaceum; and the smaller tree sizes along the edge of the prairie areas.

The last difference noted between the hill prairie now and in 1918 is the difference in dominant grasses. Vestal (1918) determined by observation the dominant grass to be Little Bluestem with Big Bluestem only nominally represented. No Little Bluestem was found on the hill prairie. There was a small amount of Little Bluestem noticed on a recently cultivated field located on top of the ridge about 50 yards from the hill prairie slope. The present Indian Grass dominate probably indicates that this prairie has been disturbed because Indian Grass seedlings readily take over disturbed areas (Weaver, 1968).

CONCLUSION

The vegetative evidence tends to indicate that the hill prairies are receeding. The encroachment of the forest will most likely continue at a relatively rapid rate, unless a more xeric climate comes into existence.

More absolute conclusions as to successional schemes could be obtained through more detailed studies of each of the parameters investigated in this study. Comparative climatological data between Western Illinois and East-central Illinois hill prairies are needed to determine if the same factor(s) are controlling the existence of both hill prairie areas. Finally, a more in-depth knowledge of these parameters is needed before realistic decisions can be made as to the preservation or maintenance of these areas.

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APPENDIX

Tables 1-6 of the Appendix give the analysis of variance for the following parameters: light, wind, relative humidity, air temperature, soil temperature. In these tables, the following legend is used:

a. SOURCE OF VARIATION:

1. TIME
   Time of day data was taken
2. ECOSYSTEM
   Prairie
   Forest
3. MONTH
   Time of year data was taken
12. FIRST ORDER INTERACTION
   Time with ecosystem
13. FIRST ORDER INTERACTION
   Time with month
23. FIRST ORDER INTERACTION
   Ecosystem with month

b. DEGREES OF FREEDOM

c. F-VALUES CALCULATED BY:

$$\frac{\text{VARIATION MEAN SQUARE}}{\text{RESIDUAL MEAN SQUARE}}$$

d. DEGREE OF SIGNIFICANCE

** = .01 level
* = .05 level
NS = Not Significant

TABLE 1. LIGHT: ANALYSIS OF VARIANCE

SOURCE[a]	DF[b]	MEAN SQUARES	F[c]
1	6	485.47583	1.5NS[d]
2	1	8501.75391	26.8**
3	3	2465.89868	7.8**
12	6	524.16406	1.7NS
13	18	123.75061	0.4NS
23	3	8816.21094	27.8**
RESIDUAL	18	317.22607	

TABLE 2. AIR TEMPERATURE: ANALYSIS OF VARIANCE

SOURCE[a]	DF[b]	MEAN SQUARES	F[c]
1	6	136.37500	13.8**[d]
2	1	80.16071	8.1*
3	3	734.39868	74.3**
12	6	2.32739	0.2NS
13	18	6.23215	0.6NS
23	3	1276.49390	129.2**
RESIDUAL	18	9.88303	

TABLE 3. SOIL TEMPERATURE: ANALYSIS OF VARIANCE

SOURCE[a]	DF[b]	MEAN SQUARES	F[c]
1	1	1242.01196	545.0840**[d]
2	6	817.5542	358.8020**
12	6	26.48438	11.6232**

TABLE 4. RELATIVE HUMIDITY: ANALYSIS OF VARIANCE

SOURCE[a]	DF[b]	MEAN SQUARES	F[c]
1	6	113.99403	4.5798**[d]
2	1	138.28571	5.5558*
3	3	564.61865	22.6841**
12	6	34.99403	1.4058NS
13	18	54.93851	2.2072*
23	3	85.57143	3.4379*
RESIDUAL	18	24.89052	

TABLE 5. EVAPORATION: ANALYSIS OF VARIANCE

SOURCE[a]	DF[b]	MEAN SQUARES	F[c]
1	4	3.23333	7.5788**[d]
2	1	29.39992	68.9120**
3	5	13.87997	32.5540**
12	4	0.81668	0.9143NS
13	20	1.76334	4.1332**
23	5	0.36004	.8439NS
RESIDUAL	20	0.42663	

TABLE 6. WIND: ANALYSIS OF VARIANCE

SOURCE[a]	DF[b]	MEAN SQUARES	F[c]
1	4	0.02193	1.01NS[d]
2	1	3.61129	138.26**
3	5	1.44515	66.35**
12	4	0.04812	2.21NS
13	20	0.02499	1.14NS
23	4	0.11186	5.13**
RESIDUAL	20	0.02178	

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