

## LIFE-FORMS OF ILLINOIS PLANTS

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### INTRODUCTION

#### *General Concept*

A plant, growing under natural outdoor conditions, is continually being acted upon by numerous and varying environmental stimuli. As a response to these surrounding influences the plant assumes a certain external appearance or form which has been termed the "life-form."

#### *Historical*

Miss Ennis [3], in her work upon the Connecticut flora, discusses fully the history of the life-form concept from the time of Theophrastus to the present day. Only a brief summary need be given here.

The form of the plant was first considered chiefly from the viewpoint of systematic classification. Although environmental relationships were recognized by the early botanists they were not thought to be important, and very little attention was devoted to them. In 1805, however, Humboldt pointed out the relationship of physiognomy to distribution, and showed that the vegetation of two regions with similar environment was similar in form.

Later, Warming noted certain characteristics of the individual plant which adapted it to its surroundings and which could be set apart from those characteristics of plainly taxonomic value. Thus the form of the plant as caused by the action of environmental factors was recognized, and the concept of the "life-form" elaborated.

Warming and other workers in the ecological field (Drude, Pound and Clements, Raunkiaer, and Gams) have developed systems for the classification of plants according to their life-form characteristics. The most widely used of these systems is that of the Danish botanist, Raunkiaer, presented in detail in 1905 (Bull. Acad. Roy. d. Sci. de Denmark, pp. 347-437).

*Raunkiaer's Life-Form System*

Raunkiaer's system for the classification of plants according to their life-forms has as its fundamental idea a representation of the climate of a region as evinced by the character of the plant life of that region. The varying degree of protection afforded to the perennating or dormant bud is considered as the adaptive feature, and with this as a basis the following five classes of plants are recognized:

1. Phanerophytes (Ph). Trees and shrubs, the perennating buds are freely exposed; characteristic of tropical and sub-tropical regions.
  - a. Megaphanerophytes (Mg). 30 m. or more in height.
  - b. Mesophanerophytes (Ms). 8 m. to 30 m. in height.
  - c. Microphanerophytes (M). 2 m. to 8 m. in height.
  - d. Nanophanerophytes (N). Less than 2 m. in height.
2. Chamaephytes (Ch). Plants with the perennating buds either at the ground level or not more than 25 centimeters above it; characteristic of regions with a long winter period.
3. Hemipterophytes (H). Plants with the perennating buds in the upper layer of the soil; characteristic of temperate climates.
4. Cryptophytes (C). Plants with the perennating buds in the deeper soil layers or protected by water; characteristic of regions with a season of drought or cold.
  - a. Geophytes (G). Land plants whose perennating buds are buried in the soil.
  - b. Helophytes. Marsh or water plants whose perennating buds are in soil or water.
  - c. Hydrophytes. Submersed aquatics, the perennating buds covered by water. Helophytes and hydrophytes (HH) are usually considered together.
5. Therophytes (T). Annual plants, characteristic of regions of intense heat and also of cultivated areas.

*The Life-Form Spectrum*

To obtain what is known as the life-form spectrum for a specific region, the flora of that region is classified into the above life-form groups and the percentage of each group is determined. This results in a series of percentages known as the "spectrum." Since the degree of protection offered the perennating bud varies according to the climate of the region under consideration, the percentages of the life-form classes will also vary, and the dominance of a particular life-form class will serve as an index to the general environmental conditions.

Raunkiaer, as summarized by Smith [12], recognizes three climatic zones:

1. Tropical regions with uniform high temperature and varying humidity; dominated by phanerophytes.

2. Regions of decreasing warmth correlated with differences between summer and winter, but where the precipitation is usually favorable for plant growth; dominated by hemicryptophytes.
3. Regions of further decreasing warmth and less precipitation; dominated by chamaephytes.

### *The Normal Spectrum*

In order to have some standard as a basis for comparison, Raunkiaer has devised what he calls the "normal spectrum." This is best summarized in the words of Smith [12] as follows:

"The normal spectrum is the base-line, and the outstanding features of the other spectra are deduced by comparison, not by the highest percentages in their own curves, but by the amount of variation from the normal spectrum. The latter is, ideally, the phyto-climatic spectrum of the whole earth; actually it is obtained by computation and at present is given only as approximate. It was arrived at by first selecting one thousand representative species, and then taking four hundred of these which were carefully analyzed." (See Table II and fig. 2.)

### *Methods of Investigation*

In working out a complete life-form spectrum for a given region it becomes necessary to consider the entire flora of that region from the standpoint of its classification into the various life-form groups. The first phase of the work, therefore, consists in the compilation of a list of plants native to the area under consideration. Such a list of the plants of Illinois was derived from the catalogs and manuals available [1, 4, 5, 7, 8, 10], and although doubtless incomplete, it is probably representative. As Miss Ennis has found that the inclusion of naturalized species "does not materially alter the spectrum," they may be left out of consideration.

In order to make life-form studies of the floras of various portions of the State, Illinois has been somewhat arbitrarily divided into four regions termed respectively: north, central, mid-south, and south, as shown on the accompanying map, figure 1. The division lines have not all been made horizontally across the State, but for the south and mid-south regions have been determined by the last killing frosts of spring and the first killing frosts of autumn [11].

The distribution of the plants in each of these four regions was determined as far as possible from the lists and floras consulted. Where the distribution was doubtful or could not be determined from these sources further data were obtained from examination of material in the herbarium of the University of Illinois.

In the determinations of the life-forms of the various species, free use has been made of previous work upon the subject, of the manuals, and also of the herbarium material. Some determinations are doubtless



FIG. 1. Map of Illinois showing the north, central, mid-south and south regions.

inaccurate, for there was no opportunity to do extensive field work, but as Miss Ennis points out, "a considerable difference in the determination of the life-forms of a region does not materially alter the deduction as to the outstanding features of climate."

In preparing the spectra the following total numbers of native species have been used: total Illinois flora, 1,734 species; north flora, 1,370 species; central flora, 1,227 species; mid-south flora, 891 species; south flora, 905 species; and a combination of the mid-south and south



TABLE I  
NUMBERS OF SPECIES OF EACH LIFE-FORM, AND THE ILLINOIS SPECTRA

No. of Species	Flora	Mg.	Ms.	Mg.-Ms.	M.	N.	M.-N.	Ph.	Ch.	H.	G.	H.H.	C.	T.	S.	E.
T.F.	25	87	112	104	62	166	278	22	862	228	96	324	244	3	1	
N.F.	18	51	69	82	58	140	209	19	686	192	68	260	193	3		
C.F.	16	52	68	58	30	88	156	10	637	165	60	225	198	1		
M.F.	20	55	75	45	24	69	144	6	454	112	31	143	142	1	1	
S.F.	23	67	90	56	18	74	164	9	446	109	41	150	135		1	
M.+S.F.	23	70	93	60	29	89	182	10	585	144	56	200	175	1	1	
Spectra (%)																
T.F.	1.4	5.0	6.4	6.0	3.6	9.6	16.0	1.3	49.7	13.1	5.5	18.6	14.1	0.17	0.06	
N.F.	1.3	3.7	5.0	6.0	4.2	10.2	15.2	1.4	50.0	14.0	5.0	19.0	14.1	0.22		
C.F.	1.3	4.2	5.5	4.7	2.4	7.1	12.7	0.8	51.9	13.5	4.9	18.4	16.1	0.08		
M.F.	2.2	6.2	8.4	5.0	2.8	7.8	16.2	0.7	51.0	12.6	3.5	16.1	16.0	0.11	0.11	
S.F.	2.5	7.4	9.9	6.2	2.0	8.2	18.1	1.0	49.3	12.0	4.5	16.5	14.9		0.11	
M.+S.F.	2.0	6.1	8.1	5.2	2.5	7.7	15.8	0.9	50.7	12.5	4.9	17.4	15.2	0.09	0.09	

TABLE II  
THE NORMAL, ILLINOIS, AND CONNECTICUT SPECTRA

Spectrum	Mg.	Ms.	Mg.-Ms.	M.	N.	M.-N.	Ph.	Ch.	H.	G.	H.H.	C.	T.	S.	E.
Normal			6.0	17.0	20.0	37.0	43.0	9.0	27.0	3.0	1.0	4.0	13.0	1.0	3.0
Ill.	1.4	5.0	6.4	6.0	3.6	9.6	16.0	1.3	49.7	13.1	5.5	18.6	14.1	0.17	0.06
Conn.	1.5	3.9	5.4	5.8	3.7	9.5	14.9	1.9	49.4	13.2	8.5	21.7	11.7	0.06	0.06

NUMBERS OF SPECIES IN THE SEVERAL LIFE-FORM GROUPS

State	Mg.	Ms.	Mg.-Ms.	M.	N.	M.-N.	Ph.	Ch.	H.	G.	H.H.	C.	T.	S.	E.
Ill.	25	87	112	104	62	166	278	22	862	228	96	324	244	3	1
Conn.	23	57	80	85	54	139	219	28	718	192	124	316	170	1	1

Legend for Tables I and II.

T.F.=Total Flora.  
N.F.=North Flora.  
C.F.=Central Flora.  
M.F.=Mid-South Flora.  
S.F.=South Flora.  
M.+S.F.=Mid-South+South Flora.

Mg.=Megaphanerophytes.  
Ms.=Mesophanerophytes.  
Mg.-Ms.=Mega- and Mesophanerophytes.  
M.=Microphanerophytes.  
N.=Nanophanerophytes.  
M.-N.=Micro- and Nanophanerophytes.  
Ph.=Phanerophytes.  
Ch.=Chamaephytes.

H.=Hemicryptophytes.  
G.=Geophytes.  
H.H.=Helophytes and Hydrophytes.  
C.=Cryptophytes.  
T.=Therophytes.  
S.=Stem-Succulents.  
E.=Epiphytes.

floras, 1,154 species. Six different spectra have been prepared, one for the entire Illinois flora, one for each of the four regions of the State, and one for the combined mid-south and south areas. The numbers of species in each life-form group and the six spectra are presented in Table I.

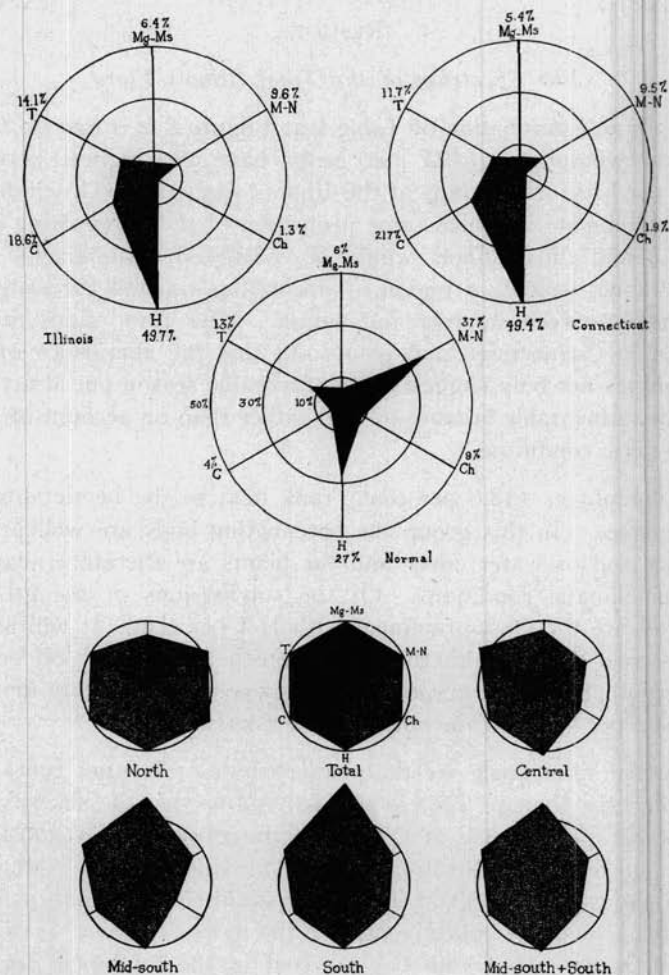


FIG. 2. (Above) Graphic representations of Raunkiaer's normal, Illinois, and Connecticut spectra.

FIG. 3. (Below) A graphic representation of the life-form spectra of Illinois showing the variations from the spectrum of the total flora taken as a standard.

As a graphic means of comparing the Illinois spectrum with other spectra, series of concentric circles representing 10, 30, and 50 per cent, have been used, and the percentages of the several life-forms in a cer-

tain spectrum plotted along six radii of these circles, 1 millimeter equaling 1 per cent. By connecting the various points thus determined, a figure is obtained which shows the spectral analysis of the flora under consideration (Fig. 2).

## RESULTS

### *The Spectrum of the Total Illinois Flora*

From an examination of Table 1 and figure 2 it is easy to see that the hemicryptophytes (49.7 per cent) have the highest percentage among the life-form groups of the Illinois spectrum. This indicates a temperate climate in which some protection of the perennating buds is required, and thus Illinois would be located in Raunkiaer's second climatic zone, namely, a region of decreasing warmth correlated with differences between summer and winter. Miss Ennis finds the same situation in Connecticut, and points out that the abundance of hemicryptophytes not only suggests an unfavorable season but also that the season is unfavorable because of cold rather than on account of intense heat or xeric conditions.

Cryptophytes (18.6 per cent) rank next to the hemicryptophytes in abundance. In this group the perennating buds are well protected by either soil or water cover and the plants are therefore adapted to rigorous climatic conditions. Of the subdivisions of the group the geophytes are the most prominent with 13.1 per cent. It will be noted that the two groups with the buds protected by either soil or water (hemicryptophytes and cryptophytes) compose considerably more than half (68.3 per cent) of the entire native flora of Illinois.

Next in abundance are the phanerophytes (16.0 per cent). This rather high percentage leads to the assumption that the severity of the unfavorable period does not prohibit the growth of a considerable number of trees and shrubs with freely exposed buds. Among the phanerophytes, the two groups of lower stature (micro- and nanophanerophytes considered collectively) are the more abundant, forming 9.6 per cent as compared with 6.4 per cent of the combined mega- and mesophanerophyte groups. This too is significant in revealing that those phanerophytes with greater bud protection are the more abundant. Of the individual phanerophyte sub-groups, the microphanerophytes are the most numerous (6.0 per cent).

After the phanerophytes the therophytes rank next in abundance (14.1 per cent). Therophytes are adapted to extremely unfavorable conditions, or to regions in a high state of cultivation. Their high per-

centage in the Illinois spectrum further emphasizes the existence of an unfavorable growth period, and also that a large portion of the state is under cultivation.

The other life-form groups are negligible in the Illinois spectrum. Chamaephytes form only 1.3 per cent, while the stem-succulents and epiphytes together make up only 0.23 per cent.

*Comparison of the Illinois, Connecticut, and Normal Spectra.*

Table II shows the normal spectrum, the spectrum for the total Illinois flora, and that for Connecticut as worked out by Miss Ennis. It also gives the actual number of species in each life-form group in the two states. The Illinois spectrum as compared with the normal shows low percentages of phanerophytes and chamaephytes, and high percentages of hemicryptophytes, cryptophytes, and therophytes. The normal percentage of phanerophytes is nearly three times that of Illinois, and the normal percentage of chamaephytes is approximately seven times as great. The hemicryptophyte percentage of Illinois is nearly double the normal. The geophyte percentage is four times as great. Therophytes are but slightly above the normal. From this comparison it may be seen that the Illinois spectrum has higher percentages of those life-forms with protected perennating buds and thus there is indicated a winter period or unfavorable season for growth and an adaptation to more extreme conditions than indicated by the normal spectrum. The relationship between the two spectra may be seen in figure 2.

A study of the Illinois spectrum as compared with that for Connecticut reveals the interesting fact that the two are almost identical (Table II and fig. 2). This is, perhaps, to be expected as both states have the same general climatic conditions. The percentage of phanerophytes for Illinois slightly exceeds that for Connecticut (Illinois, 16.0 per cent; Connecticut, 14.9 per cent), a condition which is rather striking as Connecticut lies in a generally forested region and Illinois has large areas of prairie. However, the greater north and south extension of the middle western state permits the presence of certain woody elements, particularly southern species, which are not to be found in an area as restricted as Connecticut, but would explain the slightly greater phanerophyte percentage in Illinois.

Chamaephytes have a slightly higher percentage in the eastern state (Illinois, 1.3 per cent; Connecticut, 1.9 per cent). Hemicryptophytes are almost identical in the two spectra. Geophytes are approximately the same, whereas helophytes and hydrophytes are slightly



more abundant in Connecticut (Illinois, 5.5 per cent; Connecticut, 8.5 per cent). The difference here represents the greatest variation of any of the life-form percentages. The difference in therophytes is almost as great, however (Illinois, 14.1 per cent; Connecticut, 11.7 per cent), and is probably indicative of slightly more xeric conditions in Illinois, or larger areas of land under cultivation. Stem-succulents and epiphytes are negligible in both spectra.

*Comparison of the Spectra within the State of Illinois.*

A comparison of the spectra for the various sections of the State (Fig. 3 and Table I) brings out some rather interesting facts. Most noteworthy, perhaps, is the striking similarity, indicating only slight climatic variations between the different regions. Figure 3 shows the result of attempting to bring out the existing differences by graphic means. The spectrum of the total flora of Illinois has been taken as a standard and a figure representing this made to fill a circle having a 25 millimeter radius. Each of six radii was taken to represent a life-form class and the points where these radii touched the circle were connected. With the resulting figure as a standard, similar figures were constructed for the various spectra within the State showing the variation of these spectra from that of the total flora.

It will readily be seen (Table I) that with the exception of the central region there is a progressive increase in the phanerophytes from the north to the south. In the northernmost region, phanerophytes represent 15.2 per cent, a figure but slightly below that obtained for the phanerophytes of the whole State. There is an increase to 16.2 per cent in the mid-south, and to 18.1 per cent in the south, both of these figures being above the percentage for the entire State (16.0 per cent).

The discrepancy in the successive increase of phanerophytes occurring in the central region, where there are only 12.7 per cent, may be explained, it seems, by the larger proportion of prairie in that region. Prairie conditions are relatively more xeric, the cover being herbaceous and largely composed of hemicryptophytes and geophytes. In this connection it is interesting to note that the hemicryptophytes reach their highest percentage in the central region (51.9 per cent).

As phanerophytes become more abundant in the south where climatic conditions are less extreme, their successive increase from the northern to the southern portion of Illinois is to be expected. In a state with a north-south extension of three hundred eighty-five miles there is certain to be sufficient variation in temperature and rainfall

to assure a more temperate climate in the southernmost portion. That such climatic variation actually does occur may be seen from Table III in which rainfall and temperature data have been assembled from Mosier [9] covering approximately the regions used in this study. These figures show a successive increase in both temperature and rainfall averages from north to south.

TABLE III  
AVERAGE RAINFALL AND TEMPERATURE DATA FROM ILLINOIS,  
1876-1915

Region	Rainfall Inches	Temperature Degrees
Entire State.....	38.87	53.45
North .....	34.12	48.2
Central .....	36.89	52.4
Mid-south .....	41.18	55.3
South .....	43.28	57.9

On account of the similarity between the spectra of the mid-south and south regions, and because the graphs were thought not to show enough difference to warrant the separation of the two, they were combined, and the spectrum of the resulting flora obtained (Table I and Fig. 3). Undoubtedly the most significant result of the union of these two original regions is to be seen in the percentage of phanerophytes. This percentage (15.8 per cent) is less than that of either of the two regions considered separately (mid-south, 16.2 per cent; south, 18.1 per cent), and more nearly approximates that of the north and central portions (north, 15.2 per cent; central, 12.7 per cent). Such an unexpected percentage shows that had not the area been originally divided into two separate sections, the progressive increase of phanerophytes from north to south would have been but slightly apparent. It is a well-known fact that there are certain trees common in the southern states, such as *Nyssa aquatica*, *Taxodium distichum*, *Aesculus parva*, and *Quercus phellos* which occur only in the very southern portion of Illinois. This fact is corroborated by the rise in the phanerophyte percentage in the extreme southern region.

The cryptophytes reach 17.4 per cent in the combined southern portion of the State. This is a figure above the percentage for that life-form group in either the mid-south or south regions. The other life-form percentages seem not to differ in any important way from the corresponding percentages in the mid-south and south spectra. On the whole the spectrum of the combined areas gives percentages more nearly in accord with those of the north and central spectra, thus bringing more uniformity to the spectra of the regions within Illinois.

In Table IV the trees, shrubs, and woody vines are considered as to actual numbers and percentages of species. Although the successive increase of woody plants from north to south is not always clear within each group, it is evident that, in general, such an increase occurs. A glance at the column for trees shows the increase in the mid-south and south percentages. Evergreen trees and shrubs make up but a small percentage of the Illinois flora and occur mostly in the north. Here again the percentages obtained for the combined mid-south and south areas do not show as strikingly the increase of woody elements in the extreme south.

TABLE IV  
NUMBERS AND PERCENTAGES OF TREES, SHRUBS, AND VINES

<i>For All Woody Plants</i>								
Flora	Total		Trees		Shrubs		Vines	
	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.
Total .....	272	15.7	153	8.8	89	5.1	30	1.7
North .....	206	15.0	107	7.8	82	6.0	17	1.2
Central .....	156	12.7	87	7.1	47	3.8	22	1.8
Mid-South .....	144	16.2	95	10.7	35	3.9	14	1.6
South .....	163	18.0	113	12.5	28	3.1	22	2.4
Mid-South+South ..	181	15.7	118	10.2	41	3.6	22	1.9

<i>For Deciduous Woody Plants</i>								
Total .....	261	15.0	148	8.5	83	4.8	30	1.7
North .....	196	14.3	103	7.5	76	5.5	17	1.2
Central .....	155	12.6	86	7.0	47	3.8	22	1.8
Mid-South .....	141	15.8	93	10.4	34	3.8	14	1.6
South .....	161	17.8	111	12.3	28	3.1	22	2.4
Mid-South+South ..	178	15.5	116	10.1	40	3.5	22	1.9

<i>For Evergreen Woody Plants</i>								
Total .....	11	0.6	5	0.3	6	0.3		
North .....	10	0.7	4	0.3	6	0.4		
Central .....	1	0.08	1	0.08				
Mid-South .....	3	0.3	2	0.2	1	0.1		
South .....	2	0.2	2	0.2				
Mid-South+South ..	3	0.3	2	0.2	1	0.1		

Turning now to a consideration of the chamaephytes it is seen that the greatest percentage (1.4 per cent) is in the north. The percentages decrease successively in the central and mid-south (0.8 per cent and 0.7 per cent respectively) with a slight increase to 1.0 per cent in the south. This latter increase may possibly be correlated with the presence of considerable hill country in southern Illinois. Chamaephytes are typically a northern group and their greater abundance in the northern part of the State is to be expected.

Hemicryptophytes are the dominant group in all spectra. They are well represented in the north (50.0 per cent), and attain their highest percentage in the central region (51.9 per cent). This increase over the north seems coincident with the drop in the percentage of phanerophytes discussed above, and would appear to indicate slightly more unfavorable conditions probably related to more extensive development of prairie. However, the percentages of hemicryptophytes do not vary greatly between any two regions, and it may be said that this life-form group remains fairly constant throughout the State (Fig. 3).

Cryptophytes reach their lowest percentages in the mid-south and south. Geophytes show progressive dropping off from 14.0 per cent in the north to 12.0 per cent in the south. The variation in the helophyte-hydrophyte group shows nothing significant, and would suggest no essential differences in swamp or water conditions throughout the State.

The therophytes are most abundant in the central region, and their rather high percentages in all parts of the State probably indicate the State-wide prevalence of cultivation. Therophytes are fewest in the north (14.1 per cent), and are fairly well represented in the central, mid-south, and south (16.1 per cent, 16.0 per cent, and 14.9 per cent, respectively).

Stem-succulents and epiphytes are negligible throughout the State. All of the former occur in the north, but decrease in the central and mid-south regions. They disappear entirely in the south. The one epiphyte, *Phoradendron flavescens*, occurs in the mid-south and south.

#### SUMMARY

1. A study of the spectrum for the entire native flora of Illinois reveals a "hemicryptophytic climate" as evinced by the dominance of that life-form group. There is evidence of a season unfavorable to growth due to cold rather than to heat or lack of moisture. This unfavorable period is not extreme as the phanerophytes are fairly well represented.

2. The total Illinois spectrum reveals nearly double the normal percentage of hemicryptophytes; about one-third the normal percentage of phanerophytes; four times the normal percentage of cryptophytes; approximately one-seventh the normal percentage of chamaephytes; and a percentage of therophytes nearly the same as that in the normal spectrum. These deviations from the normal indicate the existence of an unfavorable period for growth, as there is an increase of those forms



which are adapted to rigorous conditions and a decrease of those forms which are adapted to warm-temperate or tropical conditions.

3. A comparison of the Connecticut spectrum with that of Illinois reveals a striking similarity. The greatest discrepancies occur in the helophyte-hydrophyte and therophyte groups. The higher percentage of therophytes and the lower percentage of helophytes and hydrophytes are probably correlated with slightly more xeric conditions and greater cultivation in the western state. The slightly greater abundance of phanerophytes in the middle western states is to be associated with the greater north-south extension. In general it may be said that the same conclusions drawn by Miss Ennis for Connecticut also hold for Illinois.

4. An examination of the spectra of the north, central, mid-south, and south regions of the State shows that climatic conditions are less severe in the south than in the regions successively north, the greatest variation, of course, being between the extreme northern and the extreme southern portions. This climatic difference is particularly indicated by the increase of phanerophytes from 15.2 per cent in the north to 18.1 per cent in the south. Data upon rainfall and temperature support the results revealed by the plants themselves. Hemicryptophytes show a lower percentage in the south than in any other region, although the highest percentage of these is found in the central rather than in the northern region, seemingly due to extensive prairie in this middle section. Geophytes show the highest percentage in the north with progressive falling off southward, while therophytes indicate nothing significant other than that their abundance points to much cultivated land and to the existence of an unfavorable growth period. The spectrum of the combined mid-south and south regions fails to reveal as strikingly the increase of woody plants in the southern portion of the State, but tends to make the phanerophyte percentages more uniform throughout.

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REFERENCES

1. BRENDAL, FREDERICK. *Flora Peoriana, The Vegetation in the Climate of Middle Illinois*, 1887.
2. BRITTON, N. L., and BROWN, A. *Illustrated Flora of the Northern United States and Canada*, 3 Vol., 1913.
3. ENNIS, BEULAH. *The Life-Forms of Connecticut Plants and Their Significance in Relation to Climate*, Conn. State Geological and Nat. Hist. Survey, Bull. No. 43, 1928.
4. FLAGG, W. C., and BURRILL, T. J. *Catalogue of the Flowering and Higher Flowerless Plants of Illinois, Native, Introduced, and Cultivated*, 1876.
5. GLEASON, HENRY ALLAN. *The Vegetation of the Inland Sand Deposits of Illinois*, Illinois State Lab. of Nat. Hist., Bull. 19, Art. III, 1910.
6. GRAY, ASA. *New Manual of Botany*, 7th Edition, 1908.
7. MILLER, ROBERT BARCLAY, and TEHON, L. R. *The Native and Naturalized Trees of Illinois*, Illinois Nat. Hist. Survey, Bull. No. 18, Art. I, 1929.
8. MOSHER, EDNA. *The Grasses of Illinois*, Univ. of Illinois Agr. Exp. Sta., Bull. 205, 1918.
9. MOSIER, J. G. *Climate of Illinois*, Univ. of Illinois Agr. Exp. Sta., Bull. 208, pp. 11-17, 30-42, 1918.
10. PEPOON, H. S. *An Annotated Flora of the Chicago Area*, 1927.
11. REED, WILLIAM GARDNER. *Atlas of American Agriculture, Part III, Climate, Section I: Frost and Growing Season*, pp. 2-3, 6-7, 1918.
12. SMITH, WILLIAM G. Raunkiaer's "Life-Forms" and Statistical Methods, *Jour. of Ecol.*, Vol. 1, pp. 16-26, 1913.