CLIMATIC FEATURES OF VEGETATION TYPES IN SOUTHEASTERN ILLINOIS

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Analyses of data from a three-year period discriminated between the climatic regimes of several vegetation types and ranked climatic variables in terms of their contributions to the discrimination. With two sites, an exposed S-facing prickly pear cactus bluff and a N-facing sphagnum moss ledge, discriminant analysis gave 90% correct posterior classification of climatic data to the prior groupings of data collected at each site. The distinctiveness of climatic regimes was blurred when additional sites were included in the analyses.

Use of only two predictors, soil temperature and minimum air temperature, achieved nearly as much discrimination as a larger number of variables. Temperatures varied more with topography than did precipitation. Precipitation data had a slight additive effect in discriminant analysis. Vegetational influences appeared to have more effect than landscape features on the climatic regimes of the several sites.

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INTRODUCTION

Forests in southern Illinois have a reasonably predictable distribution with respect to topography (Ashby and Kelting 1963, Ashby 1968). These distributions may be explainable in terms of energy exchanges, moisture regimes, and nutrient resources--all of which are related to the climatic and edaphic factors of an ecosystem. Climatic variables traditionally associated with plant growth include moisture supply and temperature. The initial hypothesis tested in these studies was that observed differences in vegetation types in the Lusk Creek Canyon area could be related to distinctive climatic regimes. As the study progressed, an ancillary objective was to identify those climatic variables most suitable to characterize the climatic regimes found in the canyon area.

DESCRIPTION OF AREA AND INSTRUMENTATION

All climatic stations were located near or in the canyon of Lusk Creek in Pope County of southeastern Illinois (T11S, R6E, Sec. 33-34). The middle reaches of the stream at 120 m elevation are marked by

changes in direction giving varying exposures of the rock walls often 25 m high. Above the walls the sides of the valley widen out for an equivalent height in a series of steps formed by smaller rock exposures. The combinations of varying angle and degree of slope, and extent of rock exposure, are associated with a great diversity of plant and animal life. Species characteristic of the northern midwest, including sphagnum moss, royal fern, cinnamon fern, and three species of lycopods, species not generally present in southern Illinois, may be found on N-facing ledges (Hopkins 1969). Exposed S-facing bluffs support prickly pear cactus and little bluestem grass characteristic of Texas or Oklahoma.

The valley sides had been logged in earlier times. In the remaining forests a sequence of tree species from exposed S-facing bluff to canyon bottom can be approximated as red cedar (*Juniperus virginiana* L.), scarlet oak (*Quercus coccinea* Muenchh.), white oak (*Q. alba* L.), red oak (*Q. rubra* L.), sugar maple (*Acer saccharum* Marsh.), and river birch (*Betula nigra* L.). Adjacent relatively level uplands had been cleared earlier and were in volunteer old-field species or in pine plantations.

Climatic stations were located in two broomsedge (*Andropogon virginicus* L.) old fields, two pine (*Pinus* spp.) plantations, three white oak and two red oak stands, one beech-maple stand, two red cedar-little bluestem (*Juniperus virginiana* L.-*Andropogon scoparius* Michx.) bluffs, two sphagnum ledges, and two creek-side areas. Data from stations selected for length or completeness of record are listed in table 1.

Every station had two dial-type thermometers approximately 6 m apart inserted 20 cm into the soil. A bi-metallic sensing element operated at the 15 to 20 cm depth. Factory-run thermometers were all checked in a water bath, and those deviating from a NBS-calibration thermometer by 1°C or more were discarded. Calibration factors were determined for the thermometers used at each station. Each calibration was subsequently checked twice a season. Soil temp. 1 and 2 (and precip. 1 and 2) were arbitrary designations for the replicated instruments at each station.

Two no. 10 cans (15 x 15 cm) spaced 8 m apart were set into the ground as rain gauges. Rain in the cans was poured into a graduated plastic cylinder for measurement, and oil was put in the cans between weekly readings to restrict evaporation. Supplemental rain gauges were used to check discordant readings of the duplicate gauges in the very few instances where that seemed desirable.

Three stations were equipped with Friez hygrothermographs which were checked each week with a Friez battery-operated psychrometer, and calibrated as necessary. Questionable instruments were replaced and brought back to the laboratory for adjustment. Other stations had air max-min thermometers which were periodically checked for accuracy.

Table 1. Station description and history. Record periods were 1967-70 except for stations no. 1, 6, and 9 which were 1967-69. Stations no. 1, 4, 8, and 9 had max-min thermometers and no. 2, 3, and 5 had hygrothermographs from which weekly max-min temperatures were determined.

Location and Number	Landscape and Vegetational Features
Old Field	
1.	Level upland, deep soil: Broomsedge - grassy
2.	Level upland, deep soil: Broomsedge - brushy
S-facing Bluff	
3.	S-facing layered rock outcrop at top of canyon: Scattered red cedar, prickly pear
4.	SW-facing steep rock outcrop with pockets of soil: Little bluestem, no canopy
N-facing Ledge	
5.	N-facing rock ledge deep in canyon above stream: Sphagnum, no canopy
6.	NW-facing layered rock outcrop near top of canyon: Sphagnum, black oak canopy
Forest Slopes	
7.	NE-facing gentle upland slope, deep soil: Pine plantation
8.	E-facing moderate slope below a 5 m rock cliff, soil and rock: White oak
9.	SW-facing moderate slope on spur ridge, soil and rock: White oak
10.	Stream terrace at base of E-facing slope, soil and rock: Red oak

Several of the sixteen stations were abandoned or had incomplete records because of vandalism or destruction from flooding by Lusk Creek. Missing records were also caused by high water blocking access to some stations, malfunctioning equipment, and accidents. Deer season, and in the winter frozen rain gauges and dangerous hiking on icy rocky slopes together with high water or ice in the creek, discouraged attempts to take non-growing season data in the second and third years.

SEASONAL CLIMATES

Soil temperature and precipitation on a seasonal basis illustrate differences related to vegetation type (Table 2). The seasons were defined as winter (Dec., Jan., Feb.), spring (March, April, May), summer (June, July, Aug.), and autumn (Sept., Oct., Nov.). The S-facing bluffs and the old fields had the greatest annual variation in temperature, and the N-facing sphagnum ledges the least. The forested environments were relatively stable, and relatively similar. These relationships were also found in the later years of the study, for which equivalent data are not presented. Year-to-year variation in temperature was greatest for the S-facing bluffs.

Table 2. Seasonal mean soil temperature and rainfall in 1968. Readings were taken once a week.

Station	Seasonal Soil Temperature				Seasonal Weekly Rainfall			
	DJF °C	MAM °C	JJA °C	SON °C	DJF cm	MAM cm	JJA cm	SON cm
Old Field								
1.	3.6	12.9	23.1	12.5	4.0	3.2	1.1	2.3
2.	3.4	11.7	22.8	13.8	3.9	3.2	1.3	2.4
S-facing Bluff								
3.	6.3	14.0	25.9	16.0	4.2	3.4	1.4	2.4
4.	2.6	14.8	27.0	13.4	4.0	3.0	1.0	2.3
N-facing Ledge								
5.	4.4	8.9	18.9	11.3	-	3.4	1.1	1.9
6.	3.8	9.0	18.5	12.1	3.2	2.6	0.9	1.8
Forest Slopes								
7.	4.4	10.0	20.5	13.3	3.7	3.2	1.4	2.0
8.	2.5	9.7	19.5	11.4	5.1	4.1	1.4	2.4
9.	3.4	11.8	20.8	11.8	3.7	3.0	1.2	2.0
10.	4.5	10.8	19.5	12.3	3.6	2.9	1.3	1.8

Soil temperatures below freezing at the 15 to 20 cm depth were recorded for several cases in January, February or March at four of the more exposed sites. The lowest air temperature recorded was -20°C.

Rainfall showed a winter-spring maximum in 1968, and a spring maximum in 1970 (to a lesser extent in 1969) when winter precipitation was not determined. Summer rainfall in 1969 was double that in 1968, indicating high variability in this factor. Variability between vegetation types was somewhat greater than within a vegetation type in a given season.

DISCRIMINANT ANALYSIS

Discriminant analysis (Tatsuoka 1971) was used to identify the distinctiveness of the climatic patterns in the several vegetation types studied. Two programs used were BMD05M Discriminant Analysis - Several Groups - Revised May 17, 1971 and BMD07M - Stepwise Discriminant Analysis - Revised April 10, 1972, Health Sciences Computing Facility, UCLA.

Discriminant analysis, based on a regression equation, assigns probabilities of membership to data sets from prespecified groups. The number of observations (data sets) should range from five to ten for each variable. Every group in an analysis must have a complete data set.

In this study a "prior group" is the climatic station at which the variables of temperature, precipitation, etc., in the data set of a given week (case) were collected. A "posterior classification" is the probability of membership by that case in each prior group utilized in the analysis. Acceptance of correct assignment of a data set to a prior group is based upon that probability which exceeds the proportion of cases in each prior group, for example 0.50 with two groups, or 0.20 with five groups.

In a stepwise discriminant analysis the percent cases correctly assigned typically increases as additional variables increase the discrimination power. A decrease in percent cases placed correctly may, however, be found as new variables interact with the variables already selected (Nie, et al. 1975).

Discriminant Analysis for Two Vegetation Types

Stepwise discriminant analysis with 10 climatic variables for the two vegetation types judged to be most distinctive resulted in 90% of the cases being correctly classified into the groups of prior probability (Table 3). Only in 13 out of 124 cases (weeks) did the discriminant analysis place the set of 10 climatic variables in the alternate vegetation type. Two of these cases were alternately assigned from the sphagnum to the prickly pear and for both the posterior probability was nearly the 0.5 required for proper placement. An observed anomaly for those cases, both in July, was that the sphagnum did not have a higher night temperature than the prickly pear. The majority of the cases mis-classified were data sets for the prickly pear, which had a less uniform environment, being placed with the data for the sphagnum.

Two variables or predictors, soil temp. 1 and air min. temp., accounted for 88% correct placement of the cases into groups (Table 3). Air max. temp. and precip. 2 brought the total to 90%. The 2 a.m. and 2 p.m. relative humidities and the last two sets of temperature data did not contribute to the discrimination.

Table 3. Discriminant analysis for two vegetation types. Posterior classification of 62 cases (sets of weekly climatic data) into prior groups, and stepwise discriminant rank and mean values of 10 variables. Cases underlined were classified correctly.

Sta. No.	Posterior Class. Group		Prior Group: S-facing Bluff Prickly Pear	Prior Group: N-facing Ledge Sphagnum	Percent Cases Placed Correctly in each Group
			No. Classified in Each Prior Group		(n = 62 each)
3.	S-facing p. pear		51	11	82
5.	N-facing sphagnum		2	60	97
	Values in Stepwise Discriminant Analysis				
Rank	and Variable		Mean Value of Each Variable		(n = 124 each)
1.	Soil temp. 1	°C	19.5	14.3	68
2.	Air min. temp.	°C	6.7	7.8	88
3.	2 p.m. temp.	°C	26.4	23.3	85
4.	Air max. temp.	°C	32.9	28.1	89
5.	Precip. 2	cm	1.9	1.8	90
6.	Precip. 1	cm	1.9	1.8	90
7.	2 a.m. R.H.	%	97.1	97.4	90
8.	2 p.m. R.H.	%	52.0	60.1	90
9.	2 a.m. temp.	°C	13.8	14.1	90
10.	Soil temp. 2	°C	19.7	15.0	90

The mean values of each variable were computed for the number of cases represented in the discriminant analysis (Table 3). Day and soil temperatures were higher and night temperatures lower on the prickly pear bluff. Night relative humidities were equivalent. Day humidities were higher at the sphagnum station. Recorded rainfall was higher on the bluff site, perhaps because of better exposure of the gauges. The paired rain gauges at a station showed close agreement, more so than the paired soil temperatures. Using soil temperature as an index of regional temperature, the differential between these two sites was equivalent to a difference of about 800 km in latitude (Fowells 1965).

Discriminant Analysis for Five Vegetation Types

Data of these same two stations combined with data of a brushy old-field, a second S-facing bluff, and a white oak slope were examined in a stepwise discriminant analysis. Because of the requirement to have complete data sets for each week, the number of cases was reduced from 62 to 52. Only three stations had hygrothermographs, so the number of discriminant variables was reduced to six.

Fifty-three percent of the cases were correctly assigned to the five prior groupings on the basis of posterior probability for group (Table 4). This represented a drop of 37% from the discrimination for the two stations of table 3. In other words, with data from the three additional vegetation types the cases were assigned with much more overlap. In each group the posterior assignment placed the largest number of cases in the prior group. The sphagnum and the brushy field were the most distinctive of the five habitats, with 62 and 60 percent of the cases placed correctly. The largest number of cases mis-classified were assigned to the most similar habitats.

Table 4. Discriminant analysis for five vegetation types. Posterior classification of 52 cases into prior groups, and stepwise discriminant rank and mean value of 6 variables. Cases underlined were placed correctly.

Sta. No.	Posterior Class. Group		Prior Group: Field Brushy	S-facing Bluff P. Pear	S-facing Bluff Little Bluestem	N-facing Ledge Sphagnum	W. Oak Slope	% Cases Placed Correctly in Each Group
			No. Classified in Each Prior Group					(n=52 each)
2.	Brushy field		31	9	1	5	6	60
3.	S-facing p. pear		8	24	13	3	4	46
4.	S-facing little bluestem		2	16	27	6	1	52
5.	N-facing ledge sphagnum		4	1	3	32	12	62
8.	White oak slope		10	1	2	16	23	44
			Values in Stepwise Discriminant Analysis					
Rank	and Variable		Mean Value of Each Variable					(n=260 each)
1.	Soil temp. 1	°C	17.6	20.0	20.5	14.6	15.2	30
2.	Air min. temp.	°C	7.7	6.7	6.9	7.7	7.5	42
3.	Air max. temp.	°C	32.8	33.0	31.7	28.4	28.6	46
4.	Soil temp. 2	°C	17.4	20.5	20.6	15.3	15.3	53
5.	Precip. 1	cm	1.4	1.6	1.2	1.5	1.4	53
6.	Precip. 2	cm	1.3	1.6	1.2	1.5	1.4	53

The stepwise discriminant analysis again showed soil temp. 1 ranked as the first variable and air min. temp. as the second. Soil temp. 2 and air max. temp. contributed less, and precip. 1 and 2 nothing to the discriminant analysis. A computer run with the sequence of soil temperature fields in the data input reversed had results identical to those shown in table 4.

Mean values of climatic variables for the two bluffs, and the two ledge or slope habitats respectively, were similar. Soil temperatures of the brushy field were intermediate, air min. temp. was similar to the ledge or slope, and air max. temp. was similar to the S-facing bluff habitats. Differences in precipitation were moderate and likely can be attributed in part to differences in exposure and to interception loss.

Discriminant Analysis for Four Vegetation Types

The analysis of six climatic variables from two white oak and two old-field stations showed the grassy old field to be the most distinctive habitat with 45 cases, or 71%, correctly assigned (Table 5). The white oak spur ridge was the least with 25%. White oak has wide ecological amplitude (Fowells 1965), enough so that its habitat on the spur ridge with nearby species such as post oak (*Q. stellata* Wangenh.) was not comparable in terms of discriminant analysis of these climatic variables to its habitat on the mesic slope with beech (*Fagus grandifolia* Ehrh.) as a more usual associate. The mean values show lower soil and air maximum temperatures for the white oak habitats compared with the old-field stations, and reasonably equivalent air minimum temperatures and rainfall.

Table 5. Discriminant analysis for four vegetation types. Posterior classification of 63 cases into prior groups, and mean values of 6 variables with no rank ordering. Cases underlined were placed correctly.

Sta. No.	Posterior Class. Group		Prior Group: Old Field, Grassy	Old Field, Brushy	White Oak, Slope	White Oak, Ridge	Percent Cases Placed Correctly in Each Group
			No. Classified in Each Prior Group				(n = 63 each)
	Old Field						
1.	Grassy		45	8	6	4	71
2.	Brushy		17	29	11	6	46
	White Oak						
8.	Slope		5	7	39	12	62
9.	Ridge		10	22	15	16	25
Variable Listed			Mean Value of Each Variable				
Soil temp. 1		°C	16.8	16.4	13.8	15.0	
Soil temp. 2		°C	15.8	16.3	14.0	14.8	
Air min. temp.		°C	4.9	5.6	5.6	5.0	
Air max. temp.		°C	30.5	31.3	26.7	29.5	
Precip. 1		cm	2.0	1.9	2.0	1.6	
Precip. 2		cm	1.9	1.8	2.2	1.8	

INTERPRETATION OF FINDINGS

Data of the two most exposed sites, the S-facing prickly-pear bluff and the N-facing sphagnum ledge, were discriminated nearly as well as the classification of meteorological patterns in southern California by McCutchan and Schroeder (1973). These floristic areas of Lusk Creek share to a substantial degree rocky exposures with limited forest canopy. The distinctiveness of the old-field habitat was also demonstrated. Stations with greater forest cover were less well discriminated, suggesting that vegetational influences were dominant to possible topoclimatic effects.

The preeminence of soil temperature as a discriminator, followed by air minimum and air maximum temperatures, is a guide for design of forest climatic studies. Neither the precipitation nor the hygrothermograph data presented proved to be of substantial value. In the present studies this knowledge could have saved the continuing trouble and substantial expense of maintaining the hygrothermographs, and would have resulted in the maintainance of the beech-maple station which was abandoned because of vandalism related to high visibility of the hygrothermograph shelter. Shanks (1956) reported soil temperature data from the 6-inch depth to be a useful index of altitudinal and microclimatic temperature differences in the closed forest vegetation of the Great Smoky Mountains.

A factor influencing the decision not to continue data collection in the winter was poor records for precipitation. Precipitation turned out to have a negligible contribution to the discriminant analysis so that data from the colder months could have been better represented in the analyses. The growing-season data which predominate in the analyses are likely of greater importance in relation to tree growth.

The high discrimination value of soil temperature at 15- to 20-cm depth ties in with the effect of soil depth in integrating the temperature regime at a site. The importance of air minimum temperature points to a greater distinctiveness of night than day temperatures in the several vegetation types. The insignificance of precipitation, and of relative humidity, relates in part to the variability of these factors and to the similarity in average values at the several sites. A suggested conclusion is that the energy input varies more with site than does the moisture input.

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