The application of association analysis for phytosociological interpretation of plant communities in Las Piwnicki Nature Reserve near Toruń

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(Entered: July 23, 1973.)

Abstract

The paper contains the results of analysis of the herb layer carried out under different habitat conditions of two forest associations. Comparative studies of the floristic content and an analysis of the homogeneity of the herb layer were conducted with the use of objective statistical methods and a numerical classification technique.

INTRODUCTION

To distinguish floristically and ecologically homogeneous patches of phytocenosis and ecological groups of species occurring within them, Anglo-Saxon researchers apply two groups of numerical methods: the "divisive methods" including normal and inverse association analysis and nodal analysis (Williams and Lambert 1959, 1960, 1961; Lambert and Williams 1962, 1966; Lance and Williams 1965; Ivimey-Cook and Proctor 1966; Greig-Smith et al. 1967; Williams et al. 1967) and the "agglomerative methods" including among other techniques similarity analysis (Williams et al. 1966; Lance and Williams 1966; Orloci 1967; Yarranton et al. 1972) and information analysis (Orloci 1968, 1970a, 1970b; Dale and Anderson 1972). The two groups differ from each other in the manner of arranging data and in their criteria of homogeneity and similarity. Using all kinds of association analyses the set of sample plots or of species occurring in them is progressively divided with regard to the occurrence of elements reaching the highest χ^2 values. In the second group of methods the elements are fused on the basis of the highest si-

milarity or correlation coefficients, the shortest Euclidean distances or the least differences in the information content. Apart from the above hierarchical systems of classification of the phytosociological and ecological material, analysis of the principal components (Seal 1964; Yarranton 1967) and the canonical analysis (Goldstein and Grigal 1972) have recently come into more and more common use. In these techniques the relationships between sample plots are determined on the basis of correlation coefficients of species and habitat factors, and the elements of the set are grouped not in the form of a dendrogram but of two-axis clusters.

The present paper is an attempt at application of normal association analysis to the classification of the phytosociological material, for determination of the relationship between the sample plots and the species and for charting of the distinguished homogeneous groups on the surface area.

THE STUDY AREA

Association analysis was carried out in July and August 1971 in three sample plots in Las Piwnicki Nature Reserve near Toruń (Fig. 1). Rejewski and Mejnartowicz (1968) have distinguished there two forest associations: *Quercus-Carpinetum medioeuropaeum* and *Pino-Quercetum*.

Plots I and II situated within the former association differ from each other in the qualitative and quantitative composition of the herb

Fig. 1. Sketch map of Las Piwnicki Nature Reserve with the position of sample plots.

1 — roads, 2 — Struga Lysomicka (stream), 3 — sample plots, 4 — Ecological Station

layer. The reduced soil cover and different specific composition of the higher situated plot I are due to lower moisture content of the soil and higher percentage of pine in the tree-stand. In the herb layer of this part of the reserve besides species typical of *Quercus-Carpinetum*, there occur in places species typical of *Pino-Quercetum*: *Vaccinium myrtillus*, *Pteridium aquilinum* and *Trientalis europaea*.

Plot III situated in the *Pino-Quercetum* association has a well developed herb layer in which the above mentioned *Pino-Quercetum* species play an important part.

The aim of the present work was to determine the degree of homogeneity of the herb layer of the selected sample plots in two phytocoenoses with the use of the χ^2 test as criterion of homogeneity, and the differences and similarities between the patches under study as well as to compare the results obtained by the method of the Anglo-Saxon researchers with those obtained by the classical method of Braun-Blanquet.

METHOD

The selected sample plots were divided into 100 10×10 m quadrats, of which in plot II only 20 were taken into account. The total number of units studied was 220. In each quadrat a series of 10 casts with a circle 40 cm in diameter were performed. In the 1.25 m² areas thus selected all plant species were recorded according to the criterion "present-absent". The data for each quadrat, i.e. its coordinates and the numbers of species found in it were recorded on perforated cards for the ICL 4130 computer.

The relationships between the species found in the samples were determined using the value of χ^2 calculated on the basis of the 2×2 contingency table (Kershaw 1964; Bishop 1966). As criterion of division of the quadrats into groups was adapted the occurrence of the species attaining the highest value of $\Sigma\chi^2$ that is to say, showing positive or negative association with the largest number of the remaining components of the herb layer. The species thus distinguished does not cover the study area uniformly, and, being confined to a narrow range of habitat factors, shows positive association with species having similar ecological requirements and occurring in the same habitat, and a negative association with those dominating in the remaining part of the plots under study. Repeated analysis of the samples containing the species with the highest $\Sigma\chi^2$ value and of the remaining samples leads to progressive breaking up of the set and distinguishing of homogeneous groups in which the differences between the actual and the theoretical distribution for all possible pairs of species are only slight and the obtained χ^2 values do not exceed the accepted termination values.

The analysis was executed in the Computer Unit Operating Service of the University College of Wales in Aberystwyth to the termination value of $\chi^2 = 10.87$ ($p = 0.001$), using the program worked out by Dr. J. P. Savidge in Algol.

RESULTS

A total of 43 plant species were noted in the random sample plots. The highest number 32 occurred in the 20 quadrats of plot II, in plots I and III 28 and 18 species were recorded respectively.

Using the method of Williams and Lambert, in the plots under study 10 groups of quadrats and of combinations of species in them were distinguished, determined by variable habitat conditions, mainly soil conditions.

The highest value of $\Sigma\chi^2 = 312.76$ was reached by *Mycelis muralis* (Fig. 2). Fifteen quadrats with this species constitute group A. In the

Fig. 2 Association analysis diagram for 220 quadrats

remaining 205 quadrats the highest values of $\Sigma\chi^2 = 168.82$ is reached by *Galeobdolon luteum*, the occurrence of which divides the quadrats into groups with species typical of *Quercus-Carpinetum* (A, B, C, D)

Table 1
Percentual frequency of species in 10 quadrat groups

Species	Quadrat group									
	A	B	C	D	J	I	H	E	G	F
<i>Mycelis muralis</i>	100									
<i>Stellaria holostea</i>	33	33								
<i>Viola silvestris</i>	27	33		4						
<i>Stellaria nemorum</i>	53	100	13		2			14		
<i>Galeobdolon luteum</i>	87	100	100	100						
<i>Moehringia trinervia</i>	20	33	38	15			3			
<i>Vaccinium myrtillus</i>			25	33	20	42	66	71	76	100
<i>Pteridium aquilinum</i>			100		2	8	7	57	37	9
<i>Convallaria maialis</i>			50	13			100	14	34	91
<i>Trientalis europaea</i>			63	31				100	100	100
<i>Deschampsia flexuosa</i>					9	33	3		16	18
<i>Calamagrostis arundinacea</i>					7	17	10		5	36
<i>Majanthemum bifolium</i>	67	33	100	88	78	100	97	100	97	91
<i>Oxalis acetosella</i>	93	100	100	88	24	83	55	71	68	91
<i>Carpinus betulus</i>	60	33	63	38	20	17	10	71	18	
<i>Dryopteris spinulosa</i>	27	33	13	25	11	8	3	29	13	
<i>Rubus idaeus</i>	40	33	75	13	2		3	14	3	
<i>Frangula alnus</i>	27	33	13	6			21	57		100
<i>Polygonum convolvulus</i>	20	33	50	4	2	8		14	5	
<i>Quercus</i> sp.	47		25	4	11		14	100		
<i>Sorbus aucuparia</i>	7		13	8	0	10	3		10	
<i>Milium effusum</i>	7				4	8	10		10	
<i>Anemone nemorosa</i>	7			15			21		13	9
<i>Acer platanoides</i>	7			2			3	43		
<i>Sambucus nigra</i>	27	67		2					3	
<i>Luzula pilosa</i>				2					3	18
<i>Corylus avellana</i>	7		13							
<i>Melica nutans</i>	7		13							
<i>Pinus silvestris</i>	13			8						
<i>Athyrium filix-femina</i>	13			4						
<i>Poa nemoralis</i>	7			4						
<i>Asperula odorata</i>	7			2						
<i>Alnus glutinosa</i>	13									
<i>Geranium Robertianum</i>	13									
<i>Urtica dioica</i>	13									
<i>Poa annua</i>	13									
<i>Ajuga reptans</i>	7									
<i>Fragaria vesca</i>	7									
<i>Glechoma hederacea</i>	7									
<i>Impatiens noli-tangere</i>	7									
<i>Plantago maior</i>	7									
<i>Chelidonium maius</i>				2						
<i>Polygonatum multiflorum</i>								14		
No. of species in group	34	13	18	24	13	11	17	15	17	11
No. of quadrats in group	15	3	8	52	45	12	29	7	38	11

and of *Pino-Quercetum* (E, F, G, H, I, J). The composition and the frequency of species occurring in each group are presented in Table 1. Most species exhibit occur in several groups, only *Majanthemum bifolium* and *Oxalis acetosella* are frequently found in all groups.

In the distinguished groups of quadrats a progressive increase in the percentual contribution of *Pino-Quercetum* species is seen. Groups A and C dominating in plot II contain *Querco-Carpinetum* species only, in groups B and D, typical of plot I there are also small numbers of *Vaccinium myrtillus*, *Pteridium aquilinum* and *Trientalis europaea*. In the remaining quadrats of plot I with the exception of two quadrats included in group A, the percentage of *Pino-Quercetum* species slightly increases while that of *Querco-Carpinetum* species decreases. When termination value $\chi^2 = 10.87$, the latter quadrats together with those of plot III form groups E, G, H, I, J. In group F occurring only in plot III (Table 2) the exclusive occurrence of *Pino-Quercetum* species was observed.

Table 2
Number of quadrats from 3 sample plots in each group

Quadrat Group	Sample Plot		
	I	II	III
A	2	13	
C		3	
B	8		
D	48	4	
J	16		29
I	7		5
H	4		25
E	1		6
G	14		24
F			11
Total number of quadrats	100	20	100

These relationships between the distinguished groups of quadrats and species are presented by the dendrite method. The dendrite worked out from the sum of differences in species frequencies points to the distinctness of the groups and to the prevalence of *Querco-Carpinetum* and *Pino-Quercetum* species as well as confirms the ordination from group A, which is typical of *Querco-Carpinetum*, to group F consisting exclusively of *Pino-Quercetum* species (Fig. 3).

CONCLUSIONS

The numerical method used in the present work has confirmed the intermediate character of plot I determined by the classical method. This plot has certain groups in common with the remaining sample

plots. The distinctness of plots II and III, which have no groups in common, is also apparent (Fig. 4).

Apart from showing the similarities and differences between patches, association analysis facilitates the study of the successive levels of floristic and ecological differentiation of the area under study, from heterogeneity due to the existence of two different ecological systems

Fig. 3 Quadrat groups arranged in dendrite according to species frequency

to spatial heterogeneity due to uneven distribution of species within phytocenoses. In the first divisions the effects of differentiation of the habitat are prevalent, whose indicators are species distinguished, whereas in the lower levels the factor affecting most the division of the set is competition.

Association analysis can thus be used not only for distinguishing large units of the phytocenosis type, but also for analytical studies within its range and for elucidation of the relationships between the species that make it up.

A great problem in this kind of methods is the choice of the size of the sampling circles or quadrats, as it has a considerable effect on the number of species, the number of their common occurrences and the value of χ^2 . If the sample plots are large, it is possible to distinguish only units corresponding to associations; smaller samples enable the relationships between species to be pinpointed. However, high speed calculations executed with the use of electronic computers make it

Fig. 4 Diagram showing the spatial distribution of quadrats belonging to the 10 groups

possible to analyse large numbers of samples of various size, e.g., putting together data from adjoining basic units and executing computations for progressively increasing sample areas according to the principle of Greig-Smith (1952).

Acknowledgements

I wish to thank Drs A. D. Q. Agnew and J. P. Savidge for supplying the program used in this study and Professor W. Matuszkiewicz for critical reading of the manuscript.

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Zastosowanie metody „analizy asocjacji” do fitosocjologicznej interpretacji zbiorowisk roślinnych w rezerwacie Las Piwnicki koło Torunia

Streszczenie

Stosując numeryczną metodę „analizy asocjacji” (Williams, Lambert 1959, 1960) 220 kwadratów trzech badanych powierzchni rezerwatu Las Piwnicki zaliczono do 10 grup. Za kryterium podziału przyjęto występowanie gatunku osiagającego maksymalną wartość $\Sigma \chi^2$ w każdym cyklu obliczeń. Zastosowana metoda wskazuje na silne zmiany i postępujący proces borowienia w warstwie runa grądowej powierzchni I. Tworzenie wspólnych grup kwadratów z typowo grądową powierzchnią II i borową powierzchnią III potwierdza określony klasyczną metodą Braun-Blanqueta pośredni charakter tej części rezerwatu.