

STUDIA GEOBOTANICA

Vol. 4 1984

EDITORS

E. Aichinger - Klagenfurt
G. Estabrook - Ann Arbor, Mi
D. Lausi - Trieste
E. Mayer - Ljubljana
L. Orłóci - London, On.
F. Pedrotti - Camerino
A. Pirola - Pavia
S. Pignatti - Roma
L. Poldini - Trieste

SECRETARY

E. Wikus Pignatti - Trieste



Dipartimento di Biologia
Sezione di Geobotanica ed Ecologia vegetale
Università di Trieste

INSTRUCTIONS TO AUTHORS

STUDIA GEOBOTANICA publishes original articles in the field of geobotany, in particular contributions to the flora and vegetation of the Eastern Alps and of the Circumadriatic area. It also publishes book reviews, notices of scientific meetings and summaries of proceedings.

MANUSCRIPTS should be submitted in duplicate to an Editor or to the Secretary of the Editorial Board. The Secretary will confirm receipt of the manuscript. The suitability of submitted manuscripts will be judged by appropriate members of the Editorial Board. For specialized articles, appropriate referees will be consulted. The Secretary will inform authors of the acceptance or rejection of manuscripts or the need for substantial revisions or reduction. Manuscripts should be typed, double-spaced, on white bond paper with a 25 mm margin on all sides.

LANGUAGE should be preferably English. Italian, French and German are also accepted.

THE TITLE should be informative and brief. The name (s) of the author(s) should be placed below the title. References to research projects, institutional publication numbers, etc. should be placed in a footnote to the author's names. Acknowledgements and dedications should be simply phrased and given at the end of the article.

KEYWORDS, not more than 10, in English, should be placed on the title page in alphabetical order.

ABSTRACT. An English abstract must be included. A summary in either French, German, Italian or in a Slavian language may also be added. It should not exceed one manuscript page.

LITERATURE. For examples see the published *Studia Geobotanica*.

CHAPTER HEADINGS should be given without designations, second or third order subheadings are permitted.

TABLES should be typed on separate pages, and not in the text itself. They should preferably be submitted in camera-ready form, i.e. typed on an IBM electric typewriter (using, e.g., an 'Artisan' typing element and carbon ribbon). Tables should be typed without corrections in such a way that they can be reduced to one full page (width 120 mm). Large tables should be prepared in the same way. If they cannot be reduced to page-size, they will be inserted as fold-out tables: if possible, this should be avoided.

Tables must be numbered and given descriptive titles. If the tables are not prepared according to these instructions, the publishers reserve the right to ask for a contribution to the actual cost.

ILLUSTRATIONS. Figures such as drawings and graphs should be done in India ink on smooth tracing paper. Names, numbers or other symbols should also be written in India ink or, preferably, by 'Letra-set' or a similar system. Reduction of these figures should be taken into account when preparing the lettering. Titles and legends to the figures should be typed on a separate sheet. All figures should be numbered.

Plates should be avoided, but when used, they should be numbered and supplied with informative titles.

CORRESPONDENCE: on matters related to manuscripts should be addressed to the respective Editor or to the Secretary. Correspondence on manuscripts after acceptance or concerning page proofs should be addressed to the Secretary of the Editorial Board:

Prof. E. Wikus Pignatti, Dipartimento di Biologia - Sezione di Geobotanica ed Ecologia vegetale
I - 34100 TRIESTE (ITALY)

STUDIA GEOBOTANICA

Vol. 4 1984

EDITORS

E. Aichinger - Klagenfurt

G. Estabrook - Ann Arbor, Mi

D. Lausi - Trieste

E. Mayer - Ljubljana

L. Orłóci - London, On.

F. Pedrotti - Camerino

A. Pirola - Pavia

S. Pignatti - Roma

L. Poldini - Trieste

SECRETARY

E. Wikus Pignatti - Trieste



Dipartimento di Biologia
Sezione di Geobotanica ed Ecologia vegetale
Università di Trieste

Fotocomposizione ed impaginazione
Studio Gamma — Trieste

Stampa
Tipo/Lito Astra
Via Cosulich, 9 — Trieste

Contributions to the meetings on:
*SAMPLING AND ANALYSIS OF VEGETATION
PATTERNS*

Trieste, march 23-27, 1984, organized by the Department of Biology - University of Trieste.

Bologna, october 28, 1983 (preliminary meeting on: Classification and Ordination of Vegetation Data) organized by: Società Italiana di Fitosociologia and Società Botanica Italiana, promoted by the Comitato Nazionale per le Scienze Ambientali e Territoriali, in the framework of the activities on "Data Analysis in Ecology".

SOME ASPECTS OF CLASSIFICATION AND ORDINATION OF VEGETATION DATA IN PERSPECTIVE

Enrico FEOLI

Keywords: Classification, Hierarchy, Ordination, Processes, Vegetation.

Abstract. A discussion on the complementarity of classification and ordination methods in vegetation ecology is given. The need to work with different vegetation spaces and hierarchical processes is stressed.

Introduction

Paraphrasing Stebbins (1969) in his "Comments on the Search for a Perfect System", it looks to me that, similar to what others discussed about the species concept, many epigones of the Braun-Blanquet school prefer to believe that the associations are discrete entities, created by God in a particular form, and that the only task of vegetation science is to discover, define and classify these God-given associations. But as Darwin started to question the "Linnean dictum" and his followers have often posed the question in the form of absolute alternatives, it happened that Negri's (Negri, 1914) and Gleason's (Gleason, 1917) epigones took exception with respect to Clements and Braun-Blanquet views. Continuing with the analogy and using the structure of another Stebbins's sentences the question: "are the associations completely objective entities, which exist in nature in only one form, which we must discover, recognize and describe?" or "are they purely man-made artefacts, having no real existence except in the mind of the syntaxonomist?" can be raised. I conclude as Stebbins has done for the species concept, that neither of these extreme points of view is acceptable. Plant associations have a basis in nature but this basis is not so rigid that we can recognize them in only one way. Before leaving Stebbins with his nice novel about King Linnius XIV and his fair daughter, I would like to say that I got the impression that many Negri-Gleason epigones are, more or less consciously feeling that "vegetation is an entity changing in a continuous way along gradients, gradients were created by God in particular form, and that the only task of vegetation science is to discover, define and describe these God-given gradients!". I have been convinced that they in fact think in this way by reading recent papers where the new unity for measuring the vegetation

changes along gradients, the "GLEASON", has been proposed and used. If the authors were of Italian origin, I should have proposed that they would call the unit "NEGRI".

I do not want to initiate another round of discussions on the continuity and discontinuity of vegetation, which I personally consider closed by the illuminating paper of Lieth (1968). I would certainly like to conclude based on other papers (cited in Orłóci, 1978; van der Maarel, 1979; Feoli, Lagonegro & Zampar, 1982) that: "God created simultaneously vegetation types and vegetation gradients in order to make simpler the life for some ecologists and more complicated for others...".

In my opinion, multivariate analysis of vegetation data has future in vegetation science only if the complementary functions of classification and ordination are fully understood and the exercise is directed to study both vegetation types and gradients. This is the main topic I intend to address in my introduction to this meeting.

Vegetation data and vegetation spaces

The vegetation is a multi-variable which can be measured in space and time in many ways. The individual components of this medium can be chosen from among a great number which are biologically relevant. As a consequence, different "schools" of vegetation study evolved (see Whittaker, 1973). Notwithstanding efforts of integration, which have always been active, confusing and rather unpolite discussions still persist. However it is only human to try to inflict one's own ideas on one's neighbour. Fortunately it is also human to expect that the neighbour will react in some specific way.

The quality of the components chosen to describe the vegetation, in trying to understand existing patterns and processes, determines different types of vegetation data, and consequently, different types of spaces in which the vegetation states find their position. Each vegetation state is a vector of m components, the scores of which are coordinates of the state in the space. The m components define the dimensionality of this space. Three main types of spaces can be distinguished: extrinsic, intrinsic and semiextrinsic.

Extrinsic spaces are generated by the abiotic variables. They are used for the so called direct ordinations of vegetation (direct gradient analysis, see Whittaker, 1967). Semiextrinsic (or mixed) spaces are generated by biotic and abiotic variables, while intrinsic spaces by biotic variables.

Intrinsic spaces are used for ordinations in the indirect gradient analysis (see Whittaker, 1973). Since the biotic variables could be of several different types, the intrinsic spaces may be classified in several ways:

- Taxonomic spaces. These are obtained when the vegetation is described by taxonomic characters (species or genera or families etc., see van der Maarel, 1972). Such spaces, consequently, have different hierarchical meanings. The Braun-Blanquet approach is working with the space originated by species, which is the space at the lowest hierarchical level.

- Cytogenetic spaces. These are obtained when the species are described by their degree of polyploidy (Pignatti, 1960) or number of chromosomes with satellites, and so on.

- Structural spaces. These are specific to vegetation descriptions by such structural characteristics as life forms, growth forms, types of leaves, etc. Barkman (1979) uses structure as distinct from texture, which he defines as "the qualitative and quantitative composition of the vegetation as to different morphological elements... regardless of their spatial arrangement". To him, structure is the spatial arrangement (horizontal and vertical) of the morphological elements. This distinction is certainly useful, however, here, I prefer to consider the space originated by textural characters also as a structural space, because the biological parameters used in both cases could be the same.

- Anatomic spaces. These are obtained by using as descriptors anatomic characters, such as those describing the tissue structure (e.g. number of vessels, dimension of vessels, thickness of tissues, etc.), which are related to adaptation. However it appears to me useful to distinguish the anatomic space from structural spaces since I do not see now evident relationship between the anatomy of the plants and the visible structure of the vegetation.

- Functional, physiological spaces. These are obtained by using functional descriptors of the species, such as type of photosynthesis, type of response to stress, type of phenology, etc.

- Biochemical spaces. These are defined by using biochemical characteristics of the species (pigments, oils, vitamins, alkaloids, tannins, etc.).

- Chorological spaces. These are obtained when chorological characters are used.

- Syntaxonomical spaces. These are obtained when the syntaxonomic units are used rather than species as the basis of analysis.

- Sociological spaces. These are obtained when sociological species groups (see Doing, 1969) obtained on local data sets rather than single species are the units (e.g. Feoli & Orlóci, 1979).

Other spaces could be easily mentioned, e.g. evolutive, reproductive, regenerative etc. All of them can be used to describe and interpret vegetation patterns and processes in quantitative ways being the basis on which multivariate methods can be applied.

The taxonomic spaces of higher hierarchical meaning than the species space, cytogenetic space, structural space, anatomic space, functional space, biochemical space, chorological space, syntaxonomical space and sociological space, etc., can be obtained by multiplying the design matrix of species descriptions (k, m) by the matrix of species-vegetation states (m, n). K is the number of character states used to describe the species. A species may be described by a different number of them. Each species will be described by only one in case of taxonomic or sociologic spaces and by one or more in the other cases.

Since all other spaces can be obtained by the space defined by the species, this space can be designated as the basic space. If a matrix multiplication is used, the

axes of the higher hierarchical spaces are all linear combination of variables of the spaces of lower hierarchical level. All these different spaces can be the basis of measuring in an objective way, convergences and divergences of vegetation states in different ecosystems or different phytogeographic areas (see Cody & Mooney, 1978) or in time (see van der Maarel & Werger, 1978). If a suitable function is found the difference between the similarity of two vegetation states in different spaces could be interpreted as a measure of convergence or divergence. Researches in this area have yet to be addressed.

Hierarchical processes, similarity, convergence and divergence

All the spaces described before may be obtained directly by multiplying the matrix 'character states-species' by the matrix 'species-relevés'. However there are other spaces which cannot be originated by a simple multiplication or a series of successive multiplications of matrices. These spaces can be called 'conditioned spaces'. Some examples will clarify the matter and explain the definition.

Let us consider a relevé with six species: a (2), b (1), c (3), d (4), e (5), f (2). In the brackets are the species scores. Such relevé has six non-zero coordinates in the basic space. If a and b belong to genus k , c , d , e to genus l , and f to genus p , then the relevé will have three non-zero coordinates in the space of genera, i.e. k (3), l (12) and p (2). If k and p belong to family t and l belong to family z , then the relevé will have two non-zero coordinates in the space of families, i.e. t (5), z (12). The definition of the spaces follows a hierarchical process of combining the basic axes. In the case of taxonomic spaces the hierarchical process is unequivocally defined by taxonomy and all of them can be obtained by successive matrix multiplication, however in other cases many different hierarchical processes may be defined by different ways of hierarchical combination of the basic axes. A relation of order (see the set theory) may be arbitrarily established in a set of characters. A relation of order establishes automatically a hierarchy. If the following is the chosen hierarchy of a set of characters:

species < leaf type < growth form < life form

than the matrix describing the species (numbers identify character states):

species	leaf type	growth form	life form	scores
a	1	1	2	2
b	2	1	3	1
c	1	2	1	3
d	2	1	1	4
e	1	1	3	5
f	1	3	2	2

is rearranged according to the established hierarchy in the following way:

species	< leaf type	< growth form	< life form	scores
c	1	2	1	3
d	2	1	1	4
a	1	1	2	2
f	1	3	2	2
b	2	1	3	1
e	1	1	3	5

In this case the hierarchical process of combining the basic axes produce two conditioned spaces, the space of leaf types (leaf types / growth forms, life forms) and the space of growth forms (growth forms / life forms). The coordinates of the relevé in the conditioned spaces are the following: (leaf types / growth forms, life forms): 1, 2, 1, 1, 2, 1 (the same as in the basic space); (growth forms / life forms): 3, 4, 2, 2, 6.

If the hierarchy is the following:

species < growth form < life form < leaf type

than the table should be rearranged in the following way:

species	< growth form	< life form	< leaf type	scores
a	1	2	1	2
f	3	2	1	2
e	1	3	1	5
c	2	1	1	3
b	1	3	2	1
d	1	1	2	4

In this case the coordinates in the conditioned spaces are the following: (growth forms / life forms, leaf types) same as in the basic space; (life forms / leaf type): 4, 3, 1, 3, 1. It is evident that the coordinates in the conditioned life form space are different than in the non-conditioned life form space, where they are 7, 4, 6.

Similarity between relevés can be computed in the different spaces. When it is computed in a series of spaces originated according to some hierarchical process, than the convergence of vegetation states or types can be measured. Such convergence may be structural, chemical, cytogenetical, anatomical, etc. The measure of convergence makes sense only in a process. As we can say that the trajectories of two moving points are converging if the points tend to have the same coordinates in a given space, so we can say that two vegetation types or states are converging if their similarity is increasing from the basic space to spaces of higher hierarchical meaning. In vegetation study the measure of convergence is meaningful in all the described spaces in function of time (i.e. convergence during succession) or

in a hierarchical process of space generation. This last aspect is particularly suitable to explore the possibilities of comparing vegetation types at a world scale level (see Lieth, 1968; Box, 1981).

Divergence is the contrary of convergence. We can say that two vegetation states or types are diverging if their similarity is decreasing as a function of time or of the change of the meaning of the space. It is obvious that in the last case divergence should be registered only in limited circumstances as a consequence of the fact that two relevés should not be more different as they are in the basic space. For the study of convergence and divergence suitable measures of similarity should be tested or developed. They should be formulated in such a way to be comparable when applied to different spaces.

Vegetation states and vegetation types

When the vegetation of a given area is under study, it is divided into smaller or larger "portions" (vegetation stands).

These are the basis for the relevés which are the descriptions of the vegetation stands. Given a vegetation sample, i.e. a set of relevés, some basic questions ask for answers: Is the sample heterogeneous? If yes what are the ecological factors influencing the variation, and what of them are the most important in producing variations? These questions are always the basis of some hypothesis formulated by the researcher before the survey. Since the relevés are made at a certain time and a certain place, they describe states of vegetation in time and space. If the area of relevés is very small the state of only one or few individuals of the same or different species is described. If the area of relevés is very large the state of populations of many species could be described. The size of the area is related to the problem under study, however if the definition of vegetation communities is one of the aims of the research, the area should be large enough to represent a "unit of vegetation". In the Braun-Blanquet approach (see Westhoff & van der Maarel, 1973) the concrete unit is the phytocoenosis which is defined as a relatively homogeneous vegetation at a particular site. The weakness of the phytocoenosis concept is the subjective judgement of homogeneity. It appears to me that no operational solution is available to overcome this weakness other than to find ecological justifications for subdivisions or aggregations. The exercise should be considered as the search for definition of vegetation types, for which multivariate methods are suitable tools (Orlóci, 1978). In the Braun-Blanquet approach the sampling is preferential (Orlóci, 1978) and plot size should exceed the so called minimal area. The concept of minimal area may be useful to clarify the concept of phytocoenosis, however it is far to be used for making relevés of unknown vegetation. The minimal area was defined as the smallest area which should hold all the properties, morphological and functional of a phytocoenosis (see Moravec, 1973).

It follows therefore, that the minimal area is itself a property of the phytocoenosis. The definition of the minimal area of a phytocoenosis is not as obvious as it may appear from past uses. The basic problem relies on the fact that not all the species present in a phytocoenosis are typical of that phytocoenosis, because a

given phytocoenosis can contain species and therefore structural and functional characteristics more typical of other phytocoenoses. Dietvorst, van der Maarel & van der Putten (1982) use quantitative data and suggest to link the search with pattern and dominance-diversity studies. I believe that the real problem is the definition of the phytocoenosis before to look for the minimal area.

The argument is clearly circular, however I think the minimal area should be a useful parameter, as many others, to be defined only for well defined phytocoenoses. What means a well defined phytocoenosis? It means one which can be assigned to a plant community (vegetation type). If a typification is lacking the concept should have no relevance in vegetation study, in line with the conclusions of Goodall (1961). If the problem to find a suitable area to do relevés arises, how to define the vegetation types? In my opinion the problem to find a suitable area is occurring also in experimental ecology, when, for example, the interaction between different species is to be studied (see Harper, 1977). Actually the area for relevés is always a matter of subjectivity in all the approaches of vegetation study irrespective to the sampling designs. When in a paper it is declared that the relevés have been done according to the method of Braun-Blanquet, it actually means that the relevés have been done according to the author's pre-interpretation of the vegetation diversity (number of different vegetation types).

Thanks to ability of the human mind to perceive the phenetic diversity, this pre-interpretation is possible in many areas of the world, it is of course more difficult or impossible in tropical and equatorial forests, at least with the usual tools of a traditional european phytosociologist.

Given any set of relevés, numerical methods can be used to define sets of such relevés (classification) and to define the optimal classification in term of internal or external predictivity (predictivity analysis) (see Orlóci, 1978; Feoli, 1983; Popma et. Al., 1983; Feoli, Lagonegro & Orlóci, 1984). Only if a set has biotic and abiotic peculiar characteristics, i.e. characteristics significantly related to the set in terms of probability, then it should be considered a vegetation type.

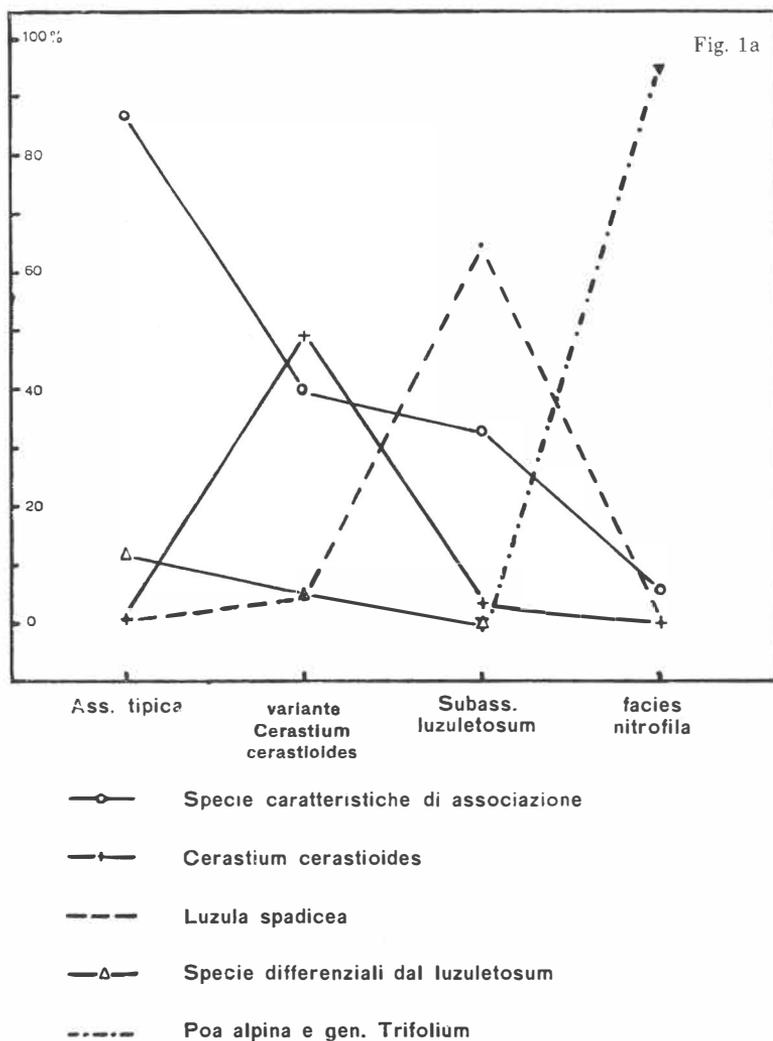
The classification of vegetation states, that can be done in all the mentioned spaces, is nothing less than a process partitioning the spaces. Classifications obtained in different spaces can be compared (congruence of classification, Sneath & Sokal, 1973), methods are largely available (see Orlóci, 1978; Feoli, 1983; Feoli, Lagonegro & Zampar, 1982; Feoli, Lagonegro & Orlóci, 1984). Different classifications may be produced with different hierarchical meaning and interesting different biological scales.

The vegetation study (vegetation science?) is an exercise involving complex systems which can be hierarchically or non-hierarchically classified in different ways, we should be open in this respect and try to explore as many ways as we can see. The vegetation types should be the basic units of vegetation study toward the auspicate development of a *comparative ecology* (see Intelcol Bulletin, 1983). They should be used to study in a more clear context ecosystem functions, infraspecific variations and spatial patterns. An example of the study of primary productivity in bentic ecosystems of the Gulf of Trieste, on the basis of previous defined types, is

offered by Lausi (1967). An example of infraspecific biochemical variation is given by Lokar et Al. (1984), while an example of pattern analysis by Juhasz Nagy & Podani (1983).

Ordination versus classification?

The possibility to distinguish vegetation types in the different spaces is due to the fact that the different species have different ecological amplitude in respect to single ecological factors and respond to them in different ways. On the other hand the fact that the niches of the species (geometric niche, sensu Hutchinson, see Hurlbert, 1981) are overlapping, is responsible of the similarity between vegetation



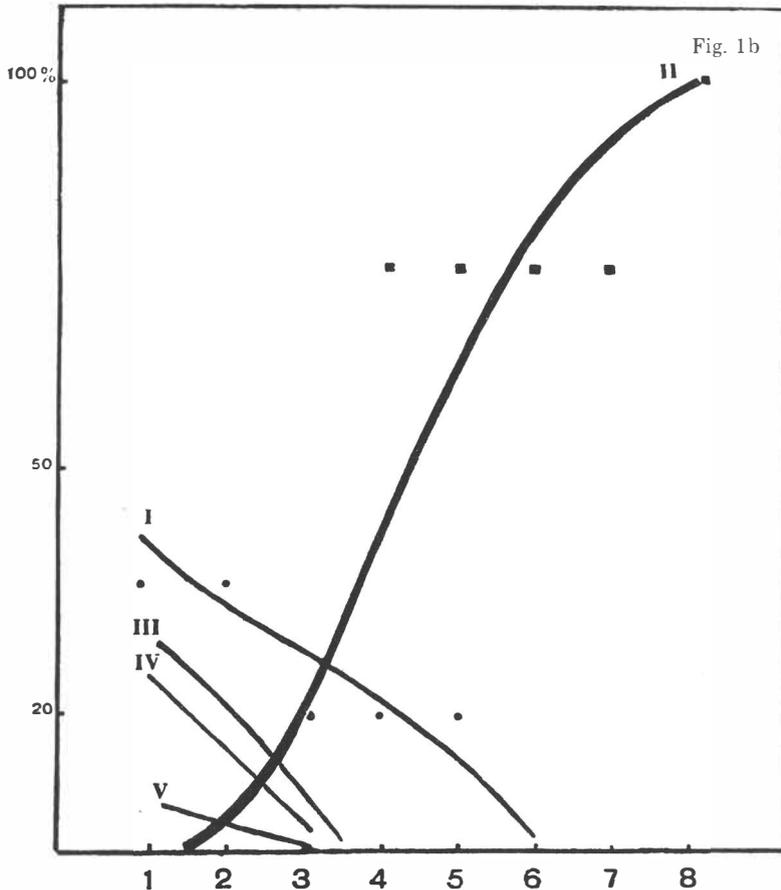


Fig. 1 — Species and groups of species responses to a gradient of nutrients (Fig. 1a) and to a gradient of soil texture (Fig. 1b). From Pirola (1959).

states and vegetation types ("continuum"). In a situation of similarity between vegetation states it necessarily could happen that many relevés can not be attributed significantly (by classification and identification methods, see Orlóci, 1978; Feoli, Lagonegro & Orlóci, 1984 and Goodall, 1968 for an alternative method based on probability) to one of the types, because of its intermediate position between two or more types in the space under study. This fact should not to be seen as a failure of classification or identification methods, but just a prove of the continuous data structure (see Orlóci, 1979) and therefore of gradual vegetation variation.

The ordination of vegetation was far to be only an exercise of north-american plant ecologists, examples can be found in the Braun-Blanquet's books and in many papers of european phytosociologists (eg. Pignatti, 1966). In the Braun-Blanquet approach it was given more emphasis to the study of total vegetation variation

rather than variation of response of single species. However the decomposition of variation in components related to single species or groups of species was focused several times.

An example, similar both to the coenocline representation of Whittaker (1967) for single species and that for species groups (Poldini & Feoli, 1976; Feoli & Lagonegro, 1982), is given in Fig. 1 from Pirola (1959).

In the study of vegetation it is quite difficult to meet a situation in which only one factor is varying when all the others remain relatively constant (Whittaker, 1967).

The simple example by Feoli Chiapella & Ganis (1980) proves in a relatively easy circumstance, the inadequacy, or better the inferiority of a direct gradient analysis in respect to the indirect method.

However if such a favourable situation is met, as it looks possible also from the paper of Austin et. al. (1984), the definition of vegetation types along the dominant gradient and within a well defined interval, can help to measure the so called *beta* diversity more correctly than it was done by Whittaker and his followers. Strictly speaking the diversity of a system is defined both by its richness, i.e. the number of its entities, and equitability or evenness, i.e. the way in which a certain quantity (number of individuals, biomass, cover, etc.) is distributed among the entities. It follows that it is conceptually weak to measure diversity by some way that does not take into account richness and evenness, at least if the *beta*, before the world diversity, would not have the property to change the meaning of diversity.

The measures of *beta* diversity suggested by Whittaker and followers (see Wilson & Mohler, 1983) are just measures of homogeneity or heterogeneity of vegetation along gradients. Rates of changes can be easily computed on the basis of any resemblance function judged suitable and the model presented in Fig. 2. A more appropriate measure for *beta* diversity should be based on the number of different vegetation types defined along the gradient (richness) and on the basis of the proportional extension of each type along the gradient (evenness). By this approach, if along a gradient, within a defined interval, there is only one type, the *beta* diversity is zero and the measurable diversity is only the *alfa* diversity.

The multivariate ordination methods, linear or non-linear (see Orłóci, 1978; 1979; Fewster & Orłóci, 1983) are mainly used to reduce the dimensionality of the spaces (all the mentioned spaces can be the objects of the reduction) with the aim to explore more easily the structure implicit in the data set, i.e. to detect the mutual position in the space of both vegetation states and vegetation descriptors. In the first case we are looking for similarity and trends of variation, in the second case for pattern of correlation between the descriptors. Both serve to discover the correlation between the intrinsic descriptors and the abiotic factors for causal analysis of vegetation variation (also in time, see van der Maarel & Werger, 1978) and for predictions (see Feoli, 1983).

The ordination methods impose an artificial order into the vegetation spaces by giving rise to ordination spaces (see Orłóci, 1974, for a description of information flow in ordination). The order imposed by the methods is more artificial as more the dimensions of the original spaces are reduced.

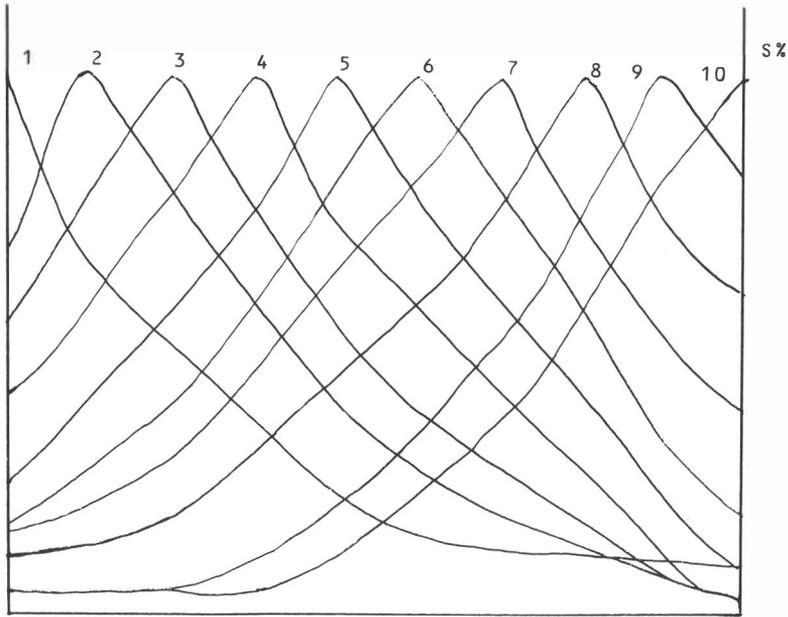


Fig. 2 — Curves of similarity of each relevé with all the other in an ordered sequence along a hypothetical gradient. The model can serve to quantify changes along gradients.

What is wrong by partitioning the ordination spaces according to some classification?

The operation allows one to analyse the spatial relationships between less entities than those original. Each of the new entity (set) is a cloud of points for which position and dispersion parameters could be computed (centroids, variances around the centroids) as well as some other shape parameters. Each point has now an extra set of new coordinates, i.e. those related to the centroid of the cloud to which it belongs and those related to the centroids of the other clouds. It is obvious that a great deal of informations has been introduced in the ordination space, these should be useful to understand the reticulate relationships between the vegetation types and between vegetation types and abiotic factors. The ordination spaces can be used in several ways to aid understanding. The superimposition of classifications (eg. Lausi & Feoli, 1977), minimum spanning trees, or values of other vegetation descriptors to detect isocoenes (Van der Maarel, 1969, 1972) are the most frequent. Ordination spaces can be presented also with the aim to reveal clusters as suggested by Andrews (see Everitt, 1978 and Mardia et. al., 1979) and they have been used explicitly for classification purposes (Parks, 1970; Noy Meir, 1973; Hill, Bunce & Shaw, 1975; Poldini & Feoli, 1976; Wildi, 1979), while some ordination methods as discriminant analysis (see Williams, 1983) and concentration analysis (Feoli & Orlóci, 1979) cannot be performed without previous classifications.

Ordinations within defined vegetation types give informations about the variability of the types and of the species within the types. An example is given by Grabherr (1979).

Ordinations of vegetation types by their centroids or frequency vectors have been the subject of several studies (e.g. Lausi & Feoli, 1977; Komarkova, 1980; Feoli & Lagonegro, 1982; Torok & Podani, 1982). The ordinations may reveal many informations about the ecology of the species. By superimposing the scores of the species on the ordination diagrams detailed patterns of distributions and information about ecological optima within the sample can be obtained for all the species. This way of using ordinations has not been yet fully explored, however it is in line with the Westhoff's views (see van der Maarel & Werger, 1978b).

Conclusions

I am not interested in answering a question whether vegetation study is a science or a pseudoscience, whether it is mature or non-mature; I think its role in understanding vegetation variation quite clear. Since vegetation is a complex system it is obvious that many approaches can be used to look into it, and that many different biological aspects can be considered as of relevance in understanding its functioning. Multivariate methods of classification and ordination are suitable tools to detect vegetation variation in respect of different biological phenomena. Classification is useful to detect vegetation diversity, ordination to detect vegetation order. We cannot speak about convergence between classification and ordination of vegetation (see Whittaker, 1972), they are just two complementary approaches that should not be bound respectively with the continuum or discontinuum ideologies. The methods can work in different vegetation spaces of biological relevance. The detection of vegetation order and vegetation diversity has nothing to do with problems related to holism or reductionsim (see Harper, 1982) (are they real problems?); diversity and order offer frames and patterns within which the total vegetation variation can be hierarchically decomposed. The decompositions may concern different phenomena down to the infraspecific variation of characters "unfortunately" (?) not used for taxonomic purposes (see again Harper, 1982) or used for very detailed taxonomic purposes (see Landolt, 1977) or for studying clinal variations (see Stebbins, 1973; Endler, 1977). The analysis of correlation between different characters useful to describe and explain variation in vegetation and the analysis of correlation patterns between such characters and environmental factors, can be a fruitful exercise directed to understanding problems related to the coexistence of different species in the same vegetation type, and the existence of a determinate structure of a vegetation type. Methods to measure such correlation can be based on both classification and ordination (see Feoli & Scimone, 1984, for a recent review in relation to the textural analysis of vegetation). Methods to measure redundancy (Orlóci, 1975; Rohlf, 1977; Feoli, Lagonegro & Orlóci, 1984) are particularly useful in decomposing total variation into the specific and common components.

An approach based on multivariate methods is clearly descriptive, but so open

that I can hardly see where it leads. Of course other approaches should be used in parallel, e.g. modelling (see Jeffers, 1982) and experimenting (see also Goodall, 1970). However, at least for me, it is difficult to make a clear separation between the descriptive approach and the experimental one, the description of the results being a necessary step after experimentation.

Description after experimentation should not be looked at in one way only; different hierarchical processes could be established also in describing experimental results!

There are many problems in describing vegetation (such problems actually render the topic interesting). The most important are related to sampling and the scale used (see Bouxin & Boulenge, 1983). Vegetation types can be defined at different scales, and they can be hierarchically arranged in various ways.

Syntaxonomy (in its broad sense, see Feoli, Lagonegro & Biondani, 1981, Maarel, van der, 1981), should be open in this respect. It should not claim to build up a general hierarchical system using only the species to characterize all the hierarchical levels (see Maarel, van der, 1972).

The introduction of multivariate methods into vegetation study offers now two new perspectives: a first related to different vegetational abstract spaces and a second related to hierarchical processes in arranging biological characters.

These should break barriers between different botanical approaches and should help the investigation into vegetation phenomena to become more consistent on the basis of underlying logical models.

Acknowledgements. I would like to thank prof. L. Orlóci and prof. D. Goodall for reading and correcting parts of the text. The Italian M.P.I. and C.N.R. supported the research.

References

- Austin M.P., Cunningham R.B. & Flemming P.M. (1984) - *New approaches to direct gradient analysis using environmental scalars and statistical curve-fitting procedures*. *Vegetatio*, 55: 11-27.
- Barkman J.J. (1979) - *The investigation of vegetation texture and structure*. In M.J.A. Werger (ed.) "The study of Vegetation". Junk, The Hague, Boston.
- Bouxin G. & Le Boulenge E. (1983) - *A phytosociological system based on multiscaled pattern analysis: a first example*. *Vegetatio*, 54: 3-16.
- Box E.O. (1981) - *Macroclimate and plant forms: an introduction to predictive modelling in phytogeography*. Task for Vegetation Science. 1. Junk, The Hague.
- Coassini Lokar L., Poldini L. & Sinosich E. (1984) - *Evidence for the existence and spatial distribution of some chemical varieties of *Helleborus multifidus* subsp. *istriacus* (Schiffner) Merxm. & Pod. in the North-Adriatic Karst region*. *Oecologia plantarum* (in press).
- Cody M.L. & Mooney H.A. (1978) - *Convergence versus nonconvergence in mediterranean-climate ecosystems*. *Ann. Rev. Ecol. Syst.* 9: 265-321.
- Dietvorst P., Maarel E. van der & Putten H. van der (1982) - *A new approach to the minimal area of a plant community*. *Vegetatio* 50: 77-91.
- Doing H. (1969) - *Sociological species groups*. *Acta Bot. Neerl.*, 18 (2): 398-400.
- Endler J.A. (1977) - *Geographic variation, speciation and clines*. Princeton University Press.
- Everitt B. (1978) - *Graphical techniques for multivariate data*. Heinemann Educational Books, London.
- Feoli E. (1983) - *Predictive use of ordination and classification methods in plant community ecology. A summary with examples*. In Ferrari et. al. (eds.) "Le comunità vegetali come indicatori ambientali",

- Regione Emilia Romagna, Studi e Documentazioni, 30: 83-108.
- Feoli E. & Lagonegro M. (1982) - *Syntaxonomical analysis of beech woods in the Apennines (Italy) using the program package IAHOPA*. Vegetatio, 50: 129-173.
- Feoli E. & Orlóci L. (1979) - *Analysis of concentration and detection of underlying factors in structured tables*. Vegetatio, 40: 49-54.
- Feoli E. & Scimone M. (1984) - *A quantitative view of textural analysis of vegetation and examples of application of some methods*. Arch. Bot. Biogeogr. Ital. 60: 73-94.
- Feoli E., Lagonegro M. & Biondani F. (1981) - *Strategies in Syntaxonomy: a discussion on two classifications of grasslands of Friuli (Italy)*. In H. Dierschke (ed.) "syntaxonomy", pp. 95-107. Cramer, Vaduz.
- Feoli E., Lagonegro M. & Orlóci L. (1984) - *Information analysis of vegetation data*. Task for Vegetation Science, 10. Junk, The Hague, Boston.
- Feoli E., Lagonegro M. & Zampar A. (1982) - *Classificazione e ordinamento della vegetazione. Metodi e programmi di calcolo*. CNR - AQ/5/35.
- Feoli Chiapella L. & Ganis P. (1980) - *Analisi di gradiente altitudinale in faggete del M. Pura (Alpi Carniche)*. Gortania, 2: 157-166. Udine.
- Fewster P.M. & Orlóci L. (1983) - *On choosing a resemblance measure for non-linear predictive ordination*. Vegetatio, 54: 27-35.
- Gleason H.A. (1917) - *The structure and development of the plant association*. Bull. Torrey Bot. Club., 44: 463-481.
- Goodall D.W. (1961) - *Objective methods for the classification of vegetation. IV. Pattern and minimal area*. Aust. J. Bot., 9: 162-196.
- Goodall D.W. (1968) - *Affinity between an individual and a cluster in numerical taxonomy*. Biometrie-Praximetrie, 9: 52-55.
- Goodall D.W. (1970) - *Studying the effects of environmental factors on ecosystems*. In: Ecological Studies, Analysis and Synthesis. Vol. 1. Analysis of temperate Forest Ecosystems, ed. D.E. Reichle, Springer-Verlag, pp. 19-29. Berlin.
- Grabherr G. (1979) - *Variability and ecology of the alpine dwarf shrub community Loiseleurio-cetrarietum*. Vegetatio 41: 111-120.
- Harper J.L. (1977) - *The population biology of plants*. Academic Press, London.
- Harper J.L. (1982) - *After description*. In E.I. Newman (ed.) "The Plant Community as a Working Mechanism". Special Publications Series of the British Ecological Society, n. 1. Blackwell Scientific Publications.
- Hill M.O., Bunce R.G.M. & Shaw M.W. (1975) - *Indicator species analysis, a divisive polythetic method of classification and its application to a survey of native pinewoods in Scotland*. J. Ecol. 63: 597-613.
- Hurlbert S.H. (1981) - *A gentle depilation of the niche: Dicean resource sets in resource hyperspace*. In May R.M. (ed.) "Evolutionary theory" 5: 177-184. The University of Chicago.
- Intercol Bulletin (1983) - *Summary*.
- Jeffers J.N.R. (1982) - *Modelling*. Chapman & Hall, London, New York.
- Juhasz-Nagy P. & Podani J. (1983) - *Information theory methods for the study of spatial processes and succession*. Vegetatio, 51: 129-140.
- Komarkova V. (1980) - *Classification and ordination in the Indian Peaks area, Colorado Rocky Mountains*. Vegetatio, 42: 149-163.
- Landolt E. (1977) - *The importance of closely related taxa for the delimitation of phytosociological units*. Vegetatio, 34: 179-189.
- Lausi D. (1967) - *Quantità di clorofilla negli ecosistemi bentonici del Golfo di Trieste*. Nova Thalassia, 3: 1-29.
- Lausi D. & Feoli E. (1979) - *Hierarchical classification of European salt marsh vegetation based on numerical methods*. Vegetatio, 39: 171-184.
- Lieth H. (1968) - *Continuity and discontinuity in ecological gradients and plant communities*. The Botanical Review, 34: 291-302.
- Maarel van der E. (1972) - *Ordination of plant communities on the basis of their plant genus, family and order relationships*. In E. van der Maarel & R. Tuxen (eds.) "Basic problems and methods in phytosociology". Junk, The Hague.

- Maarel van der E. (1979) - *Multivariate methods in phytosociology with reference to The Netherlands*. In M.J.A. Werger (ed.) "The study of vegetation". Junk, The Hague.
- Maarel van der E. (1981) - *Some perspectives of numerical methods in syntaxonomy*. In H. Dierschke (ed.) "Syntaxonomy", Cramer, Vaduz.
- Maarel van der E. & Werger M.J.A. (1978) - *On the treatment of succession data*. Phytocoenosis, 7 (1/2/3/4): 257-278. Warszawa.
- Maarel van der E. & Werger M.J.A. (eds.) (1978) - *Plant species and plant communities*. Junk, The Hague.
- Mardia K.V., Kent J.T. & Bibby J.M. (1979) - *Multivariate analysis*. Academic Press, London, New York.
- Moravec J. (1973) - *The determination of the minimal area of phytocoenoses*. Folia Geobot. Phytotax., 8: 23-47. Praha.
- Negri G. (1914) - *Le unità ecologiche fondamentali in fitogeografia*. Atti R. Accad. Scienze, 49: 1-14. Torino.
- Noy-Meir I. (1973) - *Divisive polythetic classification of vegetation data by optimized division on ordination components*. J. Ecol., 61: 753-760.
- Orlóci L. (1974) - *On information flow in ordination*. Vegetatio, 29: 11-16.
- Orlóci L. (1975) - *Measurement of redundancy in species collections*. Vegetatio, 31: 65-67.
- Orlóci L. (1978) - *Multivariate analysis in vegetation research*. 2nd ed., Junk, The Hague, Boston.
- Orlóci L. (1979) - *Non-linear data structures and their description*. In L. Orloci, C.R. Rao & W.M. Stiteler (eds.) "Multivariate methods in ecological work". Statistical Ecological Series, 7. International Co-operative Publishing House.
- Parks J.M. (1970) - *FORTTRAN IV program for a Q mode cluster analysis on distance function with printed dendrogram*. Comp. Contrib. 46, State Geol. Survey, Univ. of Kansas, Lawrence.
- Pignatti S. (1960) - *Il significato delle specie poliploidi nelle associazioni vegetali*. Ist. Ven. Sci. Lett. Arti, 118: 75-98. Venezia.
- Pignatti S. (1966) - *La vegetazione alofila della Laguna veneta*. Ist. Ven. Sci. Lett. Arti, 33: 1-174. Venezia.
- Pirola A. (1959) - *Flora e vegetazione periglaciale sul versante meridionale del Bernina*. Flora et Vegetatio Italica, 1, pp. 115, Gianasso, Milano.
- Poldini L. & Feoli E. (1976) - *Phytogeography and syntaxonomy of the Caricetum firmiae S.L. in the Carnic Alps*. Vegetatio, 32: 1-10.
- Popma J., Mucina L., Tongeren van O. & Maarel van der E. (1983) - *On the determination of optimal levels in phytosociological classification*. Vegetatio, 52: 65-75.
- Rohlf F.J. (1977) - *A note on the measurement of redundancy*. Vegetatio, 34: 63-64.
- Sneath P.H.A. & Sokal R.R. (1973) - *Numerical taxonomy*. Freeman, San Francisco.
- Stebbins G.L. (1969) - *Comments on the search for a perfect system*. Taxon, 18: 357-359.
- Stebbins G.L. (1973) - *Ecological distribution of centres of major adaptive radiation in Angiosperms*. In D.H. Valentine (ed.) "Taxonomy phytogeography and evolution". Academic Press, London and New York.
- Torok K. & Podani J. (1982) - *A numerical analysis of Karstic Bush Forests of Gewese Hills, Hungary*. Documents Phytosociologiques, 6: 339-354.
- Westhoff V. & Maarel van der E. (1978) - *The Braun-Blanquet approach*. In R.H. Whittaker (ed.) "Classification of plant communities", pp. 287-399. Junk, The Hague.
- Wildi O. (1979) - *A space analysis for recognition of nodes in vegetation samples*. Vegetatio, 41: 95-100.
- Williams B.K. (1983) - *Some observations on the use of discriminant analysis in ecology*. Ecology, 64: 1283-1291.
- Wilson M.V. & Mohler C.L. (1983) - *Measuring compositional change along gradients*. Vegetatio, 54: 129-141.
- Whittaker R.H. (1967) - *Gradient analysis of vegetation*. Biol. Rev., 42: 207-264.
- Whittaker R.H. (1972) - *Convergences of ordination and classification*. In E. van der Maarel & R. Tuxen (eds.) "Basic problems and methods in phytosociology". Junk, The Hague.
- Whittaker R.H. (1973) - *Ordination and classification of communities*. Handbook of Vegetation Science, 5. Junk, The Hague.

Enrico Feoli
Dipartimento di Biologia
Università degli Studi di Trieste
34100 Trieste, Italia

UN PUNTO DI VISTA SULLA CLASSIFICAZIONE DELLA VEGETAZIONE

Giovanni CRISTOFOLINI

"When the views advanced by me in this volume... are generally admitted... systematists will be able to pursue their labours as at present; but they will not be incessantly haunted by the shadowy doubt whether this or that form be a true species. This, I feel sure and I speak after experience, will be no slight relief".

Ch. Darwin, 1857

La sistematica dei vegetali si muove ormai da più d'un secolo in una sostanziale ambiguità tra spirito evoluzionista e prassi linneana. Mentre lo spirito evoluzionista suggerisce di rivolgere l'attenzione soprattutto alle variazioni continue, alle forme intermedie, a tutto ciò che è indice di processi in divenire, dall'altra parte la prassi linneana richiede la catalogazione in caselle chiuse, l'identificazione di *Typi*, la ricerca di discontinuità. Lo spirito gerarchico linneano ha trovato una giustificazione (ma solo parziale!) nella dottrina della filogenesi: per cui la gerarchia che in Linneo è soltanto formale e di comodo, viene elevata dall'evoluzionismo ad immagine dell'albero filogenetico monofiletico. Verso la fine del secolo scorso e nei primi decenni di questo, una scuola soprattutto Centroeuropea tentò di ingabbiare la variabilità continua e multiforme dei taxa "critici" mediante la descrizione di una pletora di *Typi* ed inquadrandoli in una gerarchia sempre più complessa (un buon esempio è offerto da Ascherson e Graebner). Pare sfuggire a questi ricercatori che la questione non è tanto di descrivere moltitudini di *Typi* quanto di affrontare la contraddizione (non nuova per la scienza) fra natura continua e schema discontinuo; e che la questione non è tanto di creare gerarchie sempre più complesse, quanto di verificare se una classificazione gerarchica ha veramente una corrispondenza in natura, cioè se la gerarchia illustra ed illumina qualche cosa di reale, o se è solo una camicia di forza.

La risposta non è univoca, nè al primo quesito nè al secondo.

Pragmaticamente, il sistematico può rispondere che una classificazione tipologica è necessaria per disporre di un vocabolario, e che di conseguenza si deve

accettare anche l'assunto della discontinuità, pur conoscendone i limiti e tenendoli in conto. E parimenti lo stesso sistematico può rispondere che egli adotta una classificazione gerarchica quando sa (o crede) che l'insieme dei vegetali che egli tratta costituiscono un insieme monofiletico, dove i livelli gerarchici della classificazione corrispondono a stadi successivi del processo storico di diversificazione. Si può discutere a lungo se queste risposte siano soddisfacenti; ma di fatto sono le risposte che, in modo esplicito od implicito, dà il sistematico evoluzionista. (Qualcuno invece, e non senza ragioni, preferisce separare la dottrina evoluzionista dalla sistematica, e praticare una pura sistematica fenetica formale. In questo caso tutto il problema è evitato; resta però da discutere quale valore conoscitivo abbia una sistematica siffatta).

La sistematica fitosociologica, da Braun-Blanquet in poi, è cresciuta portando in sé l'impronta della sistematica delle specie, della quale ha mutuato i modelli, la tipificazione, la gerarchia. La natura dell'unità tassonomica di base, l'associazione, ha reso però ancora più difficile la classificazione, sia nell'aspetto della tipificazione che in quello della gerarchizzazione. La tipificazione è resa più ambigua dal fatto che l'aspetto "continuo" è di gran lunga più rilevante nella diversità della vegetazione di quanto non lo sia nella diversità della flora: è sostanzialmente una conseguenza di questo aspetto il fatto che la definizione dell'unità di base, l'associazione, sia ancor più incerta della definizione della specie. La gerarchizzazione è resa più arbitraria in quanto non può ambire a riprodurre un fenomeno oggettivo quale è la filogenesi nella sistematica delle specie. La gerarchizzazione fitosociologica agglomera i tipi secondo parametri scelti e ponderati arbitrariamente dall'operatore, ed è sostanzialmente fenetica.

Ci si può chiedere fino a qual punto sia vantaggioso e proficuo da un punto di vista conoscitivo condurre la sistematica delle associazioni sulle tracce della sistematica delle specie, per ritrovarne amplificati gli ostacoli e per non trovarne i vantaggi. In particolare, i sistemi gerarchici di classificazione ingabbiano il complesso reticolo multidimensionale delle affinità fra fenomeni in un angusto schema ad una dimensione.

Tali sistemi sacrificano alla comodità di schematizzazione una larghissima parte di informazione, non rispecchiano tuttavia un fenomeno reale ma uno schema mentale del classificatore, secondo un principio fondamentale linneano.

Una sfida per il sistematico come per il fitosociologo contemporaneo può essere (1) trovare le vie per limitare il peso del *Typus*, introducendo sempre più, nella descrizione dei fenomeni (specie, associazioni) parametri che rappresentino la variabilità, e (2) rappresentare i rapporti tra i fenomeni (classificazione) mediante un uso sempre più largo di schemi multidimensionali e non gerarchici tali da rispecchiare nel modo più completo la complessità dei rapporti stessi: in altre parole affidare l'interpretazione a processi di ordinamento e limitare la classificazione alla funzione di catalogazione.

Giovanni Cristofolini
Istituto di Botanica
Università di Bologna, Italia

EVALUATION OF VEGETATION CLASSIFICATIONS FROM PEATLANDS IN THE DOLOMITES (S-ALPS)

Renato GERDOL & Marcello TOMASELLI

Keywords. Ecology, Information theory, Numerical classifications, Peatland vegetation, Phytosociology.

Abstract. Numerical classifications of peatland communities from the Dolomites are compared by means of information functions. Classifications were evaluated considering both the structure of contingency tables (species groups \times relevé groups) and the correlation between vegetation types and peat chemistry. A remarkable result is the coincidence of the results obtained by internal and external criteria.

Introduction

Vegetation classifications obtained by different methods may differ substantially from each other (Orlóci, 1978; Feoli & Gerdol, 1982). Because of this, the need of evaluating clustering results on a formal basis arises. An evaluation may be done either by internal or by external criteria (Feoli *et al.*, 1981). When internal criteria are used, the evaluation is concerned with the sharpness of differences between sets of relevés in terms of species composition. If external criteria are used, the predictivity of a given clustering result with respect to external variables (not included in the classification; e.g. abiotic parameters measured in relevé sites) is the basis for evaluation.

The main aim of this paper is to evaluate the efficiency of clustering procedures applied to peatland vegetation. The criteria include i) the correlation between ecological species groups and relevé sets (internal criterion) and ii) the predictivity of vegetation types regarding peat chemistry (external criterion).

The study area

The Dolomites are part of the Southern Alps (Fig. 1). Rocks deposited in the Mesozoic are most common, primarily dolomite, giving rise to the imposing mountain groups well-known to climbers all over the world, and secondarily limestones, carbonaceous sandstones as well as marls.

Peatlands are rather uncommon in the Dolomites, as the above mentioned rock types greatly enhance drainage. Nevertheless, peatlands are developed from the thalwegs to the alpine vegetation belt. They rarely cover areas larger than 5 ha.

Examples of fairly large peatlands are found only at the Alpe di Siusi (Seiseralm) on impermeable sandstones and marls. Siliceous rocks (mainly porphyrites and phyllites) are sporadic in the Dolomites. The peatlands developed on siliceous substratum were not considered in this study, since their ecology and syntaxonomy can be solved only within a vast scale research work.

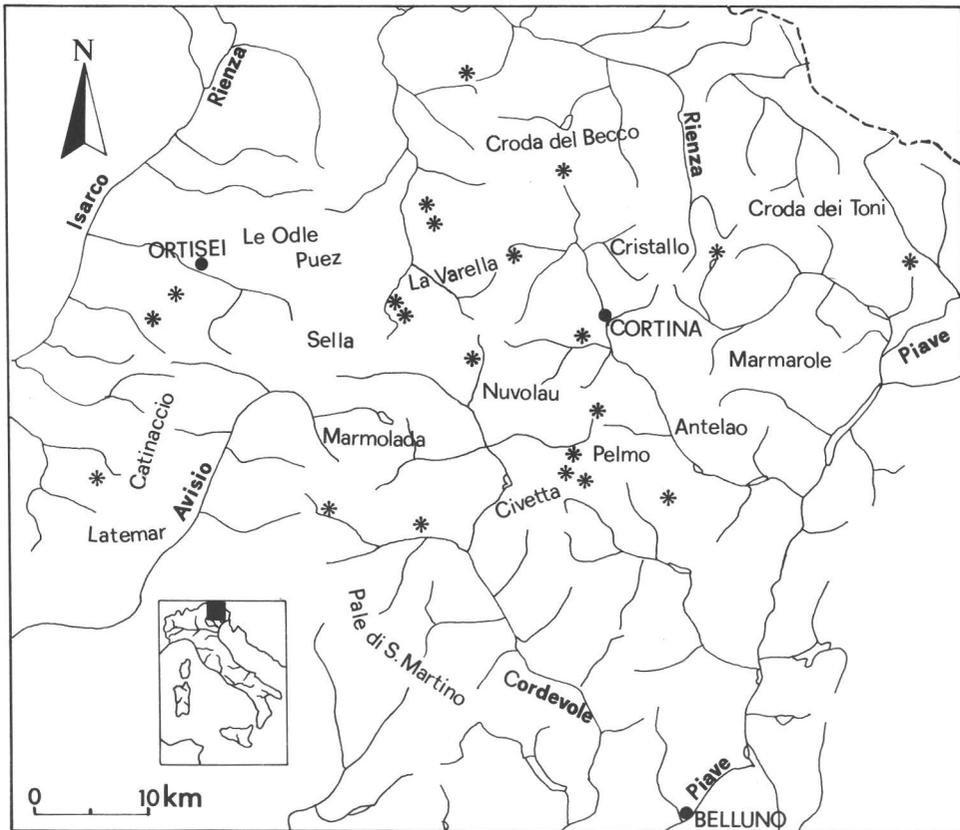


Fig. 1 — Map of the study area. Asterisks indicate the relevé sites.

Methods

The vegetation sampling followed the Braun-Blanquet method. Relevés were taken from localities considered representative of peatland vegetation in the study area (Fig. 1). The original data set was reduced by exclusion of i) species occurring in one relevé only; ii) species not belonging to the characteristic combination of

species (see Braun-Blanquet, 1964) not present in more than two relevés and iii) species accounting for less than 10% of the mutual information (Orlòci, 1976) of the matrix obtained after elimination of the rare species as identified above. All computations started from the reduced matrix.

Species nomenclature follows Pignatti (1982) for vascular plants and Augier (1966) for bryophytes. The clustering techniques employed for classifying the relevés include average linkage clustering between merged groups (ALCB) based on the similarity ratio, average linkage clustering within new groups (ALCW) based on the similarity ratio, and sum of squares clustering (SSA) based on the Euclidean distance. The species were clustered by ALCB based on the product moment correlation coefficient. Description of the clustering algorithms and computer programs is given in Anderberg (1973). Both binary and cover data were utilized in the classifications. The latter are transformations of the Braun-Blanquet cover values according to the following scale: $r = 1$, $+$ = 2, $1 = 3$, $2 = 5$, $3 = 7$, $4 = 8$, $5 = 9$ (van der Maarel, 1979).

An analysis of concentration (Feoli & Orlòci, 1979) was applied to the contingency matrix built up by calculating the mean cover values of each of the species groups in the vegetation types resulting from the relevé classification. The association between species groups and sets of relevés was demonstrated in this way.

Chemical determinations were made in water pressed from peat samples from 19 relevé sites; pH and electrical conductivity were measured since these variables are usually considered important characteristics of peatlands (Sjörs, 1950). As discussed in the introduction, these measurements were used to evaluate the classification results. They were not intended to provide a complete ecological description for which still other variables would be required, such as anion and cation concentration (Malmer & Sjörs, 1955; Malmer, 1958; Sonesson, 1970; Waughman, 1980). pH was measured by a Hanna HI-8014 portable pHmeter equipped with a glass electrode. Electrical conductivity was measured by a Hanna HI-8033 portable conductivitymeter equipped with a polyvinylchloride electrode. The conductivity values were not corrected by subtracting the conductivity due to hydrogen ions, as suggested by Sjörs (1950), because the original values are presumed to be weakly affected by the H^+ influence owing to the relatively high pH values measured in all samples.

For evaluating the classification results in terms of species composition (internal criterion), several contingency tables were constructed. They include the mean cover values of each species group in the sets of relevés recognized at different hierarchical levels in the corresponding dendrogram. The following index (Feoli & Lausi, 1980) was calculated for each of the tables:

$$D(F_{i\cdot}; F_{\cdot j}) = I(F_{i\cdot}; F_{\cdot j}) / (2I(F_{i\cdot}; F_{\cdot j}) - I(F_{i\cdot}; F_{\cdot j}))$$

where $I(F_{i\cdot}; F_{\cdot j})$ is the mutual information

$I(F_b, F_j)$ is the joint information.

For evaluating the classification results in terms of their predictivity regarding ecological conditions (external criterion), the mutual information was calculated for the contingency tables including the frequency distributions of the equivalence classes for the chemical variables in the vegetation types at the hierarchical levels tested by internal criteria. The formula is (Feoli, 1976);

$$I = \sum_i^r \sum_j^c f_{ij} \ln(f_{ij} f / f_i f_j)$$

where r = number of rows in table

c = number of columns in table

f_{ij} = a value in the ij-cell

f_i = a row total

f_j = a column total

f = the grand total.

Results

Data reduction

The data matrix obtained by species reduction as described above is given in Table 1. Species and relevés are arranged in groups according to the results of cluster analysis. Four species occurring in nearly all relevés account for less than 10% of the mutual information: *Trichophorum caespitosum*, *Molinia caerulea*, *Potentilla erecta* and *Carex fusca*; these species were eliminated. The list of rare species is available on request by the authors.

Table 1 - Phytosociological table.

SM - *Sphagnetum magellanicum*; SC - *Sphagnum compactum* community; SW - *Sphagnum warnstorffii* community; SL - *Scorpidio-Caricetum limosae*; ES - *Eriophoretum scheuchzeri*; PC - *Parnassio-Caricetum fuscae*.

	SM									SC									SW									SL									ES									PC								
Relevé n.	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
<i>Vaccinium myrtillus</i>						2	2	2																																														
<i>Callipogon argutus</i>						2	2	2																																														
<i>Sphagnum rubellum</i>						8	9	3																																														
<i>Calluna vulgaris</i>	3	2	3	5	3	5	5	3																																														
<i>Eriophorum vaginatum</i>	3	3	7	2	3	3	5																					2	3	2	2																							
<i>Sphagnum magellanicum</i>						3	5																																															
<i>Carex nauciflora</i>	5	7	2			3	5	2																																														
<i>Sphagnum quinquetarum</i>						9	8	8																																														
<i>Myrica anomala</i>						5	2	3	2																																													
<i>Sphagnum acutifolium</i>						5	3		5																																													
<i>Vaccinium uliginosum</i>						2	2	5	3	2	3																																											
<i>Polytrichum strictum</i>						3	5	7	5	5	3																																											
<i>Avenella flexuosa</i>						2	5	2	3																																													
<i>Vaccinium vitis-idaea</i>						3	2	3	3																																													

Classification of species

Nine clusters were recognized in the classification dendrogram of species at a correlation level of about 0.20 (Fig. 2a). These clusters can be interpreted as ecological species groups. Each species group is designated by the name of two phytosociologically and ecologically significant species. Comments regarding composition are given in the following. The list of species is given in Table 1

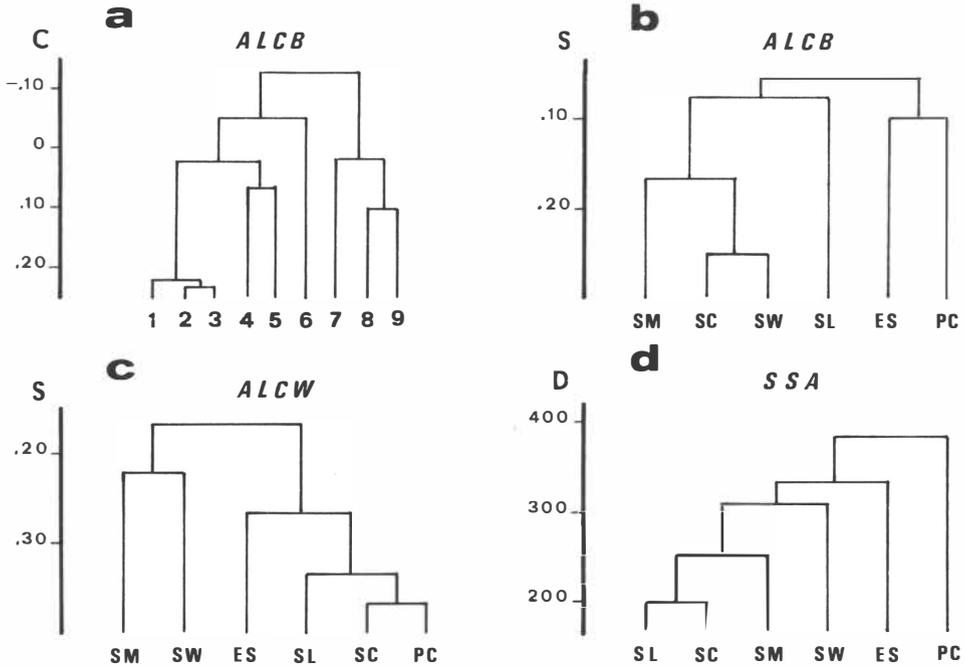


Fig. 2 — Classification dendrograms of species (a) and of vegetation types (b-d). The symbols indicate methods as in the main text; the symbols indicating vegetation types are those used in Table 1. C = product moment correlation coefficient; S = similarity ratio; D = Euclidean distance.

- 1) *Sphagnum magellanicum* - *Eriophorum vaginatum* group. This group is mainly composed of the *Oxycocco-Sphagneteta* species (*Sphagnum magellanicum*, *Eriophorum vaginatum*, *Carex pauciflora*, *Sphagnum rubellum*) and species frequently occurring in raised bogs (*Sphagnum quinquefarium* and *Calluna vulgaris*).
- 2) *Mytila anomala* - *Sphagnum acutifolium* group. These are the only species in this group. Both are characteristic of *Oxycocco-Sphagneteta*.
- 3) *Polytrichum strictum* - *Nardus stricta* group. This group includes the *Oxycocco-Sphagneteta* species *Polytrichum strictum* and other frequent companions in raised-bog communities (*Sphagnum recurvum*, *Vaccinium vitis-idaea*, *Vaccinium uliginosum*). In addition, there are also the species of acidiphytic grasslands, such as *Nardus stricta*, *Avenella flexuosa* and *Leontodon helveticus*.
- 4) *Odontoschisma sphagni* - *Sphagnum compactum* group. This group is characterized by the *Oxycocco-Sphagneteta* species *Odontoschisma sphagni* and *Sphagnum compactum*. *Carex stellulata* and *Trichophorum alpinum* are associated as was determined from the data.
- 5) *Sphagnum warnstorffii* - *Aulacomnium palustre* group. This group includes species generally occurring in poor fens. Among them, *Potentilla palustris*, *Meesea triquetra* and *Viola palustris* are considered

characteristic of the *Scheuchzerio-Caricetea fuscae*: *Sphagnum warnstorffii*, *Aulacomnium palustre* and *Dicranum bonjeani* are companion species, but frequently occurring in the associations belonging to *Oxyocco-Sphagnetea* and *Scheuchzerio-Caricetea fuscae*. There are also grassland species present, such as *Anthoxanthum odoratum* and *Festuca rubra*.

6) *Scorpidium scorpioides* - *Carex limosa* group. To this group belong three *Scheuchzerietalia palustris* species (*Scorpidium scorpioides*, *Carex limosa* and *Drosera anglica*) and *Sphagnum auriculatum* which usually occur on wet poor fens.

7) *Cratoneurum commutatum* var. *falcatum* - *Eriophorum scheuchzeri* group. This group is characterized by *Eriophorum scheuchzeri*, characteristic of *Eriophoretum scheuchzeri*, and by mosses linked to the *Montio-Cardaminetea* vegetation of springs and streams: *Cratoneurum commutatum* var. *falcatum* and *Philonotis calcarea*. To this group belongs, moreover, the *Salicetea herbaceae* species *Carex foetida*.

8) *Drepanocladus revolvens* - *Parnassia palustris* group. This group is essentially formed of the *Scheuchzerio-Caricetea fuscae* species. Most of them are basiphilous, considered characteristic of *Tofieldietalia*: *Tofieldia calyculata*, *Parnassia palustris*, *Primula farinosa*, *Drepanocladus revolvens*, *Bartsia alpina*, *Juncus alpino-articulatus*, *Pinguicula vulgaris*, *Selaginella selaginoides*, *Sesleria uliginosa*, *Carex lepidocarpa*, *Carex davalliana*, *Carex hostiana*, *Campylium stellatum*, *Carex capillaris*, *Epipactis palustris* and *Kobresia simpliciuscula*. *Aster bellidiastrum*, though not being considered characteristic of any *Scheuchzerio-Caricetea fuscae* syntaxon, is a common species in the N-alpic basiphytic fen communities (Oberdorfer, 1977). There are also the *Molinietalia* species, such as *Valeriana dioica*, *Cirsium palustre*, *Dactylorhiza majalis*, *Trollius europaeus*, *Crepis paludosa* and *Linum catharticum*.

9) *Calliargon trifarium* - *Willemetia stipitata* group. This group includes some *Scheuchzerio-Caricetea fuscae* species linked to subalpine fens (*Allium schoenoprasum* ssp. *sibiricum*, *Willemetia stipitata*, *Carex dioica*, *Calliargon trifarium*) and also *Caltha palustris* ssp. *laeta*, a common species in the stream vegetation.

Classification of relevés and definition of vegetation types

The classifications, based on binary and cover data, yielded practically identical results for all of the employed methods. Therefore, only dendrograms obtained for cover data are given (Fig. 2b-d). Interestingly, six relevé groups of nearly identical composition can be identified in the dendrograms. These correspond to plant communities recognizable in the field which are, in fact, considered as the main vegetation types in the studied peatlands.

The mean cover values of the 9 species groups in each vegetation type are given in Table 2. The results of concentration analysis are represented in Fig. 3. This diagram clearly indicates correlation between species groups and vegetation types. The correlations, and information about ecology and syntaxonomy from literature, served as the basis for a phytosociological interpretation of the vegetation types. The main points are synthesized in the following.

Parnassio-Caricetum fuscae (PC). This is the most widespread peatland community in the Dolomites, in the elevation belts of 1300-2000 m. It is characterized by species from the *Drepanocladus revolvens* - *Parnassia palustris* and *Calliargon trifarium* - *Willemetia stipitata* groups (see Fig. 3); this fact indicates nutrient richness. All species of the characteristic combination for *Parnassio-Caricetum fuscae* are present. Contrary to Oberdorfer's scheme (1977), however, this association should really be included in the order *Tofieldietalia* (= *Caricetalia davallianae*), as suggested by Dierssen (1978), because the *Tofieldietalia* species are much more abundant than the *Caricetalia fuscae* ones.

Eriophoretum scheuchzeri (ES). This is the only peatland community found in the alpine belt in the Dolomites. The relevés in the sample are very poor in species, almost all belonging to the *Cratoneurum commutatum* var. *falcatum* - *Eriophorum*

Table 2 - Mean cover values of the species groups in the main vegetation types. Legends of the symbols are those used in Table 1.

	SM	SC	SW	SL	ES	PC
1	2.24	-	0.37	-	-	-
2	1.39	-	-	-	-	-
3	1.27	0.30	1.57	-	-	-
4	0.05	3.75	0.86	-	-	0.42
5	0.39	0.55	1.84	0.55	0.38	0.27
6	-	0.25	0.07	3.37	-	0.10
7	0.01	-	-	-	2.55	0.53
8	0.03	0.19	0.27	0.06	0.12	1.26
9	0.04	-	-	-	-	0.40

scheuchzeri group. The dominance of *Eriophorum scheuchzeri* and the presence of some other *Scheuchzerio-Caricetea fuscae* species (*Eriophorum angustifolium*, *Juncus triglumis* and *Drepanocladus revolvens*) clearly justify the inclusion of this community in the *Eriophoretum scheuchzeri*. This association is quite uncommon in the Dolomites, owing to the fact that suitable morphological features only exceptionally exist in the alpine belt of this region. Characteristically, water slowly flows on the surface. This is reflected by the abundance of mosses (above all *Cratoneurum commutatum* var. *falcatum* and *Philonotis calcarea*) characteristic of springs and streams.

Sphagnum warnstorffii community (SW). This community forms very low hummocks settled here and there on fens occupied by the *Parnassio-Caricetum fuscae*. It is characterized by species of the group *Polytrichum strictum* - *Nardus stricta* and the group *Sphagnum warnstorffii* - *Aulacomnium palustre*. Both groups include species indicating nutritionally poor conditions, mainly characterizing *Scheuchzerio-Caricetea fuscae* syntaxa, but frequently occurring in *Oxycocco-Sphagnetetea* associations too. This community is fairly similar to the *Sphagno-Caricetum dioicae* described from the French Jura (Gillet, 1982) and assigned to the alliance *Sphagno-Tomenthyprion* (class *Scheuchzerio-Caricetea fuscae*). The Dolomitic *Sphagnum warnstorffii* community differs, however, from the *Sphagno-Caricetum dioicae* mainly because of the absence of *Carex dioica*, which is considered characteristic of the *Sphagno-Caricetum dioicae*.

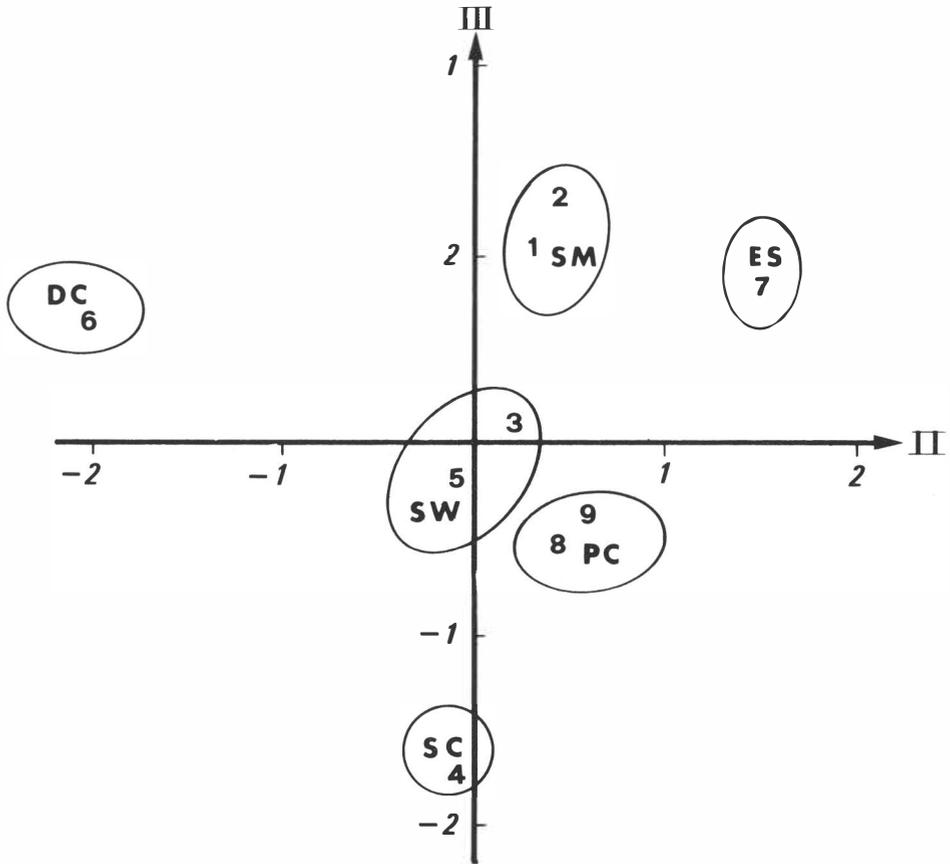


Fig. 3 — Reciprocal ordering of species groups (numbers) and vegetation types (letters) according to the analysis of concentration. The symbols indicating vegetation types are as in Table 1.
 1 - *Sphagnum magellanicum* - *Eriophorum vaginatum* group; 2 - *Mylia anomala* - *Sphagnum acutifolium* group; 3 - *Polytrichum strictum* - *Nardus stricta* group; 4 - *Odontoschisma sphagni* - *Sphagnum compactum* group; 5 - *Sphagnum warnstorffii* - *Aulacomnium palustre* group; 6 - *Scorpidium scorpioides* - *Carex limosa* group; 7 - *Cratoneurum commutatum* var. *falcatum* - *Eriophorum scheuchzeri* group; 8 - *Drepanocladus revolvens* - *Parnassia palustris* group; 9 - *Calliergon trifarium* - *Willemetia stipitata* group.

Sphagnetum magellanicum (SM). This community forms isolated well-developed hummocks within the *Parnassio-Caricetum fuscae*. Exceptionally, it may cover areas larger than few square meters: then, the morphology of the *Sphagnum* cover resembles that of raised bogs. This vegetation type is characterized by species of the *Sphagnum magellanicum* - *Eriophorum vaginatum* group, most of which are considered characteristic of different syntaxa within the class *Oxycocco-Sphagneteta*. The characteristic combination of species coincides with that of the *Sphagnetum magellanicum*. The relevés (see Table 1) are somewhat heterogeneous as

several *Sphagnum* species (*S. rubellum*, *S. quinquefarium*, *S. acutifolium*) may dominate, dependent on the water level (Dierssen, 1978).

Sphagnum compactum community (SC). This community is very rare in the Dolomites as it is found only at the top of well-developed peat bodies, established on impermeable marls. This vegetation type is characterized by species of the *Odontoschisma sphagni* - *Sphagnum compactum* group. It is fairly similar both to the *Sphagno compacti* - *Trichophoretum germanici* and to the *Eriophoro* - *Trichophoretum caespitosi* (Oberdorfer, 1977). Our relevés differ from the former of these associations, owing to the absence of *Trichophorum germanicum*, and from the latter as *Sphagnum compactum* is not so frequent in the *Eriophoro-Trichophoretum caespitosi*.

Scorpidio-Caricetum limosae (SL). Also this community is very rare in the Dolomites. It colonizes only depressions within well-developed peat bodies. This vegetation type is characterized by species of the *Scorpidium scorpioides* - *Carex limosa* group, including indicator species of wet mesotrophic fens, most of which are considered characteristic of the order *Scheuchzerietalia palustris*. The relevés were assigned to the *Scorpidio-Caricetum limosae* (Krisai, 1971), owing to the abundance of *Scorpidium scorpioides*.

Evaluation of classifications

The dendrograms of relevés are identical at the 6-cluster level, but rather different at higher hierarchical levels (Figs. 2b-d). Classification efficiency was tested only at the 3- and the 2- cluster level, since the corresponding groups represent the most inclusive vegetation types in the studied wetland vegetation.

Table 3 - Contingency tables (species groups x relevé sets) and values of the D indices. (See explanation in the text).

	<i>3 clusters</i>			<i>2 clusters</i>	
ALCB					
	SM		ES	SM	
	SC	SL	PC	SC	ES
	SW			SW	PC
				SL	
1-5	1.09	0.17	0.13	1-6	0.93 0.13
6	0.05	3.37	0.08	7-9	0.11 0.98
7-9	0.11	0.04	0.98		
	$D(F_h; F_i) = 0.359$			$D(F_h; F_i) = 0.230$	

		<i>3 clusters</i>			<i>2 clusters</i>		
ALCW				ES			ES
		SM	SW	SL		SM	SL
				SC		SW	SC
				PC			PC
	1-5	1.08	1.21	0.17	1-6	1.02	0.18
	6	-	0.07	0.29	7-9	1.08	0.87
	7-9	0.03	0.21	0.87			
		$D(F_h; F_i) = 0.112$				$D(F_h; F_i) = 0.020$	
SSA							
		SM				SM	
		SC				SC	
		SW	ES	PC		SW	PC
		SL				SL	
						ES	
	1-5	1.00	0.12	0.14	1-6	0.77	0.13
	6	0.39	-	0.10	7-9	0.17	1.08
	7-9	0.11	0.45	1.08			
		$D(F_h; F_i) = 0.119$				$D(F_f; F_i) = 0.159$	

The efficiency of the classifications was evaluated by calculating the mean cover of the species groups formed at the 3- and respectively at the 2- clusters levels (see the classification dendrogram of species; Fig. 2a) in the relevé clusters identified at the same hierarchical levels (see the classification dendrograms of the types; Fig. 2b-d). The contingency tables and the $D(F_h; F_i)$ values calculated for each are reported in Table 3. On the basis of this test, the classification obtained by ALCB proved to be the most efficient at both levels.

For evaluating classifications by external criteria, contingency tables were constructed, correlating the frequency distributions of the equivalence classes for both pH and electrical conductivity in the vegetation types at the same hierarchical levels. The contingency tables and 2I values are given in Tables 4 and 5. It appears that the most predictive classification for both pH and electrical conductivity is again that obtained by ALCB at the specified hierarchical levels.

Table 4 - Contingency tables for pH and values of the 2I index. (See explanation in the text).

	<i>3 clusters</i>			<i>2 clusters</i>		
ALCB	SM		ES	SM		
	SC	SL	PC	SC	ES	
	SW			SW	PC	
				SL		
5-5.99	6	-	1	5-6.49	7	1
6-6.99	2	1	2	6.50-8	2	9
7-8	-	-	7			
	2I = 16.27 (99.7)			2I = 9.83 (99.8)		
ALCW			ES		ES	
	SM	SW	SL	SM	SL	
			SC	SW	SC	
			PC		PC	
5-5.99	4	1	2	5-6.49	5	3
6-6.99	-	2	3	6.50-8	2	9
7-8	-	-	7			
	2I = 14.46 (99.4)			2I = 3.99 (95.4)		
SSA	SM			SM		
	SC	ES	PC	SC	PC	
	SW			SW		
	SL			SL		
ES			ES			
5-5.99	6	-	1	5-6.49	7	1
6-6.99	3	-	2	6.50-8	4	7
7-8	-	2	5			
	2I = 15.48 (99.6)			2I = 5.41 (98)		

Table 5 - Contingency tables for electrical conductivity (μs) and values of the 2I index. (See explanation in the text).

ALCB	<i>3 clusters</i>			<i>2 clusters</i>		
	SM	SL	ES	SM	ES	PC
	SC		PC	SC		PC
	SW			SW		SL
≤ 50	8	-	1	≤ 75	9	3
51-100	-	1	3	> 75	-	7
> 100	-	-	6			
	2I = 21.79 (100)			2I = 12.79 (100)		
ALCW	SM	SW	ES	SM	ES	SL
			SL	SW		SC
			SC			PC
		PC		PC		
≤ 50	4	3	2	≤ 75	7	5
51-100	-	-	4	> 75	-	7
> 100	-	-	6			
	2I = 15.47 (99.6)			2I = 8.71 (99.7)		
SSA	SM	ES	PC	SM	PC	SL
	SC		PC	SC		ES
	SW			SW		
	SL		SL	ES		
≤ 50	8	1	-	≤ 75	10	2
51-100	1	-	3	> 75	1	6
> 100	-	1	5			
	2I = 20.11 (100)			2I = 9.31 (99.8)		

Discussion

The efficiency tests applied to the contingency matrices show that all classifications are highly predictive for the environmental conditions ($P < 0.05$). It is noteworthy that the evaluations based on external criteria support those obtained by internal criteria: in both cases the classification by ALCB proved to be the most efficient. This coincidence of evaluations might be owing to the fact that peatlands are natural and not disturbed environments. Interestingly, when classifications from secondary grasslands were compared by similar methods (Feoli *et al.*, 1981), the results obtained based on internal and external criteria did not coincide. This conclusion cannot be, however, generalized since insufficient data are available for comparison. Further research will be devoted to this topic.

The groups distinguished at the 3-cluster level (Fig. 2b) are interpretable as phytosociological units: the cluster including the *Sphagnetum magellanicum*, the *Sphagnum compactum* community and the *Sphagnum warnstorffii* community may correspond to the order *Sphagnetalia magellanicum*; the cluster including the *Scorpidio-Caricetum limosae* to the order *Scheuchzerietalia palustris*; and the cluster of *Eriophoretum scheuchzeri* and *Parnassio-Caricetum fuscae* to the order *Tofieldietalia*.

Riassunto. Le comunità vegetali delle torbiere dolomitiche sono state indagate con il metodo fitosociologico. I dati vegetazionali sono stati classificati con vari metodi di *cluster analysis*. I risultati così ottenuti sono stati valutati su base quantitativa considerando sia la struttura delle tabelle di contingenza gruppi di specie x gruppi di rilievi (predittività interna) sia la correlazione esistente fra tipi vegetazionali e chimismo della torba (predittività esterna). Un risultato interessante è dato dal fatto che le valutazioni ottenute con i due criteri sono fra loro coincidenti.

Acknowledgements.

We would like to thank prof. L. Orlóci for reading and correcting the manuscript.

This research was supported by the C.N.R. (grant n. 82/02409.04 "Gruppo di Biologia Naturalistica"; resp. A. Pirola).

References

- Anderberg M.R. (1973) - *Cluster analysis for applications*. Academic Press, New York-London.
- Augier J. (1966) - *Flore des Bryophytes*. Lechevalier, Paris.
- Braun-Blanquet J. (1964) - *Plant sociology*. Mc Graw-Hill, London.
- Dierssen K. (1978) - *Some aspects of the classification of oligotrophic and mesotrophic mire communities in Europe*. Colloques Phytosociologiques, 7: 399-423.
- Feoli E. (1976) - *Correlation between single ecological variables and vegetation by means of cluster analysis*. Not. Fitosoc., 12: 77-82.
- Feoli E. & Gerdol R. (1982) - *Evaluation of syntaxonomic schemes of aquatic plant communities by cluster analysis*. Vegetatio, 49: 21-27.
- Feoli E., Lagonegro M. & Biondani F. (1981) - *Strategies in syntaxonomy: A discussion of two classifications of grasslands of Friuli (Italy)*. In: H. Dierschke (ed.): *Syntaxonomie*. Ber. Int. Symp. IV/V Rinteln 1980. Cramer, Vaduz, pp. 95-107.
- Feoli E. & Lausi D. (1980) - *Hierarchical levels in syntaxonomy based on information functions*. Vegetatio, 42: 113-115.
- Feoli E. & Orłóci L. (1979) - *Analysis of concentration and detection of underlying factors in structured tables*. Vegetatio, 40: 49-54.
- Gillet F. (1982) - *L'alliance du Sphagno-Tomenthypnion dans le Jura*. Documents Phytosociologiques, 6: 155-180.
- Maarel E. van der (1979) - *Transformation of cover-abundance values in phytosociology and its effects on community similarity*. Vegetatio, 39: 97-144.
- Krisai R. (1971) - *Zur Gliederung des Schlammseggenmoores (Caricetum limosae s.l.) in Mitteleuropa*. Verh. Zool.-Bot. Ges. Wien, 110-111: 99-110.
- Malmer N. (1958) - *Notes on the relation between the chemical composition of mire plants and peat*. Botaniska Notiser, 111: 274-283.
- Malmer N. & Sjörs H. (1955) - *Some determinations of elementary constituents in mire plants and peat*. Botaniska Notiser, 108: 46-80.
- Oberdorfer E. (1977) - *Süddeutsche Pflanzengesellschaften*. Pflanzensoziologie, 10. I Teil, 2. Aufl. Fischer, Jena.
- Orłóci L. (1976) - *Ranking species by an information criterion*. J. Ecol., 64: 417-419.
- Orłóci L. (1978) - *Multivariate analysis in vegetation research*. 2nd ed. Junk, The Hague.
- Pignatti S. (1982) - *Flora d'Italia*. Edagricole, Bologna, 3 vols.
- Sjörs H. (1950) - *On the relation between vegetation and electrolytes in North Swedish mire waters*. Oikos, 2: 241-258.
- Sonesson M. (1970) - *Studies on the mire vegetation in the Torneträsk area of Northern Sweden*. IV. *Some habitat conditions of the poor mires*. Botaniska Notiser, 123: 67-111.
- Waughman G.J. (1980) - *Chemical aspects of the ecology of some South German peatlands*. J. Ecol., 68: 1025-1046.

Renato Gerdol
Istituto ed Orto Botanico
Università ed Orto Botanico
Università di Pavia
Via S. Epifanio, 14
Pavia, I-27100, Italy

Marcello Tomaselli
Istituto ed Orto Botanico
Università di Bologna
Via Irnerio, 42
Bologna, I-40126, Italy

ECOLOGICAL INFERENCES FROM PHYTOSOCIOLOGICAL DATA IN AN ALLUVIAL FOREST ON THE PO PLAIN (Northern Italy)

Carlo FERRARI & Maria SPERANZA

Keywords: Alluvial forest. Ecology, Numerical classification, Phytosociology, Po plain.

Abstract. The vegetation of an alluvial forest of the Po plain, known as the Forest of S. Agostino, has been surveyed using the Braun-Blanquet method. Analysis of the data revealed two main ecological situations characterized chiefly by differences in pedological factors identified by the cover values of *Carex pendula* and *Brachypodium sylvaticum*.

1. Introduction

This study is concerned with the vegetation of the Forest of S. Agostino, or "Panfilia" Forest. This is one of the few alluvial forest still existing in the Po plain. For this reason, its vegetation serves as a reliable model to describe the potential forest vegetation on the alluvial terraces of the plain.

A previous phytosociological study (Corbetta & Censoni Zanotti, 1974) ascribed the vegetation to the association *Carici-Fraxinetum angustifoliae* (Pedrotti 1970 ; Pedrotti e Cortini Pedrotti, 1978), without any subunit. Our paper reports on the results of a phytosociological study, performed to evaluate the ecological features through correlations between relevé groups and species groups. The results confirm the reliability of the phytosociological approach to supply information in an indirect gradient analysis.

2. The study area

The Forest of S. Agostino lies outside a meander that the Reno River forms just south of the village of S. Agostino in the province of Ferrara (Northern Italy).

The forest covers an area of about 50 ha on an alluvial terrace. The local climate has annual average rainfall of about 700 mm, with minima in February, July, and August. The average annual temperature is 12,9° C, with minimum in January (average 0.3°C) and maximum in July (average 23.4°C). These features are typical

of the climate of the Po plain. From a pedological point of view the soils are river sediments of silt, sand and clay. Wolf (1983) has shown that starting from the river bank, there exists a gradient from coarse texture soils, with good porosity, to increasingly fine textured soils, often very compact at the surface.

During the second world war the forest underwent extensive logging during which especially oaks were highgraded. Today the forest is mainly used for recreation and it is managed by the Azienda Regionale of Emilia-Romagna.

3. Materials and methods

Vegetation relevés were made according to the Braun-Blanquet method (Braun-Blanquet, 1964, Westhoff & van der Maarel, 1978). The relevés were classified by sum of squares clustering (SSA: Orłóci, 1967) using Euclidean Distance (Orłóci, 1978) after transformations of the cover/abundance values according to the van der Maarel (1979) scale: $r = 1$; $+$ = 2; 1 = 3; 2 = 5; 3 = 7; 4 = 8; 5 = 9. All species were considered, except those occurring only in one relevé.

The correlation between relevé groups and species groups is discussed on the basis of the results of concentration analysis (AOC: Feoli & Orłóci, 1979), applied to a matrix of mean cover within species group in the relevé groups. An ecological evaluation of the relevé groups has been attempted by Landolt indicator values (Landolt, 1977) concerning the following edaphic factors: moisture (F), free H-ions (R), nutrient content (N), aeration (D), average light intensity (L). For every factor the significance of the differences between the mean values of the groups of relevés was tested by a t-criterion.

The taxonomic nomenclature follows Pignatti (1982).

4. Results

Treatment of vegetation data

A total of 39 relevés were considered in cluster analysis and three clusters were recognized in the dendrogram at the level of about 550 SS representing a classification efficiency of 30% (Fig. 1). We use these clusters as the main groups in further analyses. The species considered in the classification are 29. The dendrogram obtained with SSA (Fig. 2) shows 4 clusters at a value of about 700 SS. This value is nearly corresponding to the level chosen for defining relevé groups. The correlation between species groups and relevés groups, resulting from AOC, is given in Fig. 3. Species group S_i is not related to a particular relevé group.

Ecological evaluations

Inference about vegetation ecology can be drawn from the results of AOC and the species indicator values (Landolt, 1977). The factors being considered are listed in Section 3. The indicator values weighted by the cover values gave the results in Table 2a. The results of t-tests applied to the mean indicator values of each relevé

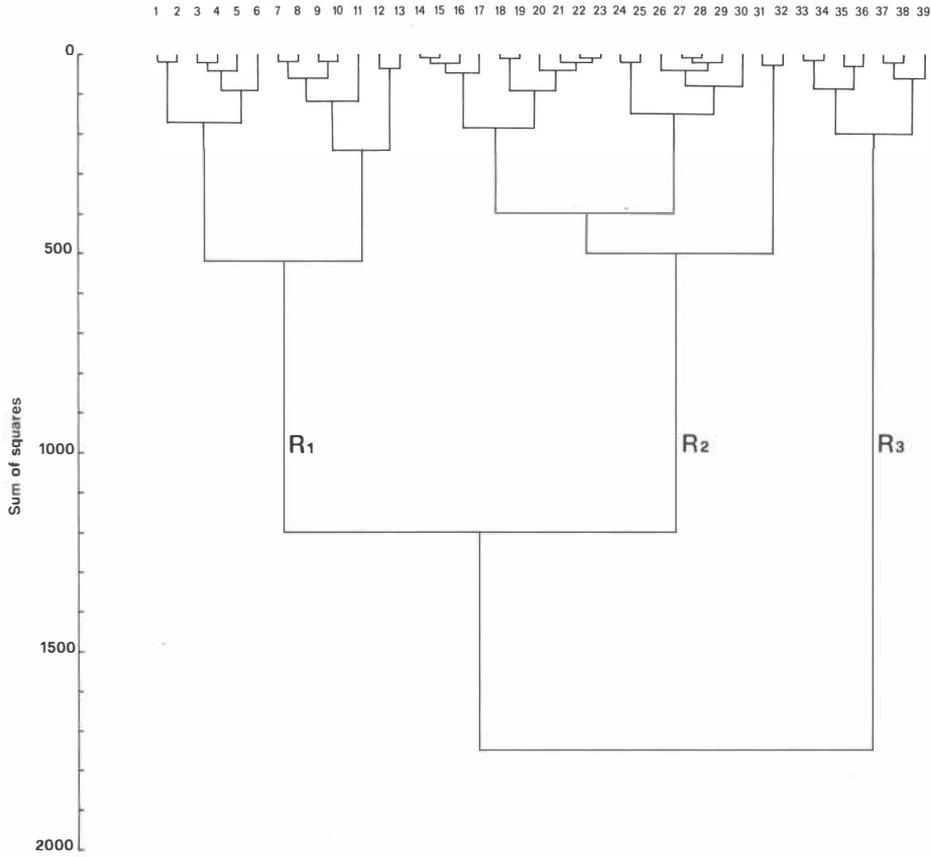


Fig. 1 — Fusion topology of relevés based on cover/abundance data. The clustering method is SSA. The R symbols identify major groups: the numbers are labels for relevés as in Table 1.

group (R_1 , R_2 , R_3) are given in Table 2b. We observe that: i) groups R_1 and R_2 differ only in soil acidity and aeration: group R_2 indicates weakly acid and more compact soils; ii) group R_3 is isolated. Compared with R_1 it represents more acid soils but when compared to R_2 it is more aerated, has more light, and drier soils.

From these results we conclude that the ordination of Fig. 3 can be explained by a prevailing particle size gradient and subsequent decreasing aeration in the sense of the sequence R_3 , R_1 , R_2 . Interestingly these findings coincide with those observed by Wolf (1983), corresponding to an increasing distance from the river.

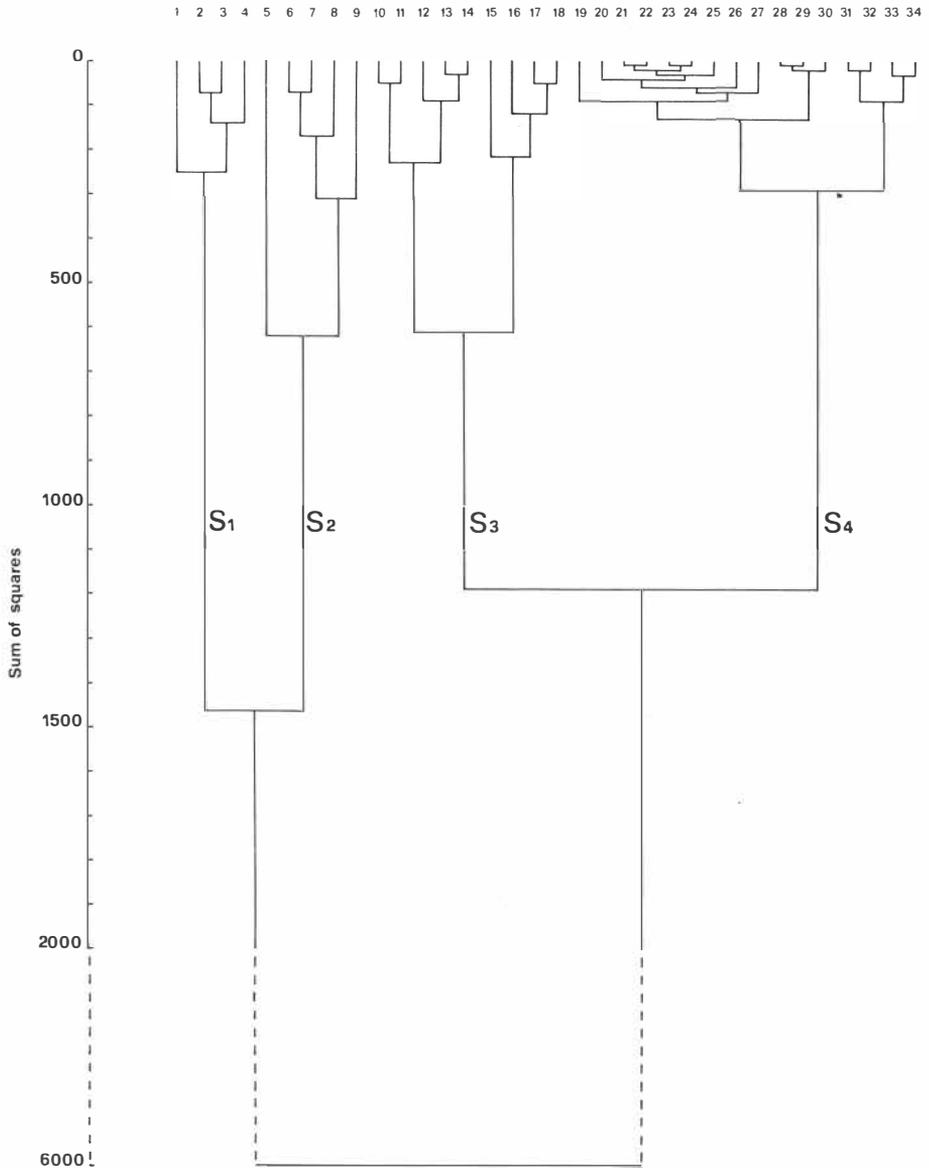


Fig. 2 — Fusion topology of species based on cover/abundance data. The clustering method is SSA. The S symbols identify major groups: the numbers are labels for species as in Table 1.

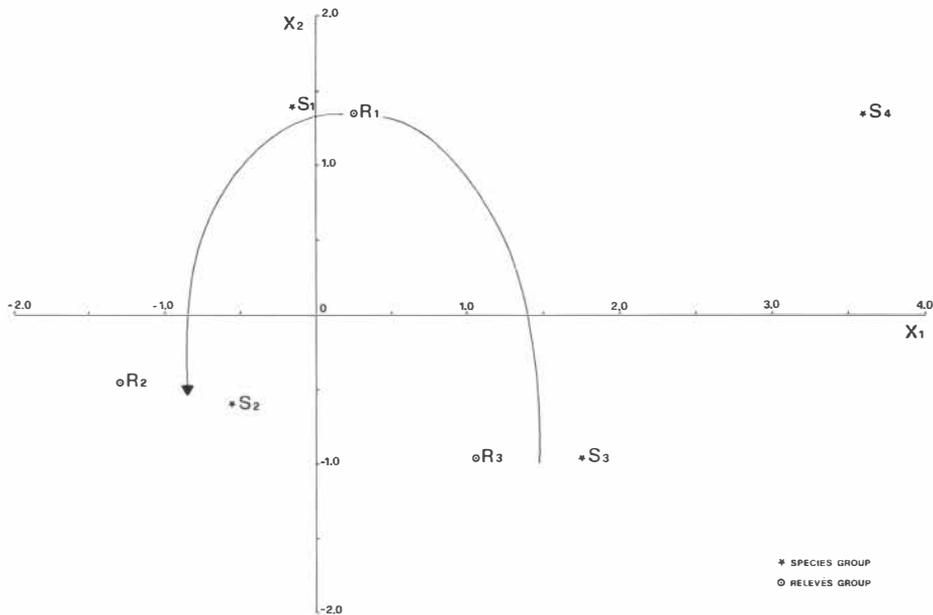


Fig. 3 — Reciprocal ordination of species and relevé groups according to the first two canonical variates. See explanation of the symbols in Tables 1 and 2. Further explanations are given in the text.

5. Conclusions

Which species are most useful to characterize the different ecological situations we have identified? It has been seen that a correlation exists between relevé groups and species groups, but only based on the magnitude of cover. It has also been seen that groups R_1 and R_2 are weakly differentiated. The situation with the highest particle size and the lowest acidity (R_1) can be tentatively recognized by the high cover values of species belonging to groups S_1 (chiefly *Quercus pedunculata* as a tree and *Prunus spinosa*) concordant with the high frequencies of some species of groups S_1 , such as *Rhamnus frangula*, *Robiniapseudacacia*, *Acer campestre*, and saplings of *Quercus pedunculata* (see Table 1).

The identification of the ecological conditions of group R_3 is less ambiguous. On the one hand, the correlation between S_3 and R_3 is marked by a clear increase in the mean cover of *Brachypodium sylvaticum*. On the other hand, *Carex pendula*, with high covers in R_1 and R_2 , drastically decreases its covers in R_3 . We can conclude that, for a field prediction of the ecological conditions, the mean cover of *Brachypodium sylvaticum* and *Carex pendula* has high indicator value. Where the particle size is coarser, light intensity is higher, the soil more humid and richer in nutrients (R_3),

Brachypodium sylvaticum and *Carex pendula* have similar cover values (from 20% to 40%). Where the soils are finer and light intensity, soil moisture, and nutrient concentration lower (R_2 , R_1), *C. pendula* has high cover (up to 100%), but *B. sylvaticum* is only sporadic with cover up to 20% at the best.

The groups inferred from the phytosociological data, might be assumed as variants of the association *Carici-Fraxinetum angustifoliae* (Corbetta & Censoni Zanotti, 1974), corresponding to changes in the ecological conditions.

Riassunto. È stata studiata la vegetazione di una foresta golenale della pianura padana, il bosco di S. Agostino o bosco "Panfilia" (Ferrara) con il metodo di Braun-Blanquet. L'elaborazione dei dati ha evidenziato due situazioni ecologiche principali caratterizzate da differenze pedologiche. Queste situazioni possono essere individuate mediante i valori copertura di *Carex pendula* e *Brachypodium sylvaticum*.

Acknowledgements.

We would like to thank prof. L. Orłóci for reading and correcting the manuscript.

The research was supported by a grant from the Azienda Regionale delle Foreste, Emilia-Romagna Region, Italy.

References

- Braun-Blanquet, J. 1964. Pflanzensociologie. 3 Aufl. Springer, Wien.
- Corbetta, F. & Censoni Zanotti, A.L. 1974. La foresta Panfilia: caratteristiche fitosociologiche e strutturali. Arch. Bot. Biogeogr. Ital. L., 4^s. XIX, 3-4:159-170.
- Feoli, E. & Orłóci, L. 1979. Analysis of concentration and detection of underlying factors in structured tables. Vegetatio 40:49-54.
- Landolt, E. 1977. Okologische Zeigerwerte zur Schweizer Flora. Veroff. Geobot. Inst. Eidg. Techn. Hochschule, Stiftung Rübel, 64. Zurich.
- Maarel, E. van der 1979. Transformation of cover abundance values in phytosociology and its effects on community similarity. Vegetatio 39:97-144.
- Orłóci, L. 1967. An agglomerative method for classification of plant communities. J. Ecol., 55:193-206.
- Orłóci, L. 1978. Multivariate analysis in vegetation research. Junk, den Haag.
- Pedrotti, F. 1970. Un relitto di bosco planiziale a *Quercus robur* e *Carici-Fraxinetum angustifoliae* lungo la costa adriatica (Italia centro-meridionale). Mitt. Ostalp. Din. Ges. Vegetationskd., 14:255-261.
- Pedrotti, F. & Cortini Pedrotti, C. 1978. Notizie sulla distribuzione del *Carici-Fraxinetum angustifoliae* lungo la costa adriatica (Italia centro-meridionale). Mitt. Ostalp. Din. Ges. Vegetationskd., 14:255-261.
- Pignatti, S. 1982. Flora d'Italia. 3 voll. Edagricole, Bologna.
- Westhoff, V. & Maarel, E. van der, 1978. The Braun-Blanquet approach. 2nd ed. In: R.H. Whittaker (ed.): Classification of plant communities, pp. 287-399. Junk, den Haag.
- Wolf, U. 1983. Relazione sulla ricerca "Bosco Panfilia" - Settore pedologico. Azienda Regionale delle Foreste dell'Emilia Romagna, Bologna.

Carlo Ferrari & Maria Speranza
Istituto e Orto Botanico,
Via Innerio, 42
I 40126 Bologna (Italy)

CONTRIBUTIONS TO QUANTITATIVE PHYTOGEOGRAPHY OF SICILY II: CORRELATION BETWEEN PHYTOGEOGRAPHICAL CATEGORIES AND ELEVATION

Pier Luigi NIMIS

Keywords: Phytogeography, Flora, Sicily.

Abstract. Data source: Central Databank of the Italian flora and vegetation. Database: phanerogamic flora of Sicily; percents of species with similar distribution patterns, subdivided into 49 phytogeographical categories, in 23 elevation intervals of 100 m each. Methods: Complete Linkage Clustering with Correlation Coefficient for the classification of categories and of elevation intervals; Concentration Analysis for the ordination. Results: species with similar distribution tend to be most frequent along given sections of the elevation gradient. The degree of correlation between phytogeographical categories and elevation has been quantified.

Introduction

Phytogeography has been one of the branches of Botany in which the use of non-operationally defined concepts, the adoption of intuitive thinking and the formulation of non-falsifiable hypotheses has always been more the rule than the exception. The adoption of numerical methods in the analysis of phytogeographical data is likely to produce a shift towards a more formalized type of phytosociological analysis. This process, however, is still at the beginnings; new methods are to be developed, and a consistent numerical database has to be assembled before quantitative phytogeography will produce biologically new and original results. Phytogeographical data in numerical form could be the basis to disengage phytogeography from a merely descriptive stage, and move it toward the use of formalized quantitative models, in which more abstract and general parameters will play a major role (Crovello, 1981; Lausi & Nimis, 1984, 1985).

The present paper is the second of a series in which phytogeographical data concerning the phanerogamic flora of Sicily at species level are analyzed by multivariate methods. Data source is the Data Bank of the Italian Flora and Vegetation (Pignatti, 1981; Nimis, 1981; Nimis et al., 1983). In the first paper of the series (Nimis, 1984) the analysis was addressed to the study of the relations between phytogeographical categories (as in Pignatti, 1982) and environment-types. The present study is dedicated to the analysis of the relations between

phytogeographical categories and elevation.

There are three points concerning the data that could cause misunderstandings in the interpretation of the results; they are discussed in the following:

- 1 the grouping of species into phytogeographical categories is not based on objective criteria (see Pignatti, 1982). In general, the accuracy in the delimitation of categories decreases with increasing distance of the areas covered by species ranges from the Italian territory (e.g. there are several categories for Mediterranean species s.l., just one for circumboreal species s.l.). A numerical elaboration of distribution maps to obtain clearly defined types of ranges is not yet possible, since detailed distribution maps are not available for the greatest part of the species in the flora of Europe.
- 2 the elevation range of each species is calculated on the basis of the behaviour of the species on the whole of the Italian territory. This is a major handicap, particularly for the study of the flora of Sicily, since the region is located at the southern end of Italy. This is likely to be reflected in lower elevation ranges than the actual ones, above all as far as northern species are concerned.
- 3 some of the phytogeographical categories are defined on the basis of the response of species to elevation (e.g. Mediterranean-montane, orophytes etc.). This could lead to circular reasoning, this study being centered just on the relations of phytogeographical categories with an elevation gradient.

The first and last points are related: although the analysis of detailed distribution maps is the best way to obtain a satisfactory classification of species into phytogeographical categories, it is a fact that the species listed as "orophytes" or "montane" have specific distribution patterns (e.g. SW-Mediterranean orophytes should have a fragmented range in the Southwestern part of the Mediterranean Region, and their distribution patterns should differ from those of typical SW-Mediterranean species). This means that reference to elevation in the names of these categories is actually related with their distribution patterns. For the rest, the degree of approximation in the delimitation of the various categories seems to be fairly satisfactory, also considering the very high correlation that has been found between them and ecological factors (Nimis, 1984).

The second point is the most troublesome: it should be always kept in mind when interpreting the results. The elevation range in Italy is here considered as a character of each species, and the frequency distribution of species included in the same phytogeographical category along the elevation gradient is considered as a character of the category. Phytogeographical categories, and not Sicily, are the main object of the analysis. The curves representing the frequency distributions of the categories along the elevation gradient, if referred to the actual situation in Sicily, depict just trends of species responses to elevation.

The results will be tested with field-data in another paper of this series and this will be the basis for the introduction of a correction factor in the data bank, that should contribute to solve the problem. This is in line with the main aim of this series of papers: to test the data of the Data Bank towards their utilization for the construction of phytogeographical quantitative models.

Data and methods

The data matrix is in Tab. 1. It contains the relative frequencies of 49 phytogeographical categories in 23 elevation intervals of 100 m each, from sea level to 2300 m. The highest mountain in Sicily is M. Etna, that is more than 3000 m high. However, the number of species occurring above 2300 m is so small that they have been omitted. This in order to avoid extremely high frequencies in the upper elevation intervals due to categories formed by only a few species.

The frequencies in Tab. 1 are calculated over the total number of species present in each elevation interval. This means that the Operational Geographic Units (OGUs, sensu Crovello, 1981) that are compared are 23 portions of the sicilian territory, obtained by its subdivision into belts of 100 m each. The Operational Geographic Set (Crovello, 1981) corresponds to the isle of Sicily and the surrounding small islands. The reason why the data have been normalized by columns is the following: surfaces with different areas are included in the different elevation intervals, the areas in each interval becoming narrower along with the increase in elevation. If the data would have been normalized by rows, the different areas of the elevation belts could have strongly affected the results; for instance, the frequency of SW-mediterranean species in the elevation belts, calculated over the total of SW-mediterranean species present in Sicily, depends on the floristic diversity of each belt; the latter is probably related to their respective areas. However, the relation between the areas of OGUs and their floristic diversity is not known, so that the interpretation of the results would have been extremely difficult.

The analysis of the data matrix (Tab. 1) has been performed in the following steps:

- Classification of OGUs, in order to obtain elevation belts with similar phytogeographical features.
- Classification of phytogeographical categories, to obtain groups of categories with similar response to the elevation gradient.
- Concentration Analysis (AOC) of the matrix in Tab. 1, to quantify the correlation between each category and each of the OGUs.
- Ranking categories on the basis of the percentages of chi square accounted for by each of them on the two first canonical variates of AOC in the previous analysis. Only those categories have been retained for further graphical displays that retain more than 2% of the interaction chi square on either canonical variate.
- Construction of graphs reporting the frequency distributions along the elevation gradient of the species included in those categories that have been retained after ranking.

The methods adopted for data analysis are:

- Complete Linkage Clustering (Anderberg, 1973) on Correlation Coefficient (Orloci, 1978) for classifications, with the package of programs by Wildi & Orloci (1980).
- Concentration Analysis (Feoli & Orloci, 1979) for the ordination.

PHYT. CATEGORY	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	
Saharo-Sindic	0.4	0.4	0.4	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Pantropical	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
NW-Medit.Montane	0.2	0.2	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.6	0.6	0.6	0.7	0.6	0.3	0.4	0.5	0.7	0.0	0.0	0.0
N-Stenomedit.	0.4	0.4	0.4	0.5	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.6	0.3	0.2	0.3	0.3	0.4	0.5	0.7	0.0	0.0	0.0
W-Stenomedit.	5.3	5.1	5.0	5.2	5.0	4.7	3.0	2.2	2.5	1.7	1.6	0.8	0.6	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
S-Stenomedit.	2.9	3.0	2.9	2.5	2.4	2.1	1.2	1.1	1.1	0.7	0.6	0.6	0.4	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Paleotropical	0.7	0.7	0.7	0.5	0.6	0.6	0.2	0.2	0.3	0.3	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SW-Stenomedit.	2.5	2.4	2.4	2.0	1.9	1.8	1.1	1.1	1.1	0.9	0.9	0.8	0.7	0.7	0.8	0.3	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Subtropical	1.6	1.5	1.4	1.3	1.2	1.1	0.8	0.8	0.6	0.4	0.5	0.3	0.3	0.2	0.3	0.3	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Introduced	4.9	5.2	5.1	4.7	4.5	4.2	2.7	2.7	2.2	1.9	1.3	1.4	1.5	1.2	1.4	0.8	1.0	1.2	0.5	0.7	1.2	0.0	0.0	0.0
NW-Stenomedit.	0.3	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
E-Eurimedit.	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Amphiatlantic	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eurimedit.-Atl.	1.0	1.1	1.1	1.1	1.1	1.1	1.3	1.2	0.8	0.9	0.6	0.6	0.6	0.5	0.4	0.3	0.3	0.4	0.5	0.7	1.2	0.0	0.0	0.0
Subatlantic	1.2	1.1	1.1	1.2	1.2	1.0	1.1	1.1	1.1	1.1	0.9	0.9	0.9	0.9	0.8	0.8	1.0	0.8	0.5	0.0	0.0	0.0	0.0	0.0
E-Stenomedit.	2.0	2.2	2.2	1.9	1.9	1.9	1.5	1.8	1.3	1.3	1.1	1.2	1.2	1.4	1.2	1.4	1.4	1.2	0.5	0.0	0.0	0.0	0.0	0.0
Medit.-Turanic	2.4	2.2	2.2	2.0	2.1	2.1	2.3	2.2	2.1	2.2	1.8	1.7	1.6	1.9	1.8	1.7	1.7	1.6	2.0	1.3	1.2	1.6	1.9	1.9
E-Medit. Montane	0.4	0.4	0.5	0.5	0.5	0.5	0.6	0.6	0.4	0.5	0.4	0.5	0.4	0.5	0.5	0.6	0.6	0.3	0.4	0.5	0.0	0.0	0.0	0.0
SE-Stenomedit.	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.3	0.3	0.3	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NE-Stenomedit.	0.8	0.9	0.9	0.8	0.8	0.7	0.8	0.7	0.8	0.7	0.7	0.7	0.7	0.7	0.2	0.3	0.3	0.4	0.0	0.0	0.0	0.0	0.0	0.0
N-Eurimedit.	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.5	0.4	0.5	0.3	0.3	0.2	0.2	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eurimedit.	15.4	15.6	15.5	16.1	15.9	16.1	17.9	17.6	16.8	17.1	15.6	15.6	14.3	11.9	9.2	8.2	7.4	7.3	6.3	7.3	7.1	3.1	3.8	3.8
W-Eurimedit.	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.3	0.2	0.2	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Steno Med. Atl.	1.5	2.2	2.2	2.2	2.2	0.9	0.8	0.8	1.0	1.0	0.9	0.7	0.6	0.5	0.4	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Stenomedit.	16.6	16.4	16.2	16.6	16.1	16.4	14.6	14.3	11.7	10.9	9.9	9.1	7.2	6.6	5.9	5.6	4.7	5.3	4.4	4.0	2.4	0.0	0.0	0.0
SE-European	1.1	1.1	1.1	1.2	1.2	1.3	1.4	1.4	1.6	1.7	1.7	1.5	1.0	1.0	1.2	0.6	0.7	0.8	1.0	0.7	0.0	0.0	0.0	0.0
NW-Eurimedit.	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SW-Med.Montane	1.2	1.1	1.1	1.2	1.3	1.1	1.0	1.1	1.2	1.4	1.5	1.4	1.5	1.4	1.4	1.4	1.7	1.4	1.2	1.5	1.3	1.2	1.6	0.0
Subcosmopolitan	3.8	3.8	3.7	3.7	3.7	3.7	4.2	4.2	4.3	4.3	4.5	4.5	4.7	4.4	4.5	4.2	3.7	4.1	3.4	4.7	3.6	4.7	1.9	1.9
S-Eurimedit.	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Paleotemperate	5.8	4.0	5.9	6.4	6.4	6.4	7.7	7.7	8.3	8.5	8.4	8.4	8.5	9.0	8.8	8.8	9.8	8.1	7.3	8.0	6.0	7.8	7.7	7.7
Europ.-Caucas.	3.4	3.6	3.6	3.8	3.9	4.2	5.1	5.1	6.0	6.1	7.0	7.3	7.2	7.1	7.3	6.5	6.8	6.5	7.3	6.7	4.8	4.7	5.8	5.8
NE-Med.Montane	0.8	0.8	1.0	1.0	1.1	1.3	1.7	2.0	2.3	2.2	2.6	2.7	2.8	2.7	2.9	3.4	4.1	3.3	3.4	2.7	2.4	3.1	1.9	1.9
Eurasianic	4.8	4.9	4.9	5.2	5.2	5.3	6.1	6.1	6.9	7.3	8.3	8.6	9.9	10.2	11.0	11.3	11.1	11.4	9.8	11.3	8.3	9.4	9.6	9.6
EuroSiberian	1.4	1.5	1.5	1.5	1.5	1.7	2.1	2.1	2.4	2.4	2.5	2.5	2.8	3.2	3.5	4.2	3.7	2.8	3.4	3.3	3.6	4.7	3.8	3.8
Circumboreal	2.3	2.3	2.3	2.6	2.7	2.9	3.4	3.5	4.1	4.3	4.8	4.7	5.4	6.1	7.1	6.8	4.7	4.9	5.9	6.7	4.8	4.7	3.8	3.8
W-European	0.4	0.4	0.4	0.4	0.4	0.3	0.4	0.4	0.5	0.6	0.7	0.7	0.9	0.9	1.0	1.4	1.7	1.2	1.0	0.7	0.0	0.0	0.0	0.0
Central European	0.5	0.7	0.7	0.7	0.7	0.8	1.0	1.0	1.1	1.2	1.5	1.5	1.8	1.9	2.0	2.0	2.0	2.4	2.0	2.7	0.0	0.0	0.0	0.0
Cosmopolitan	1.5	1.5	1.4	1.5	1.4	1.4	1.5	1.6	1.7	1.7	1.8	1.9	1.9	2.2	2.8	3.4	3.4	3.7	3.9	3.3	3.6	0.0	0.0	0.0
NE-Eurimedit.	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.3	0.3	0.1	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.5	0.0	0.0	0.0	0.0	0.0
S-Europ.Orophytes	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.1	0.1	0.1	0.2	0.4	0.6	0.7	0.8	1.0	1.3	2.4	3.1	3.8	3.8
SE-Europ.Orophytes	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.3	0.4	0.4	0.4	0.5	0.4	0.5	0.8	1.4	1.7	2.0	2.4	2.0	2.4	3.1	3.8	3.8
N-Medit.Montane	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.5	0.6	0.6	0.6	0.7	1.0	1.1	1.0	1.2	1.0	1.3	2.4	3.1	3.8	3.8	3.8
Endemic	4.6	4.6	4.9	4.8	5.3	5.4	5.3	6.0	5.7	6.1	7.0	7.6	9.3	10.4	11.8	11.9	13.5	14.6	16.6	15.3	22.6	25.0	26.9	26.9
W-Medit.Montane	1.1	1.2	1.2	1.1	1.1	1.1	1.1	1.2	1.3	1.4	1.6	1.6	1.6	1.7	2.0	2.3	2.4	2.8	2.4	2.0	2.4	3.1	3.8	3.8
European	0.6	0.5	0.6	0.6	0.6	0.6	0.7	0.7	0.8	0.8	0.9	0.9	1.2	1.4	1.4	1.1	1.4	1.2	1.5	2.0	2.4	1.6	1.9	1.9
S Eur-S Siberian	2.5	2.6	2.6	2.5	2.7	2.9	3.5	3.5	3.6	3.6	3.8	3.8	3.5	3.6	3.3	3.1	3.4	3.3	3.9	2.7	4.2	6.2	7.7	7.7
S-Medit.Montane	1.5	1.5	1.4	1.1	1.2	1.0	0.8	0.9	0.9	0.9	0.9	0.9	0.7	0.7	0.8	0.8	1.4	1.2	1.5	1.3	1.2	1.6	1.9	1.9
SW-Europ.Orophytes	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.2	0.3	0.3	0.6	0.6	0.7	0.9	1.0	1.4	1.7	2.4	3.4	4.7	8.3	7.8	7.7	7.7

Table 1 — Data matrix. Percents of species belonging to 49 phytogeographical categories in 23 elevation intervals of 100 m each.

Results

The variation of species diversity in the OGU's along with the elevation gradient is shown in Fig. 1. Species diversity tends to decrease with increasing elevation. The decrease is slight from 0 to 600 metres, more pronounced and almost linear from 600 to 1600 m, with an average loss of 100 species every 100 m, and slight again from 1600 to 2300 m. How far this is due to elevation or to the progressive reduction of the surface of the OGU's along with elevation is not known. Probably both facts are involved, but the problem could be solved only after a quantitative analysis of the relation between surface of OGU's and species diversity.

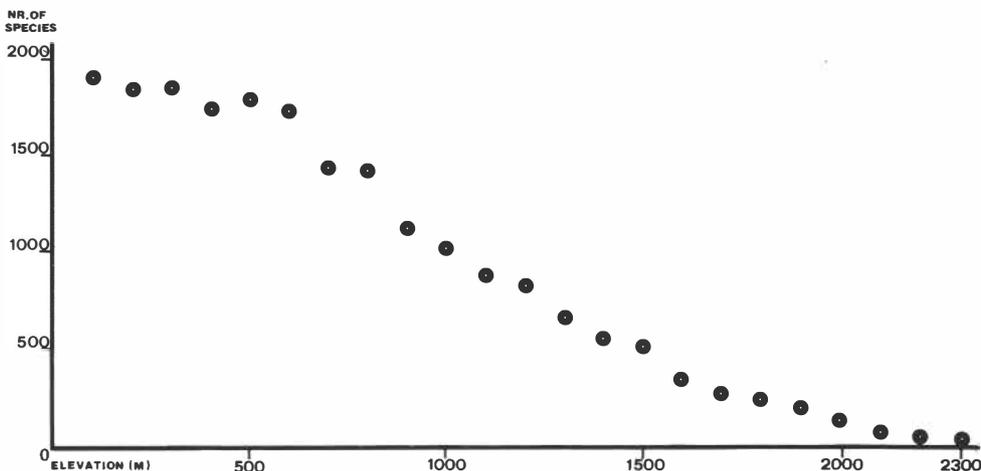


Fig. 1 — Floristic diversity along the elevation gradient in Sicily. Number of species in the 23 elevation intervals of 100 m each.

Classifications

The dendrograms of the OGU's and of the phytogeographical categories are respectively in Fig. 2 and in Fig. 3.

Two main clusters are formed in the dendrogram of OGU's, and each of them is subdivided into three subclusters, as follows (Fig. 2):

Cluster 1: it includes the elevation intervals from sea level to 1000 m. The first interval (0-100 m), forms a subcluster by itself. Two further subclusters respectively include the elevation intervals from 100 to 600 m and those from 600 to 1000 m.

Cluster 2: it includes the elevation intervals from 1000 to 2300 m; the three subclusters are as follows: 1000-1400 m, 1400-2000 m, 2000-2300 m.

The subclusters contain OGU's that are contiguous along the elevation gradient, and correspond to the following vegetation belts:

Lowland belt: 0-100 m.

Hill belt: 100-600 m.

Lower montane belt: 600-1000 m.

Montane belt: 1000-1400 m.

Upper montane belt: 1400-2000 m.

Alpine belt: 2000-2300 m.

Being this subdivision based on the frequency distributions of phytogeographical categories in the OGU, it is to be expected that each belt will be characterized by a typical phytogeographical spectrum.

In the dendrogram of phytogeographical categories (Fig. 3), only those clusters have been considered, that are formed at levels of the Correlation Coefficient above 0.0. The two clusters obtained under this level (each with two categories) include categories with very low frequency in each of the OGUs. Between 0.2 and 0.3 four main clusters are formed, as follows:

Cluster 1: it mostly includes categories limited to restricted portions of the Mediterranean Region. Tropical and Introduced species are also included in this cluster.

Cluster 2: the greatest part of the species included in the categories of this cluster are characterized by ranges extending over the whole of the Mediterranean Region (Euri- and Stenomediterranean species).

Cluster 3: the categories in this cluster either include species with very broad ranges (Subcosmopolitan, Cosmopolitan, Paleotemperate) or species whose distribution is centered north of the Mediterranean Region (Eurosibirian, Circumboreal, Central European etc.).

Cluster 4: this cluster mostly includes Orophytes. Endemic and European species s.l. also belong to it.

The frequency distributions of the four clusters of categories in the 23 elevation intervals are in Fig. 4:

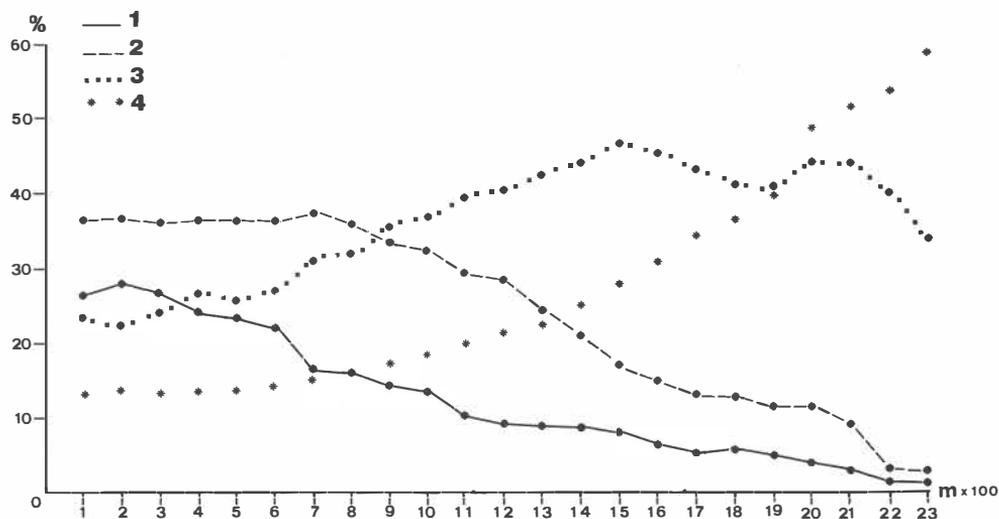


Fig. 4 — Frequency distributions of the species in clusters 1, 2, 3, 4 (Fig. 3) along the elevation gradient.

- the species included in the categories of Cluster 1 are most frequent in the lowland and colline belts (20-30% of the flora in each OGU); from 700 to 1000 m they tend to decrease and fall under 10% after 1100 m. They characterize the arid-mediterranean and the mediterranean vegetation belts (Pignatti, 1979). The fact that introduced species are included in this cluster is indicative of the fact that in these belts human impact on the natural ecosystems is maximal.
- The species included in the categories of Cluster 2 are most frequent (30-40% of the flora in each OGU) from sea level to 1200 m. They still constitute 20-30% of the floras up to 1400 m. Their frequency distribution curve differs from the previous one for a less marked decrease at lower elevations. Most of the species in this cluster are Steno- or Eurimediterranean. They characterize the Mediterranean Vegetation belt (*Quercus ilex* stands and their degradation stages).
- The species included in the categories of cluster 3 have a frequency maximum around 1500 m, and more or less regularly decrease both at lower and higher elevations. They characterize the deciduous summergreen belt dominated by *Quercus pubescens*, and the subatlantic belt (Pignatti, 1979), dominated by *Fagus sylvatica*.
- Finally, the species included in the categories of Cluster 4 have a maximum at higher elevations, and characterize the alpine vegetation belt.

Concentration analysis

The results of AOC performed on the contingency table of phytogeographical categories and OGUs are shown in Fig. 5. Tab. 2 gives the percentages of the total interaction chi square accounted for by the first and second Canonical Variates in AOC, and its relative shares accounted for by phytogeographical categories.

In Fig. 5 the sequence of the OGUs along the first Canonical Variate reflects a regular elevation increase from sea level to 2300 m. The OGU and the category points are further arranged along a horse-shoe shaped curve. The first Canonical Variate accounts for 53.2% of the total interaction chi square, the second for 27.1%. The fact that the sequence of OGUs along the first Canonical Variate corresponds with a regular elevation increase, and the high share of the interaction chi square accounted for by the two first Canonical Variates (altogether 80.3%) indicate a very high degree of correlation between phytogeographical categories and OGUs.

Over a total of 49 phytogeographical categories, 16 account for more than 2% of the chi square on either the first or the second Canonical Variates (boldface in Tab. 2). These categories have been retained to characterize the phytogeographical changes along the elevation gradient. Four graphs have been constructed (Fig. 6, 7, 8, 9), each of them respectively showing the frequency distributions of those of the 16 categories that are included in the four clusters obtained in the classification of categories (Clusters 1, 2, 3, 4, see Fig. 3).

Fig. 6 shows the frequency distributions of four categories included in Cluster 1: W-Stenomediterranean, Introduced, S-Stenomediterranean and SW-Stenomediterranean. They have a similar response to elevation, with high frequencies in the lowland and colline belts, and a sharp decrease after 600 m.

Fig. 7 shows the frequency distributions of two categories included into cluster

Table 2 — Absolute and percentual values of the chi square accounted for by phytogeographical categories (Ist and IInd canonical variates).

	Ist CANONICAL VARIATE		IInd CANONICAL VARIATE	
	X ²	%	X ²	%
SAHARO-SINDIC	12.60	0.550	0.855	0.165
PANTROPICAL	5.92	0.259	3.890	0.752
NW-MEDIT. MONT.	1.76	0.072	3.440	0.665
N-STENOMEDIT.	0.50	0.022	0.002	0.001
W-STENOMEDIT.	200.00	8.734	29.100	5.692
S-STENOMEDIT.	112.00	4.891	22.100	4.275
PALEOTROPICAL	5.92	0.259	6.160	1.191
SW-STENOMEDIT.	60.80	2.655	7.720	1.493
SUBTROPICAL	41.40	1.808	5.390	1.043
INTRODUCED	126.00	5.502	23.200	4.487
NW-STENOMEDIT.	7.280	0.318	0.965	0.187
E-EURIMEDIT.	3.850	0.168	0.004	0.001
AMPHIATLANTIC	2.630	0.115	0.168	0.032
EURIMEDIT.-ATL.	11.400	0.498	0.264	0.051
SUBATLANTIC	4.690	0.205	0.705	0.136
E-STENOMEDIT.	20.100	0.878	0.500	0.097
MEDIT.-TURANIAN	3.040	0.133	0.007	0.001
E-MED. MONTANE	0.216	0.009	1.220	0.236
SE-STENOMEDIT.	4.980	0.217	0.197	0.038
NE-STENOMEDIT.	7.100	0.310	0.672	0.130
N-EURIMEDIT.	3.700	0.162	1.190	0.230
EURIMEDIT.	56.700	2.476	19.900	3.149
W-EURIMEDIT.	4.460	0.195	0.362	0.070
STENOMEDIT.-ATL.	19.700	0.860	0.006	0.001
STENOMEDIT.	242.000	10.568	3.810	0.737
SE-EUROPEAN	0.901	0.039	6.630	1.282
NW-EURIMEDIT.	0.455	0.020	0.602	0.116
SW-MEDIT. MONT.	1.060	0.046	0.472	0.091
SUBCOSMOPOLITAN	1.700	0.074	2.710	0.524
S-EURIMEDIT.	0.914	0.040	1.830	0.354
PALEOTEMPERATE	28.400	1.240	13.000	2.515
EUROPEAN-CAUCAS.	58.200	2.541	22.500	4.353
NE-MED. MONTANE	72.300	3.570	11.900	2.302
EURASIATIC	116.000	5.066	7.820	1.513
EUROSIBERIAN	43.700	2.000	1.270	0.246
CIRCUMBOREAL	79.800	3.485	13.000	2.515
W-EUROPEAN	12.900	0.563	1.920	0.371
CENTRAL EUROPEAN	29.900	1.306	8.590	1.662
COSMOPOLITAN	20.000	0.873	0.007	0.001
NE-EURIMEDIT.	1.790	0.078	1.170	0.226
S-EUROP. OROPHYTES	244.000	10.655	0.602	0.116
SE-EUROP. OROPHYTES	142.000	6.201	18.300	3.540
N-MED. MONTANE	35.800	1.563	4.700	1.909
ENDEMIC	273.000	11.921	31.000	5.996
W-MED. MONTANE	19.800	0.865	0.994	0.192
EUROPEAN	21.600	0.943	0.113	0.022
S-EUR./S-SIBER.	17.900	0.782	9.850	1.805
S-MED. MONTANE	2.100	0.022	6.930	1.340
SW-EUR. OROPHYTES	90.000	3.930	76.600	14.816

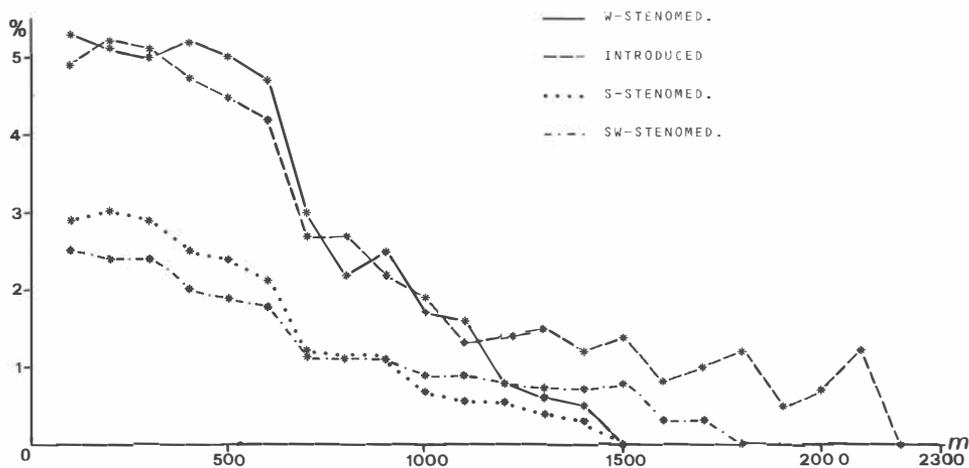


Fig. 6 — Frequency distributions of 4 phytogeographical categories in Cluster 1 (Fig. 3) along the elevation gradient.

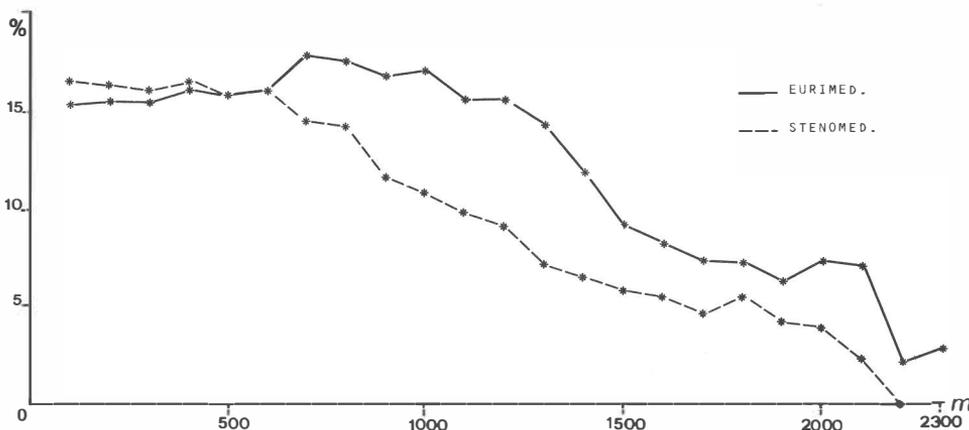


Fig. 7 — Frequency distributions of 2 phytogeographical categories in Cluster 2 (Fig. 3) along the elevation gradient.

2: Steno- and Eurimediterranean. They differ from the categories in Cluster A for a more regular decrease along the elevation gradient. Eurimediterranean species are most frequent in the OGU between 700 and 1000 m (lower montane belt).

Fig. 8 shows the frequency distributions of three categories included in cluster 3: European-Caucasian, Circumboreal and Eurosibirian. Also in this case they have similar responses to elevation, with higher frequencies in the montane belt.

Fig. 9 shows the frequency distributions of three categories included in cluster 4: Endemic: SW-European Orophytes and S-European Orophytes. They have the maximum frequency in the alpine belt.

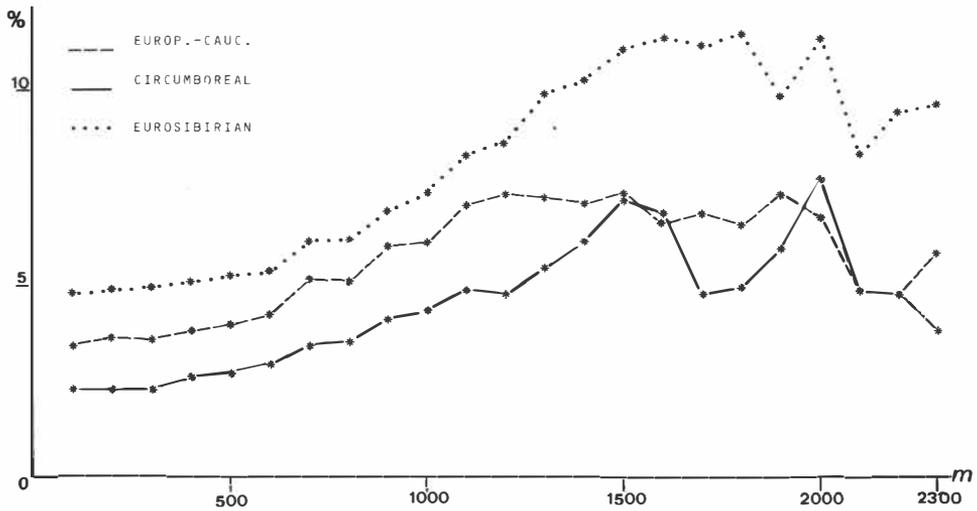


Fig. 8 — Frequency distributions of 3 phytogeographical categories in Cluster 3 (Fig. 3) along the elevation gradient.

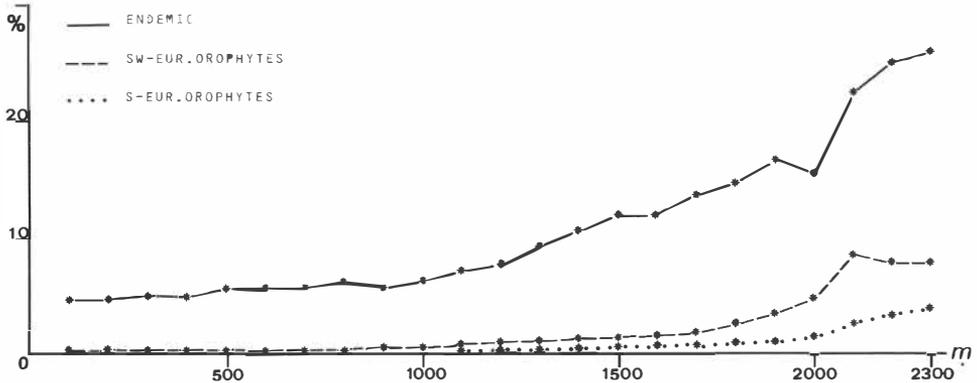


Fig. 9 — Frequency distributions of 3 phytogeographical categories in Cluster 4 (Fig. 3) along the elevation gradient.

In Mediterranean orobiomes temperatures and precipitation increase with elevation. Potential evapotranspiration is highest at lower elevation, and increases upwards. From the previous results, it seems that there is a relation between latitudinal range of species and their relative frequencies along the elevation gradient: the more the range of a species extends towards the north, the higher this species occurs in the mountains. The entire range of a species can be considered as one of the expressions of its genotype. From the study of the entire range, it is possible to make assumptions on some ecological requirements of a species in a

given area. In Mediterranean orobiomes an exception is given by the alpine vegetation belt, that has a great number of species with narrow ranges, mostly restricted to the mediterranean high mountains. This exception is due to historical factors, chiefly the very old age of the oromediterranean flora. A chorological-ecological interpretation of this flora cannot be based on pure actualistic hypotheses, but mostly on historical factors, whose age may date back to the late Tertiary period; for this reason, an analysis at taxonomic levels higher than the one of species is probably more suited to the phytogeographical study of the mediterranean flora at high elevations (Nimis, 1981b).

Concluding remarks

A general remark on the results presented above is that the very high degree of correlation between phytogeographical categories and OGU's represents a positive test of the Data Bank from which the data have been obtained.

The regular responses of the phytogeographical categories to elevation may be a suitable basis to produce quantitative predictive models in phytogeography. The next step will be the joint analysis of the response of phytogeographical categories to environment-types and to elevation and the test of these results against field-data. This will be presented in further papers of this series.

Riassunto. I dati sottoposti ad elaborazione provengono dalla Banca Dati sulla Flora e Vegetazione d'Italia. Essi si riferiscono alla flora fanerogamica della Sicilia. La matrice dei dati riporta le percentuali di specie, raggruppate in 49 categorie fitogeografiche sulla base della somiglianza dei loro areali, in 23 intervalli altitudinali di 100 m ciascuno. Essa è stata sottoposta a programmi di classificazione e di ordinamento. I cluster di intervalli ottenuti dalla classificazione corrispondono bene alla suddivisione della Sicilia in fasce altitudinali di vegetazione. La classificazione delle categorie fitogeografiche ha permesso di individuare 4 gruppi di categorie fitogeografiche con diverse distribuzioni di frequenza lungo il gradiente altitudinale. In base ai risultati dell'ordinamento sono state individuate le categorie fitogeografiche maggiormente correlate con il gradiente altitudinale. I risultati si inseriscono in una serie di elaborazioni sulla flora vascolare della Sicilia il cui scopo è di fornire una base metodologica per l'applicazione di modelli quantitativi in fitogeografia.

Acknowledgements. The author expresses his thanks to Prof. D. Lausi and E. Feoli (Trieste), Prof. S. Pignatti (Rome) and Prof. D. Goodall (Perth, Australia) for comments to the manuscript. The work has been supported by a CNR grant to "Gruppo Biologia Naturalistica".

References

- Anderberg M.R. (1973) - *Cluster Analysis for Applications*. Academic Press, New York-London.
- Crovello T.J. (1981) - *Quantitative Biogeography: an overview*. *Taxon*, 30 (3): 563-575.
- Feoli E. & Orloci L. (1979) - *Analysis of Concentration and detection of underlying factors in structured tables*. *Vegetatio*, 40: 49-54.
- Lausi D. & Nimis P.L. (1984) - *Quantitative Phytogeography of the Yukon Territory (NW Canada) on a chorological - phytosociological basis*. *Vegetatio*, 57: 65-76.
- Lausi D. & Nimis P.L. (1985) - *Ruderal Weed Vegetation in Boreal NW-America (S-Yukon, Canada - S-Alaska, USA)*. *Phytoceonologia* (in press).
- Nimis P.L. (1981) - *La Banca Dati relativi alla flora e vegetazione d'Italia*. *Quad. CNR, AC/1/105*: 83-86.
- Nimis P.L. (1981) - *The Thorny-cushions Vegetation in Mediterranean Italy*. *Phytogeographical problems*. *Anales Jard. Bot. Madrid* 37 (2): 339-351.
- Nimis P.L. (1984) - *Contributions to Quantitative Phytogeography of Sicily: I: Relations between Phytogeographical Categories and Environment-types*. *Webbia* (in press).
- Nimis P.L., Feoli E. & Pignatti S. (1984) - *The Network of Databanks for the Italian Flora and Vegetation*. In R. Allkin & F.A. Bisby (ed.) *Databases in Systematics*: 113-124. Academic Press, London and Orlando.
- Orloci L. (1978) - *Multivariate Analysis in Vegetation Science*. 2nd ed. Junk, The Hague, 451 pp.
- Pignatti S. (1979) - *I Piani di Vegetazione in Italia*. *Giorn. Bot. Ital.*, 113: 411-428.
- Pignatti S. (1981) - *Check-list of the Flora of Italy with codified plant names for computer use*. *Quad. CNR AQ/5/13*. Rome.
- Pignatti S. (1982) - *Flora d'Italia*. Calderini, Bologna, 3 vv.
- Wildi O. & Orloci L. (1980) - *Management and Multivariate Analysis of Vegetation Data*. *Swiss Fed. Inst. For. Res. Rep. Nr. 215*, Birmensdorf, 68 pp.

Pier Luigi Nimis
Dipartimento di Biologia
Università degli Studi
di Trieste, 34100 Italia

SPAGHET: A COENOCLINE SIMULATOR USEFUL TO CALIBRATE SOFTWARE DETECTORS

M. LAGONEGRO

Keywords: calibration, simulation, software.

Abstract. A coenocline simulator is described, which allows one to calibrate programs or chains of programs before using them on survey data. An example is given, and the listings of two versions of the simulator, in BASIC and FORTRAN respectively.

Introduction

When a research branch grows beyond a certain threshold level, more and more facts drive the researches and the scholars toward the use of computer programs, often linked into sophisticated chains. The first is the horrendous amount of data collected in decades of field surveys or laboratory experiments, which makes it impossible to extricate sensible result by sheer visual inspection and clever intuition. One has to sort, select and reorganize the data sets into data banks, in order to achieve tables reflecting the logical structure of a targeted search through all the archives. This new table will be cleared of all the information not consistent with the intersection of parameters which have driven the search process.

Eventually the need arises to try to extract would be relations among these parameters. They are indirectly represented in the table, as species counts or states. For this, as it is typical of a mature science, one uses indirect techniques, that is computer codes which make use of numerical indexes, which in turn reflect some assumptions on the underlying structure of the involved relations in the data.

At this point there is the danger of finding artifacts rather than the real structure. To reduce the chances of this actually happening, one has to follow the path of calibration of software detectors he is going to use. So let us see what we need to perform a reasonable calibration.

A calibrating program must allow the user to simulate a good many features of the actual working condition, under which data are usually collected. For this purpose some error generating routine must be provided, which allows to simulate

errors usual in data collection. However, user control must be allowed at any level he chooses. Finally, the program must be able to give the user some theoretical reference condition that could be thought of as the result of a perfect measurement. In this way one will know how near to or far from the perfect condition the software detector is working.

SPAGHET is one of these calibrating programs. Another for example is by Gauch (1976), SPAGHET assumes a certain underlying model of coenocline, in which a given number of characters reacts to a complex of conditioning factors, which interact with each other in some not always known way to give size to an X axis. This axis represents the field of definition of the response functions, whose shapes, intensity and types can be varied (Austin, 1976a and b).

SPAGHET has already been used to test the performance of program COCHIS (Feoli & Lagonegro, 1983) and in teaching. It is routinely employed when a program chain has to be tested before release to the users. Another example of its usefulness is given in this volume (Feoli & Lagonegro, 1984). SPAGHET has been written in FORTRAN IV for a CDC 170/730 CYBER, operating under NOS 2.1. Two simplified versions have been realized in BASIC for APPLE II plus and OLIVETTI M20 ST respectively. The differences will be pointed at in the following. In the appendix are reported the listings of an updated FORTRAN version, called NEWSPAG and of the OLIVETTI M20ST version. APPLE users who want to implement it on their computers may have only to change the OPEN and CLOSE instructions and substitute the LPRINT instruction with the usual DOS command which sends the output to the appropriate printer slot.

1. Technical description of SPAGHET

In Figure 1 is given a simple example of the coenocline model on which SPAGHET is based. In the example all the response functions are Gaussian, since it gives a clearer picture, but other shapes are allowed, in order to attain a more realistic simulation.

1.1. Types of response functions

Four types of response functions are possible in Spaghet, and they are:

Gaussian $g(i, X) = h(i) * \exp(- (X - m(i)) / s(i))^2$

Bimodal $b(i, X) = g(i, X) - g(i, X + 4s(i))$

where $m(i)$ is the position of the mode, while $s(i)$ is the dispersion parameter sigma

Poisson $p(i, X) = h(i) * (1/X!) * m(i)^X * \exp(-m(i))$

Mirror-poisson $p(i, X \max - X)$

where $X \max$ is described in Fig. 2 and $m(i)$ is the mean value, equal to $s(i)^2$. This sort of response function assumes non-zero values in an interval from 0 to 16, centered at the mean position.

Only the first type has been implemented on the APPLE II plus and OLIVETTI M20ST.

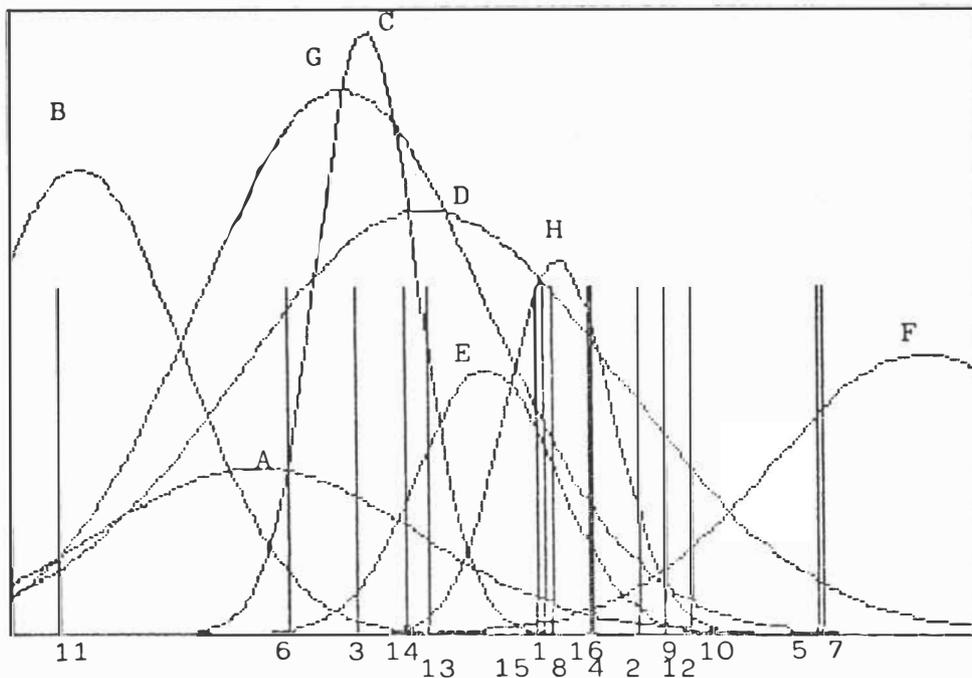


Fig. 1 — Plot of the 8 response functions and of the 16 sampling units reported in Table 1. Capital letters label the functions, while numbers label the units.

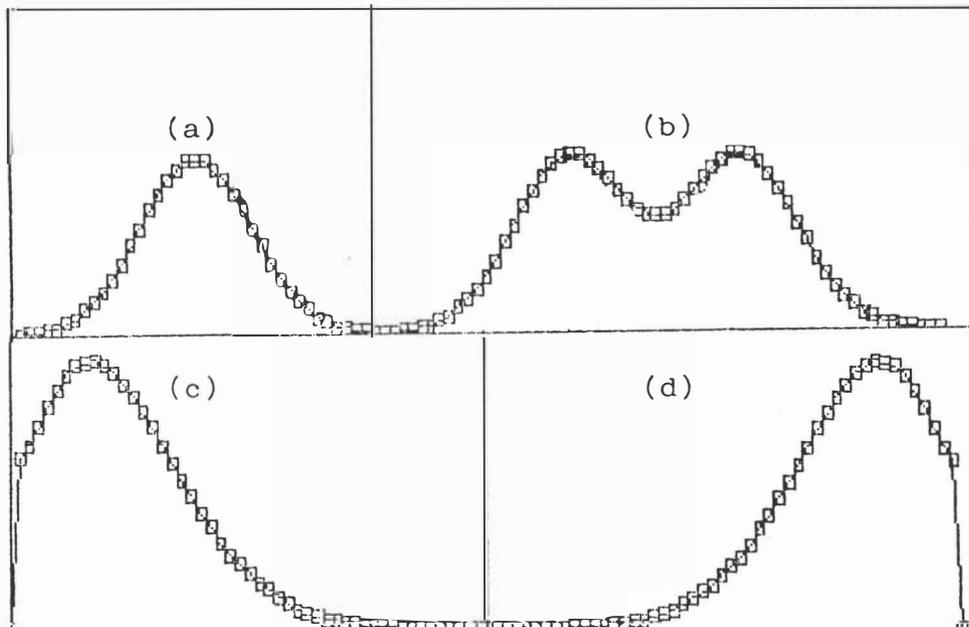


Fig. 2 — Types of response functions allowed in NEWSPAG: (a) gaussian, (b) bimodal, (c) poisson, (d) mirror-poisson. Only the first type is allowed in the versions for APPLE II and OLIVETTI M20.

1.2. Evaluation of function parameters and sampling unit positions

The type can be fixed from outside by the user, if he wants to test some ideas, or it can be randomly generated and assigned. The variable X ranges from 0 to a maximum value given in input, together with the number of the response functions and sampling units. The later are indicated in Fig. 1 by vertical bars. The value of the i -th response function in the j -th sampling unit is just the value assumed by the function at point $X = X_j$ (Fig. 3). Errors are introduced by allowing it to be randomly chosen inside an interval centered on the theoretical value, with amplitude allowed by a given "noise" factor, which is also an input quantity. Eventually, to simulate frequency counts, the value is given that of the nearest integer number.

The range depends on the desired average density of response function per arbitrary unit of the coenocline. In the case shown in Fig. 1, 8 functions have been generated, with 16 sampling units, in a range of value 4; so we have there an average density, both of response functions and sampling units, equal to 2 and 4 respectively. On this range value depend also the minimum and maximum values of the parameter $s(i)$, measuring the dispersion of the i -th function. The values are

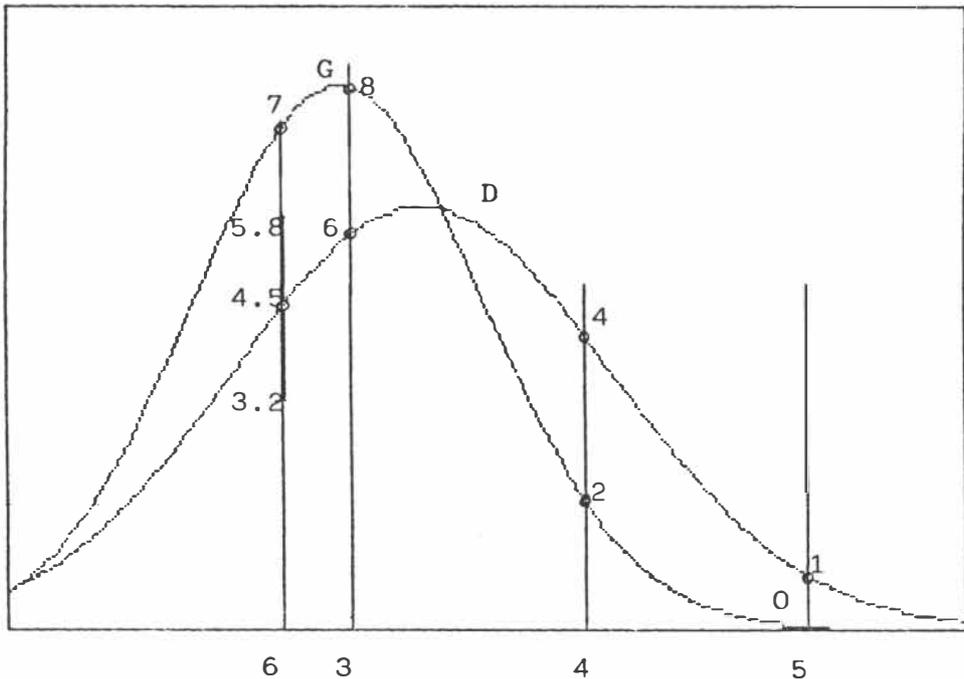


Fig. 3 — Two functions (D and G) and four sampling units (3, 4, 5, 6) from Fig. 1 are reported. In case of 0% noise, the values of the response functions in the four units would be those written near the circles. On unit 6 is reported an interval (from about 3 to about 6) into which would have fallen the simulated datum in case of 60% noise ($\pm 30\%$ around theoretical value, and then rounded to the nearest integer).

computed according to:

$$\begin{aligned} s(\text{min}) &= \text{Range value}/20 \\ s(\text{max}) &= \text{Range value}/5 \end{aligned}$$

The functions and the sampling units are generated at random and the letter labels indicate the order of generation of the first, while the numbers are employed for the others.

The height $h(i)$ of the functions at the mode is given in input or randomly computed inside an interval depending on the maximum value which the user chooses. The interval limits are:

$$\begin{aligned} h(\text{min}) &= 1 \\ h(\text{max}) &= \text{Max value} \end{aligned}$$

The $m(i)$ are assigned by the user or randomly generated in the interval from 0 to the Range value.

1.3. Generation of tables

When all the functions and the sampling units are defined, a table is produced with the response functions as columns and the units as rows. The table, including noise and rounding effects, is then written to a proper file. In this form it is ready for input in a chain of software detectors.

In the case of Fig. 1, the maximum response value is 9 and the noise level is 30% (0.3). The simulated coenocline has the characteristics of Table 1.

The resulting data table (including a noise fluctuation of 30%, that is $\pm 15\%$ around the theoretical value) is shown on Table 2.

Generating the same simulated experiment, but with 0% noise, gives a table with 23 non zero numbers differing by one or two units from the corresponding elements of the 30% table; this incorporates a good 18% of the whole table and a 37% of the non zero elements.

The simulation of the condition of "perfect measurement" is performed via a large number of equally spaced sampling units; it is clear that the larger the number the better the simulation. Anyhow, after a certain number of units the results become stable and one chooses the least expensive in terms of time and computer resources. Such a perfect sample, with 100 units, is reported in Fig. 4. One could think that also a very dense random sampling could simulate this condition; may be, but one has to generate a very large number of data points, without being sure of having obtained the asymptotic condition of the theoretical measurement. To look at the effect of this technique a random sample of 100 units has also been generated. In the following paragraph the three tables will be processed via a well known procedure and the results will be compared to one another and with the content of Fig. 1.

Table 1 — Characteristics of the 8 response functions and positions of the 16 random generated sampling units.

$h(\min)=1$	$h(\max)=9$	$s(\min)=4/20=0.2$	$s(\max)=4/5=0.8$
Function number $i=1(A)$	$h(i)=2.39$	$m(i)=1.02$	$s(i)=0.67$
2(B)	6.71	0.29	0.43
3(C)	8.69	1.49	0.21
4(D)	6.09	1.73	0.79
5(E)	3.80	1.98	0.28
6(F)	4.01	3.78	0.63
7(G)	7.84	1.39	0.60
8(H)	5.36	2.28	0.22
Sampling unit number $j= 1$	$X_j=2.22$		
2	2.60		
3	1.44		
4	2.41		
5	3.34		
6	1.15		
7	3.36		
8	2.25		
9	2.70		
10	2.82		
11	0.20		
12	2.71		
13	1.74		
14	1.64		
15	2.19		
16	2.40		

2. Calibration of a software tool

Suppose now that we want to calibrate the well known procedure of eigenanalysis on a correlation coefficient matrix derived from the data table. What we want to see is if the procedure can work with a sampling error rate of up to 30%. We first compute the symmetric correlation matrix, which is given in Table 3.

Now we submit this matrix to an eigenanalysis in order to get the eigenvalues and the associated eigenvectors. After having written the last ones to a file, we call into action a plot routine. The results of the plot is displayed in Fig. 4. We note the appearance of the typical horseshoe trend in the scatter of the 8 response functions.

Table 2 — Data table resulting from computing the response function values at the 16 sampling units and allowing 30% noise, that is a 15% range of fluctuation both over and under the theoretical value; the values cannot anyhow be greater than the maximum allowed for the response functions.

Sampling units	Response functions							
	A	B	C	D	E	F	G	H
1	.	.	.	4	2	.	3	5
2	.	.	.	3	.	1	1	0
3	2	.	6	5	0	.	6	.
4	.	.	.	3	1	.	2	4
5	.	.	.	1	.	3	.	.
6	2	1	2	4	.	.	5	.
7	.	.	.	1	.	2	.	.
8	.	.	.	4	2	.	2	5
9	.	.	.	2	.	1	1	1
10	.	.	.	2	.	1	.	.
11	1	6	.	1	.	.	1	.
12	.	.	.	2	.	1	1	1
13	1	.	3	5	2	.	6	.
14	1	.	5	4	2	.	6	.
15	.	.	.	4	3	.	3	5
16	.	.	.	3	1	.	2	4

One can now compare sequence and groupings with the situation depicted in Fig. 1. We submit then the first three components (eigenvectors) to a three-dimensional Minimum Spanning Tree (MST) procedure, to obtain a more complete information about mutual relationships between pairs of response functions. The result is shown by the arrows in Fig. 4.

We impose this sequence as column order on the original table and rearrange it internally, by shifting the elements of each sampling unit after this order of functions. Then we reorder the unit positions (that is the row sequence) in the table by putting first that which has non zero valued elements corresponding to as many as possible of the response functions coming first in the column sequence, and so on. The results are shown in Table 4a. One can easily spot the characteristic trend of a coenocline. By comparing the sequence of sampling units with those in Fig. 1, one can see that the analysis has been quite successful, since the groups and their sequence have been properly identified.

A minimum has been found between functions *G* and *C*, thus suggesting the existence of two broad groups of functions, (*H, D, G*) and (*C, A, B, E, F*). The same grouping is suggested by average linkage clustering performed on Table 3, the

Table 3 — Matrix of correlation coefficients between pairs of response functions, computed based on the 16 random sampling units.

		Columns							
		1	2	3	4	5	6	7	8
Rows	1	1.	.733	.583	-.929	.503	.006	-.339	-.572
	2		1.	.143	-.716	.293	.006	-.447	-.378
	3			1.	-.491	.172	-.204	.260	-.719
	4				1.	-.639	-.104	.415	.401
	5					1.	-.191	-.472	.192
	6						1.	-.577	-.265
	7							1.	-.110
	8								1.

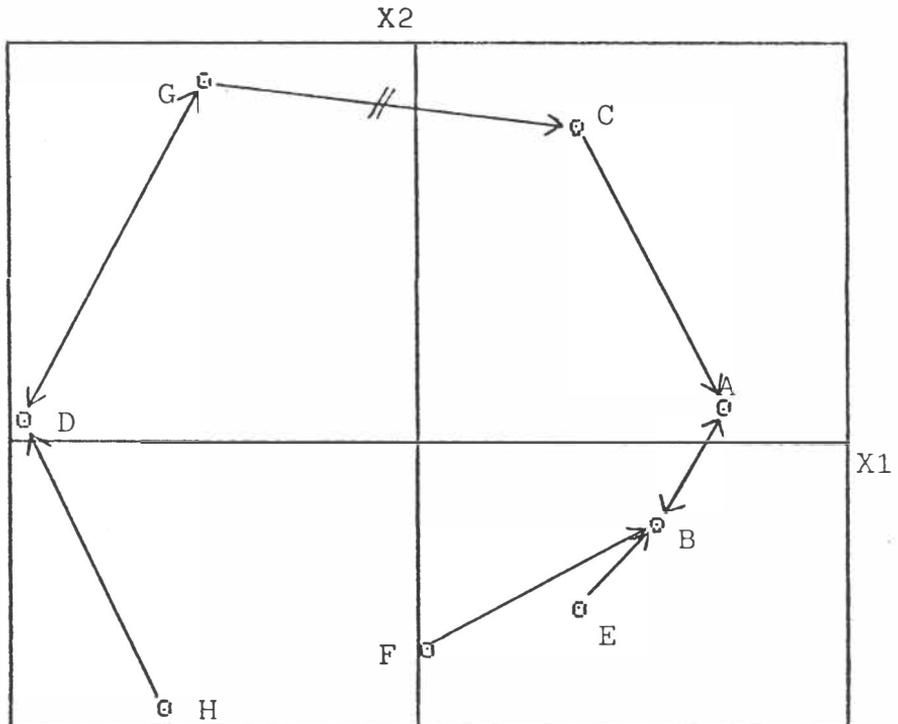


Fig. 4 — Results of eigenanalysis on the correlation matrix among functions. First two eigenvectors used with 45.66% and 23.9% (cumulative 69.56% of variance accounted for). Arrows indicate mutual M.S.T. relations suggested by a three-dimensional plot routine which uses three eigenvectors (cumulative 87.5%) and a distance matrix to give M.S.T. pairings (for its listing see in Appendix C). A minimum has been found between C and G, thus suggesting the existence of two broad groups (H D G) and (C A B E F). F has been joined to B as the last unassigned function left at the end of the clustering process.

Table 4 — Data table (Table 2) rearranged first by ordering columns according to MST based on response functions (a), then by performing the same but with order from MST based on sampling units (b).

Sequence from MST	Response functions								
	B	A	E	C	G	D	H	F	
Sampling unit number	6	1	2	.	2	5	4	.	.
	11	6	1	.	.	1	1	.	.
	13	.	1	2	3	6	5	.	.
	14	.	1	2	5	6	4	.	.
	3	.	2	.	6	6	5	.	.
	1	.	.	2	.	3	4	5	.
	4	.	.	1	.	2	3	4	.
	8	.	.	2	.	2	4	5	.
	15	.	.	3	.	3	4	5	.
	16	.	.	1	.	2	3	4	.
	9	.	.	.	.	1	2	1	1
	12	.	.	.	.	1	2	1	1
	2	.	.	.	.	1	3	1	.
	5	.	.	.	.	.	1	.	3
	7	.	.	.	.	.	1	.	2
	10	.	.	.	.	.	2	.	1

(a)

Sequence from MST	Sampling unit numbers																
	5	7	10	9	12	2	16	15	8	4	1	13	14	6	3	11	
Response functions	D	1	1	2	2	2	3	4	4	4	3	4	6	5	3	5	1
	F	3	3	1	1	1	1	.	.	.	.	.	.	.	.	.	.
	G	.	.	.	1	1	1	1	2	2	2	3	6	7	6	6	1
	H	.	.	.	1	1	2	3	4	5	4	5	.	.	.	.	.
	E	.	.	.	.	.	.	1	2	2	1	2	2	1	.	1	.
	A	.	.	.	.	.	.	.	.	.	.	.	1	1	2	2	1
	C	.	.	.	.	.	.	.	.	.	.	.	4	5	2	8	.
	B	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	5

(b)

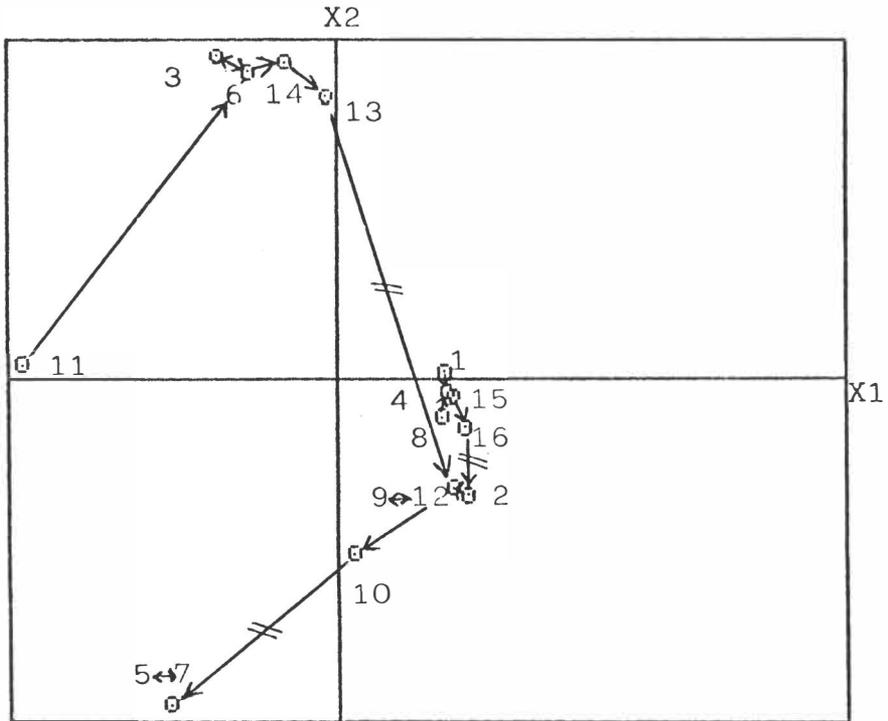


Fig. 5 — Results of eigenanalysis of correlation matrix for sampling units. First two eigenvectors account for 48,79% and 22,80% (cumulative 71,59% of the total variance). Arrows indicate suggestions of a three-dimensional M.S.T. procedure (cumulative 89,56%). Three minima are found, thus isolating four groups of units, (5 7) (10 9 12 2) (16 15 8 4 1) (13 4 6 3 11). This fits well with the structure shown in Fig. 1, all the lateral branches are very short and the sequence looks good indeed.

dendrogram of which is given in Fig. 6. If one examines Fig. 1, one sees the two function groups appear well isolated. The only exception is function *F*, which does not belong to the group it has been assigned to. The assignment is due to the fact that *F* was the last unassigned item and it was connected with the nearest of the other ones, no matter how feeble the bound was. Identical results were obtained by sum of squares agglomeration using the euclidean distance matrix based on Table 2.

By submitting to the same analysis the sampling units, the results shown in Fig. 5 and Fig. 6 are obtained. Table 4b contains the transpose of Table 2, rearranged this time after the order of the sampling units. We can see that four groups of relevés are put into evidence by the MST procedure, that is (5, 7) (10, 9, 12, 2) (16, 15, 8, 4, 1) (13, 14, 6, 3, 11). This fits very well with the evidence of Fig. 1; all the lateral branches are very short and the sequence looks pretty good. The clusters from an average linkage procedure are shown in Fig. 7, and give the same suggestion, with only unit 11 out of the groups. One can see the typical stairwise linking of groups,

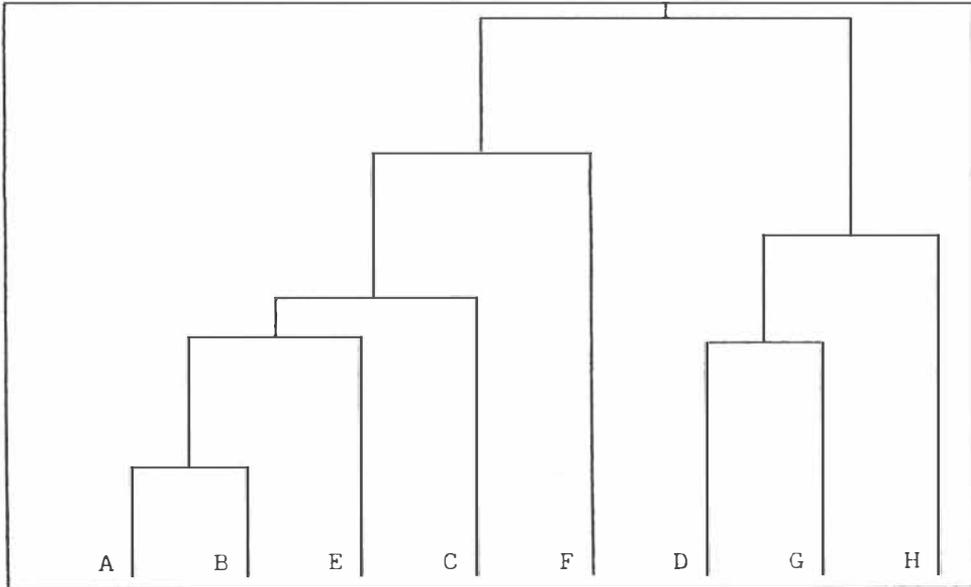


Fig. 6 — Cluster formed by average linkage clustering based on the correlation matrix among functions. Two groups are suggested (A B E C F) and (D G H).

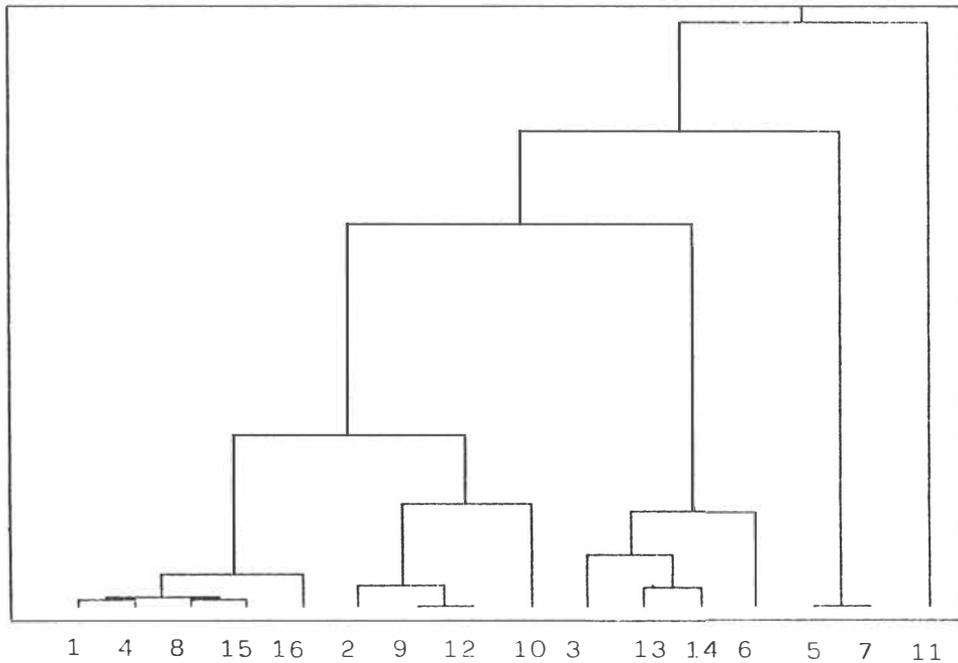


Fig. 7 — Cluster formed by average linkage clustering based on correlation matrix among sampling units. Five groups are suggested (1 4 8 15 16) (2 9 12 10) (3 13 14 6) (5 7) (11).

from left to right, which also hints the presence of a coenocline inside the data. A clustering procedure performed via sum of squares agglomeration adds elements 5.7.11 to another group, thus showing only three broad groups. The cross matrices are reported in Table 5, together with the level of significance of the comparisons. We see that the three classifications are statistically identical, so that we can use whichever of them we want to. By the way this comparison was not necessary in the case of the response functions, since the three suggestions were identical.

So much for the sampling units, since they have been classified and ordered quite satisfactorily and one can say that the praxis works very well on coenocline detection via their analysis.

Now it comes to do the same processing on the data matrix produced by the "perfect sampling", in order to verify the correspondence that the best experimental condition we could ever dream of (Fig. 8a) has with the preceding case. In Fig. 8b we have the scattergram and the suggestions of MST: three groups can be identified, that is (D, G) (C, A, B) (E, H, F), with the last two closer each other than with respect to the first. The average linkage clustering shows (Fig. 9) the structure (A, B, C, E, H) (F) (D, G), with the first group exhibiting the two substructures (A, B, C) and (E, H). The sum of squares procedure shows two broad groups, (A, C, E, H, F, B) and (D, G).

Table 5 — Matrices of comparison between pairs of classifications of the 16 sampling units randomly generated.

	Classes from MST
Classes from euclidean distance	0 0 5 0 2 4 0 1 0 0 0 4
	2I=29.3 for 6 degrees of freedom (sign.=0.000055%)

	Classes from average linkage
Classes from euclidean distance	0 0 0 1 4 1 2 0 4 0 0 0 4 0 0
	2I=29.3 for 8 degrees of freedom (sign.=0.00029%)

	Classes from average linkage
Classes from MST	0 2 0 0 0 0 0 0 4 0 0 0 0 1 4 1 0 4 0 0
	2I=37.7 for 12 degrees of freedom (sign.=0.00017%)

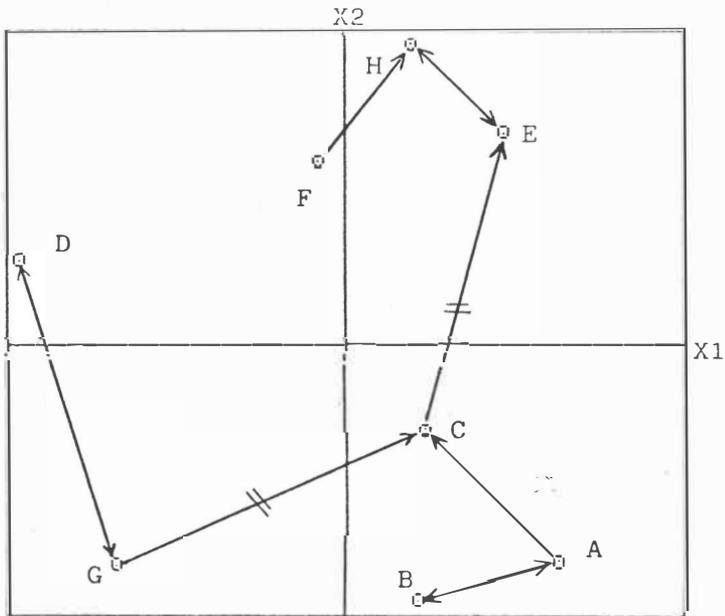
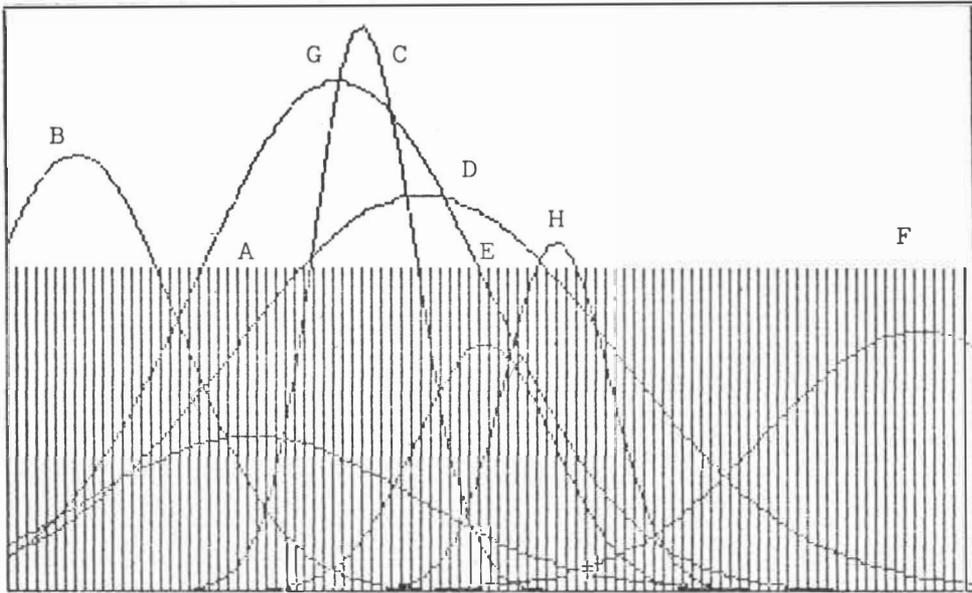


Fig. 8 — Perfect measurement sampling (a) and scattergram with M.S.T. suggestions. Two minima are found, between G and C and between E and C, thus suggesting three groups (F H E) (C A B) (G D).

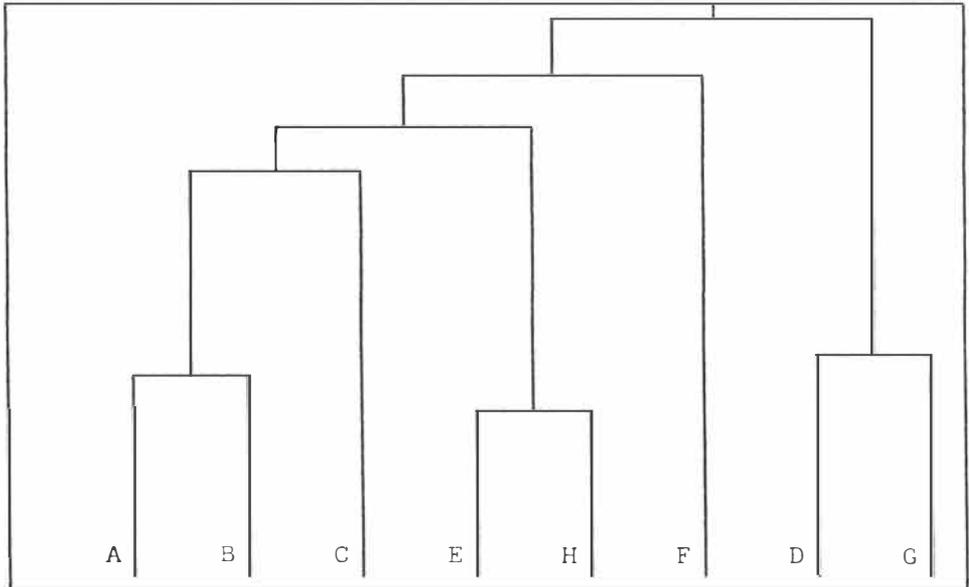


Fig. 9 — Cluster based on average linkage clustering based on correlation matrix among functions, computed using the perfect sampling condition. Three groups appear (A B C E H) (F) (D G), with the first one showing two substructures (A B C) and (E H).

Table 6 — Comparisons of classifications obtained from data representing the perfect measurement.

	Classes from euclidean distance
Classes from average linkage	5 0
	1 0
	0 1
	2I=8.99 for 2 degrees of freedom (sign.=1.1%)

	Classes from MST
Classes from average linkage	2 3 0
	1 0 0
	0 0 2
	2I=10.58 for 4 degrees of freedom (sign.=3.2%)

	Classes from MST
Classes from euclid. dist.	3 3 0
	0 0 2
	2I=8.99 for 2 degrees of freedom (sign.=1.1%)

Table 7 — Data Table 2 restructured following the order of MST from (a) 100 equidistributed sampling units, (b) 100 randomly chosen sampling units. In both the coenocline trend is clearly seen. The ordering groups response functions and sampling units into homogeneous blocks.

		Response functions						Response functions											
		F	H	E	C	A	B	G	D			B	A	C	G	D	E	H	F
Sampling unit N.	9	1	1	.	.	.	.	1	2	Sampling unit N.	6	1	2	2	5	4	.	.	.
	12	1	1	.	.	.	.	1	2		11	6	1	.	1	1	.	.	.
	5	3	.	.	.	.	.	.	1		13	.	1	3	6	5	2	.	.
	7	2	.	.	.	.	.	.	1		14	.	1	5	6	4	2	.	.
	10	1	.	.	.	.	.	.	2		3	.	2	6	6	5	.	.	.
	1	.	5	2	.	.	.	3	4		1	.	.	.	3	4	2	5	.
	4	.	4	1	.	.	.	2	3		4	.	.	.	2	3	1	4	.
	8	.	5	2	.	.	.	2	4		8	.	.	.	2	4	2	5	.
	15	.	5	3	.	.	.	3	4		15	.	.	.	3	4	3	5	.
	16	.	4	1	.	.	.	2	3		16	.	.	.	2	3	1	4	.
	2	.	1	.	.	.	.	1	3		9	.	.	.	1	2	.	1	1
	13	.	.	2	3	1	.	6	5		12	.	.	.	1	2	.	1	1
	14	.	.	2	5	1	.	6	4		2	.	.	.	1	3	.	1	.
	6	.	.	.	2	2	1	5	4		5	.	.	.	.	1	.	.	3
	3	.	.	.	6	2	.	6	5		7	.	.	.	.	1	.	.	2
	11	.	.	.	.	1	6	1	1		10	.	.	.	.	2	.	.	1

(a)

(b)

In table 6 are reported the cross matrices of the comparisons and the related significativity level, which tell us they are statistically equivalent. In Table 7a we have the data Table 2 rearranged in the way already described before: the coenocline trend is evident, with the less important functions D and G put aside. The sampling units are well grouped and so happens in Table 7b, resulting from the already known procedure applied to a table of 100 randomly chosen sampling units. The clustering procedures give results which are identical to those of the theoretical case.

Now it comes to comparing the results obtained for the response functions from the analysis of the 16 units table and those of the perfect case and of the 100 randomly chosen units. While the latter two give the same results and are therefore completely equivalent, the first and the theoretical case have a similarity level of 6,1%, very high but not significant, good but not perfect.

3. Conclusions

Having done all this, what can we conclude? Same things may in my opinion be

deduced:

- a) the software procedure based on correlation coefficient is a tool capable of detecting a coenocline, also in presence of 30% of "noise", that is experimental random errors;
- b) the parallel procedure employing the euclidean distance is a good one too;
- c) since the 16 random sampling units are enough to characterize their groups, but not enough to completely sample the response functions, while the 100 randomly chosen do, it would be wise to retrace all again with more units, for instance 20 or 30, anyhow a number placed between 16 and 100. Another trial could be made with a smaller noise, which in turn means a more careful sampling and therefore a better survey planning.
- d) since on practical ground one hasn't any Fig. 1 which he can look at, but one's professional skill and experience, it is highly advisable to use parallel procedures, both previously calibrated with the same calibrating "source", so that the probability of getting out lovable artifacts both ways can be considered very low, when not negligible;
- e) the calibration must be performed with different noise levels, in order to correctly evaluate the threshold level of a given procedure, that is the level over which all the method breaks down and starts to give unstable results or no results at all.
- f) the ratio between the number of sampling units, which allow to reconstruct the structure of the simulated data, and the number of response functions should be considered a sort of lower limit indicator when the actual number of survey units must be planned. This means that, if 24 units work well when 8 functions are present, the number of planned survey sampling units should be at least three times the number of characters or species taken into account.

4. Working structure of SPAGHET

While the APPLE II and OLIVETTI M20ST versions are completely manageable through the user menu they give, the FORTRAN version NEWSPAG needs some explaining. This will be given in this section in a flow-chart like fashion.

Before starting, an advice is in order. The program has been implemented on a CDC machine and therefore all the alphanumeric strings are thought of in blocks of 10 per CDC word. The computation label, for instance, may have up to 40 characters and the associated variable is dimensioned in 4 words. If a user has to use a machine with 6 bytes per word, for example, he has to dimension the variable in 7 words so that all the 40 characters can find room, or else maintain the old dimension and reduce the label length to 24 characters.

4.1. Data flow and steps

The parameters are presented to the program in the following sequence:

- 1) TITLE (up to 40 characters, format 4A10), that is the computation label.
IF the first 10 characters are all blank THEN the program stops ELSE it goes to read the second string of parameters.
- 2) these parameters are:

NC, NR, NBOH, MAXALT, IRANGE, IPLOT, IFIS, IFIR, NOISE, LSLP, JACCA (free format)

NC: number of response functions (up to 100);

NR: number of sampling units (up to 300);

NBOH: arbitrary number of unused random number generations before starting the actual computation. This allows a user to change pattern to the sequence of random numbers produced by function RANF (library). We shall use the word RANF in the following to indicate a random number generation. The numbers are generated with uniform distribution density in the 0-1 interval;

MAXALT: maximum value allowed for the modal value of the response functions;

IRANGE: range of X (in undimensioned arbitrary units);

IPLOT: IF $> = 0$ THEN the response functions are printed on paper in noiseless values (JACCA values)
 ELSE IF < 0 THEN the Minimum Spanning Tree groups are recognized through inspection of a similarity ratio matrix, computed based on JACCA equidistributed noiseless valued sampling units;

IFIS: IF > 0 THEN the parameters of the response functions are given in input by the user
 ELSE IF $< = 0$ THEN they are randomly generated in the chosen field of definition;

IFIR: the same as before but for the sampling units;

NOISE: in %, it is the maximum percentage indeterminacy allowed in the simulated data;

LSLP: IF $= -1$ THEN the similarity ratio is computed with cover scores
 ELSE IF $= 0$ THEN normalized-cover (normacover) scores are used
 ELSE IF $= 1$ THEN presence-absence (binary) scores are used;

JACCA: this has been already explained. The number of equidistributed sampling units can be up to 3000. A similar option, but with less units, is present in the BASIC version.

3) IF IFIS > 0 THEN the parameters of the NC response curves must be given in input, for each curve; they include:
 TYPE (format A10), PMOD, VMED, SIG, HMOD (free format)
 where:
 TYPE: GAUSS (gaussian function)
 BIMODAL (two gaussian functions of the same standard deviation SIG but mean value VMED differing $4 * SIG$, in order to generate two maxima);
 POISSON (poissonian profile, with the maximum on the left);
 MIRRORPOIS: like POISSON, but with the maximum on the right.

PMOD: mode of the function;
 VMED, SIG: already explained;
 HMOD: modal value.

ELSE the parameters are randomly generated in the following way:

```
generated      a = RANF
IF 0 <= a <= 0,25 THEN TYPE = POISSON
ELSE IF 0,25 < a <= 0,5 THEN " = BIMODAL
ELSE IF 0,5 < a <= 0,75 THEN " = GAUSS
ELSE IF 0,75 <= a <= 1 THEN " = MIRRORPOIS
```

(only the GAUSS shape is provided by the APPLE II and M20ST versions)

```
generated      b = RANF
THEN PMOD = b*IRANGE
```

```
generated      c = RANF
THEN VMED = 2+c* (SIGMAX - SIGMIN) IF TYPE = POISSON or
MIRRORPOIS
ELSE VMED = PMOD
```

```
generated      d = RANF
THEN SIG = SIGMIN+d* (SIGMAX - SIGMIN) IF TYPE = GAUSS or
BIMODAL
ELSE SIG = (VMED)0,5
```

```
generated      e = RANF
THEN HMOD = 1+e* (MAXALT - 1).
```

- 4) IF IFIR > 0 THEN the NR values of positions of the sampling units must be given in input (free format);
ELSE the NR sampling unit positions are randomly generated in the interval (0, IRANGE);
- 5) The simulated data table is written to file 2, with format (10X, 10F10. 0);
- 6) IF JACCA = 0 THEN the program goes back to step 1;
ELSE the table of JACCA equispaced noiseless sampling units is written to file 1 and printed (option IPLOT >= 0).
- 7) Similarity ratio matrix is computed, following options specified by the value of LSLP, on the theoretical table and the nearest neighbour sequence extracted.
- 8) IF IPLOT > 0 THEN the program goes back to step 1;
ELSE the MST groups and sequence are found and the MST sequence replaces the JACCA records of the equispaced sampling units table on file 1.
- 9) Then the program goes back to step 1.

Riassunto. Viene descritto un simulatore di cenoclini utile per valutare i risultati dell'applicazione di metodi di ordinamento e classificazione a particolari strutture di dati. La simulazione di cenoclini avviene mediante il programma SPAGHET. Vengono presentati esempi di applicazione di metodi di largo uso sui dati provenienti dalla simulazione.

Acknowledgements. The work has been supported by a grant from M.P.I. 60%. The author is very grateful to prof. L. Orlóci for having revised this paper.

References

- Austin M.P. (1976a) - *On non-linear species response models in ordination*. Vegetatio 33: 33-41.
Austin M.P. (1976b) - *Performance of four ordination technique assuming different non-linear species response models*. Vegetatio 33: 43-49.
Feoli E. & Lagonegro M. (1983) - *A resemblance function based on probability: Applications to field and simulated data*. Vegetatio 53: 3-9.
Gauch H.G. & Whittaker R.H. (1976) - *Simulation of community patterns*. Vegetatio 33: 13-16.

Mario Lagonegro
Dipartimento di Biologia dell'Università di Trieste
Sezione di Geobotanica ed Ecologia Vegetale

Appendix A — FORTRAN listing, sample case and output of NEWSPAG.

```

PROGRAM NEWSPAG(INPUT=100,OUTPUT=100,TAPE1=514,TAPE2=
1514,TAPE6=OUTPUT)
DIMENSION ITIP(100),PMD(100),VMED(100),SIG(100),HMOD(100)
1,ITITLE(4)
C (M.LAGONEGRO-1984)
C---SIMULATOR OF COENOCLINES-TO CALIBRATE SOFTWARE DETECTORS
C---ITITLE:TITLE OF THE RUN(MAX.A40/CHAR.)
C---NC,NR:N.OF RESPONSE FUNCTIONS/MAX100/N.OF RELEVES/MAX.300/
C--- RELEVES TO TAPE 2 WITH FORMAT(10X,10F10,0)
C---NBOH:ANY INTEGER FIVE DIGITS NUMBER TO INITIALIZE RANF
C---MAXALT:MAX.VALUE FOR RESPONSE FUNCTIONS
C---IRANGE:UPPER LIMIT OF THE INTERVAL OF DEFINITION FOR
C--- RESPONSE FUNCTIONS AND GENERATED RELEVES
C---IPLOT:IF GT.0,RESP.FUNCT. WRITTEN/JACCA VALUES/
C--- TO TAPE1 (FORMAT:10X,10G10,3);IF LT.0,NO PRINTING IN SIMRAT.
C--- IN THIS CASE MIN. SP. TREE PRODUCED BY MISPAT
C---JACCA: N. OF RELEVES FOR COMPUTATION OF LIMITING VALUE OF SIMRATIO.
C--- IF LE.0,NO COMPUTATION.ZERO NOISE ASSUMED IN SIMRAT.
C---LSLP : GT.0,BINARY SCORES IN SIMRATIO,EB.0.NORMCOVER.I.T.O.COVER.
C---IFIS:IF LE.0,PARAMETERS OF FUNCTIONS RANDOMLY PRODUCED
C--- ELSE GIVEN IN INPUT/IN MAIN:ITIP,PMD,VMED,SIG,
C--- HMOD/
C---IFIR:SAME FOR RELEVE POSITION/SUB.GENRIL.VECT.PRIL/
C---NOISE:IN %,IS THE NOISE SUPPOSED IN THE SIMULATED-DATA TABLE
C---A BLANK CARD MUST TERMINATE THE INPUT CARDS
C
PRINT 9999
9999 FORMAT(1HT)
REWIND 1
REWIND 2
NCEN=0
3 PRINT 102
102 FORMAT('OIN HEADLINE-4A10')
READ 1,ITITLE
1 FORMAT(4A10)
IF(ITITLE(1).EQ.1H ) GO TO 100
PRINT 103
103 FORMAT('OIN NS,NREL,NBOH,MAXALT,IRANGE,IPLOT,IFIS,IFIR,NOISE'/
1' LSLP AND N. OF RELEVES FOR THEOR.VALUE OF SIMRATIO COMPUTATION')
READ *,NC,NR,NBOH,MAXALT,IRANGE,IPLOT,IFIS,IFIR,NOISE,LSLP,JACCA
PRINT 2,ITITLE,NC,NR,NBOH,MAXALT,IRANGE,IPLOT,IFIS,IFIR,NOISE
1,JACCA,LSLP
2 FORMAT(1H1,4A10/' FUNCT.N.',I5/' RELEVES N.',I5/' INITIAL RANF N
1 ' ,I5/' MAX.ALT.CURVE ',I5/' RANGE COENOCLINE ',I5/' IPLOT ',I5/
2' OPTION ON FUNCTIONS',I5/' OPTION ON RELEVES ',I5/
3' NOISE LEVEL(%)',I4/' JACCA NUMBER',I5/' LASOLP',I3/)
FNOIS=FLOAT(NOISE)/100.
DO 8 I=1,NBOH
8 CALL RANF(I)
NCEN=NCEN+1
RANGE=IRANGE
IF(IFIS.LE.0) GO TO 4

```

```

C
C---READS DATA OF RESPONSE FUNCTIONS(IF IFIS GT.0)
C---ITIP CAN BE:GAUSS /POISSON /MIRRORPOIS/BIMODAL /
C
      DO 5 I=1,NC
      PRINT 204,I
204  FORMAT('0IN TYPE OF RESP.CURVE',I4,' :GAUSS/BIMODAL/POISSON/'
1' MIRRORPOIS')
      READ 6,ITIP(I)
      PRINT 205
205  FORMAT('0IN PMOD,VMED,SIG,HMOD')
      READ *,PMOD(I),VMED(I),SIG(I),HMOD(I)
5    PRINT 11,I,ITIP(I),PMOD(I),VMED(I),SIG(I),HMOD(I)
6    FORMAT(A10)
11   FORMAT(' FUNCT.',I5,' TYPE ',A10,4F10.2)
      GO TO 7
C
C---GENERATES RANDOMLY THE NC FUNCTIONS(USES LIBRARY RANF)
C
4    CALL GENCURV(NC,ITIP,PMOD,VMED,SIG,HMOD,MAXALT,RANGE)
7    CALL GENRIL(NC,NR,RANGE,ITIP,PMOD,VMED,SIG,HMOD,IFIR,FNOIS)
      IF(JACCA.EQ.0) GO TO 3
C
C---IF REQUESTED,TABULATES FUNCTIONS FOR PLOT ON PRINTER(IFPLOT GT.0)
C---IF IPLOT LT.0,MINIMUM SPANNING TREE PRODUCED
C
      CALL SIMRAT(NC,IRANGE,ITIP,PMOD,VMED,SIG,HMOD,JACCA,IPLOT,LSLP)
      GO TO 3
100  PRINT 101,NCEN
101  FORMAT('////' ,I5,' COENOCLINES READY TO COOK')
      STOP
      END
      SUBROUTINE GENCURV(NC,ITIP,PMOD,VMED,SIG,HMOD,MAXALT,RANGE)
      DIMENSION ITIP(1),PMOD(1),VMED(1),SIG(1),HMOD(1)
      SIGMAX=RANGE/5.
      SIGMIN=RANGE/20.
      ALT=MAXALT
      IF(NC.GT.100) NC=100
      PRINT 3
3    FORMAT(15X,'TYPE' ,8X,' MODA ' ,5X,'MEAN V.' ,4X,'SIGMA' ,6X,'MAX.VAL.
1'//)
      DO 1 I=1,NC
      RAT=RANF()
      ITIP(I)=10HMIRRORPOIS
      IF(RAT.LE.0.25) ITIP(I)=7HPOISSON
      IF(RAT.GE.0.75) ITIP(I)=5HGAUSS
      IF(RAT.GT.0.25.AND.RAT.LE.0.5) ITIP(I)=8HBIMODAL
      PMOD(I)=RANF()*RANGE
      IM1=I-1
      DO 4 KK=1,IM1
      RAP=(PMOD(I)-PMOD(KK))/PMOD(I)
      IF(ABS(RAP).LT.0.01) PMOD(I)=RANF()*RANGE
4    CONTINUE
      VMED(I)=2.*RANF()*(SIGMAX-SIGMIN)
      IF(ITIP(I).EQ.5HGAUSS.OR.ITIP(I).EQ.8HBIMODAL) VMED(I)=PMOD(I)
      SIG(I)= RANF()*(SIGMAX-SIGMIN)+SIGMIN
      IF(ITIP(I).EQ.7HPOISSON.OR.ITIP(I).EQ.10HMIRRORPOIS)

```

```

1SIG(I)=VMED(I)
  WMED(I)=1.+RANF()*(ALT-1.)
1  PRINT 2,I,ITIP(I),PMD(I),VMED(I),SIG(I),HMOD(I)
2  FORMAT(' FUNCT.N.2,15,1X,A10.4G11.4)
  RETURN
  END
SUBROUTINE GEHRIL(NC,NR,RANGE,ITIP,PMD,VMED,SIG,HMOD,IFI,RUM)
DIMENSION ITIP(1),PMD(1),VMED(1),SIG(1),HMOD(1),PRIL(300)
1,QUADR(100)
  IF(IFI.LE.0) GO TO 8
  PRINT 11,NR
11  FORMAT('0IN',15,' VALUES OF RELEVES POSITIONS')
  READ *,(PRIL(I),I=1,NR)
8  DO 1 I=1,NR
  IF(IFI.GT.0) GO TO 10
  RIL=RANF()*RANGE
  IF(1.EQ.1) GO TO 5
  IM1=I-1
  DO 4 X=1,IM1
  RAP=(RIL-PRIL(X))/RIL
  IF(ABS(RAP).LE.0.01)RIL=RANF()*RANGE
4  CONTINUE
5  PRIL(I)=RIL
10  DO 2 J=1,NC
  IF(ITIP(J).NE.5HGAUSS.AND.ITIP(J).NE.8HBIMODAL ) GO TO 3
  QUADR(J)=AINT(STAGAU(SIG(J),PRIL(I),VMED(J),HMOD(J),RUM))
  IF(ITIP(J).NE.8HBIMODAL ) GO TO 2
  SECMOD=VMED(J)+4.*SIG(J)
  IF(SECMOD.GT.RANGE)SECMOD=VMED(J)-4.*SIG(J)
  QUADR(J)=QUADR(J)+AINT(STAGAU(SIG(J),PRIL(I),SECMOD,HMOD(J),RUM))
  IF(QUADR(J).GT.HMOD(J)) QUADR(J)=HMOD(J)
  GO TO 2
3  RI=PMD(J)-PRIL(I)-0.5
  R=AINT(VMED(J)-RI)
  IF(ITIP(J).EQ.10HMIRRORPOIS) R=AINT(VMED(J)+RI)
  QUADR(J)=AINT(POISS(R,VMED(J),HMOD(J),RUM))
2  CONTINUE
  WRITE(2,6)(QUADR(KK),KK=1,NC)
6  FORMAT(10X,10F10.0)
1  PRINT 7,I,PRIL(I),(QUADR(KK),KK=1,NC)
7  FORMAT('0REL. ',15,' X =',F10.1/(1X,10F10.0))
  RETURN
  END
FUNCTION POISS(AR,EM,H,RUM)
  POISS=0.
  IF(AR.LT.0.OR.AR.GT.16.) RETURN
  IAR=AR
  IF(IAR.LT.1) IAR=1
  IF(IAR.GT.16) IAR=16
  FACT=1.
  DO 1 I=1,IAR
1  FACT=FACT*FLOAT(I)
  HI=3.694528049*H*(1.+RUM*(RANF()-0.5))
  FORM=EXP(-EM)*(EM)**AR/FACT
  POISS=I*FORM+.05
  RETURN
  END

```

```

FUNCTION STAGAU(SIG,AR,EM,H,RUM)
STAGAU=0.
DIST=ABS(AR-EM)
RAM=3.*SIG
IF(DIST.GT.RAM) RETURN
HI=H*(1.+RUM*(RANF()-0.5))
DIST=DIST/SIG
STAGAU=EXP(-(DIST**2/2.))*HI*0.5
IF(STAGAU.GT.H) STAGAU=H
RETURN
END
SUBROUTINE SIMRAT(NC,IRANGE,ITIP,PMOD,VMED,SIG,HMOD,NP,IPLOT,LSLP)
DIMENSION ITIP(1),PMOD(1),VMED(1),SIG(1),HMOD(1),RIG(3000)
1,SIM(4950)
REAL MASPE(100)
RANGE=IRANGE
TRAPA=0.
IF(NP.GT.3000) NP=3000
PASSO=RANGE/FLOAT(NP)
DO 4 J=1,NC
DO 1 I=1,NP
VAL=FLOAT(I-1)*PASSO
IF(ITIP(J).NE.5HGAUSS.AND.ITIP(J).NE.8HBIMODAL) GO TO 3
RIG(I)=STAGAU(SIG(J),VAL,VMED(J),HMOD(J),TRAPA)
IF(ITIP(J).NE.8HBIMODAL) GO TO 1
SECMOD=VMED(J)+4.*SIG(J)
IF(SECMOD.GT.RANGE)SECMOD=VMED(J)-4.*SIG(J)
RIG(I)=RIG(I)+STAGAU(SIG(J),VAL,SECMOD,HMOD(J),TRAPA)
GO TO 1
3
RI=PMOD(J)-VAL*0.5
R=AINT(VMED(J)-RI)
IF(ITIP(J).NE.7HPOISSON) R=AINT(VMED(J)+RI)
RIG(I)=POISS(R,VMED(J),HMOD(J),TRAPA)
1
CONTINUE
WRITE(1)(RIG(K),K=1,NP)
CALL GRAND(RIG,NP,NC,MASPE,J)
IF(IPLOT.LT.0) GO TO 4
PRINT 6,J,(RIG(K),K=1,NP)
4
CONTINUE
6
FORMAT(' FUNCT. ',I5/(1X:10G10.3))
CALL CPSIM(NC,NP,LSLP,SIM,RIG,MASPE)
IPLOT=-IPLOT
CALL GRDSPEC(NC,NP,SIM,RIG,IPLOT)
RETURN
END
FUNCTION ILPOCU(I,K)
ILPOCU=0
IF(K.EQ.I)RETURN
IF(K.GT.I) GO TO 1
ILPOCU=(I-2)*(I-1)/2+K
RETURN
1
ILPOCU=(K-2)*(K-1)/2+I
RETURN
END
SUBROUTINE CPSIM(NSPEC,NQUAD,IE,SIM,RIG,MASPE)
DIMENSION SIM(1),RIG(1),ROG(3000)
REAL MASPE(100)

```

```

APARK=0.
APORK=0.
DO 3 I=1,4950
3 SIM(I)=0.
DO 1 I=2,NSPEC
KONT=0
REWIND 1
11 READ(1)(RIG(IL),IL=1,NQUAD)
KONT=KONT+1
IF(KONT.LT.I)GO TO 11
REWIND 1
IM1=I-1
DO 1 K=1,IM1
READ(1)(ROG(IL),IL=1,NQUAD)
PRSC=0.
PNORMI=0.
PNORMK=0.
DO 2 J=1,NQUAD
APARK=RIG(J)
APORK=ROG(J)
IF(IE.LT.0)GO TO 4
IF(IE.EQ.0)GO TO 8
IF(APARK.GT.1.)APARK=1.
IF(APORK.GT.1.)APORK=1.
GO TO 4
8 APARK=100.*APARK/(MASPE(I))
APORK=100.*APORK/(MASPE(K))
4 DPRSC=APARK*APORK
DNORMI=APARK**2
DNORMK=APORK**2
PRSC=PRSC+DPRSC
PNORMI=PNORMI+DNORMI
2 PNORMK=PNORMK+DNORMK
DENOM=PNORMI+PNORMK-PRSC
IF(DENOM.LE.0.)DENOM=-1.E-6
LPOS=ILPOCU(I,K)
SIM(LPOS)=PRSC/DENOM
1 CONTINUE
RETURN
END
SUBROUTINE ORDSPEC(NSPEC,NQUAD,SIM,RIG,ITREF)
DIMENSION SIM(1),RIG(1),TRUF(100),ISPEC(100)
DIMENSION IORD(100),IMXM(100),IMXM(100),VMXM(100)
NPROC=0
INTRUFL=9999
DO 15 I=1,NSPEC
15 ISPEC(I)=I
14 IACEGAT=0
IMAX=0
IMAX=0
SMAX=-1.E-6
IEFATTO=NSPEC*(NSPEC-1)/2
IORD(1)=10H.
DO 12 I=2,10
12 IORD(I)=10H
WRITE(6,200)
200 FORMAT(1X////4X,16HDENDROGRAM TABLE,9X,1H1.8X,2H.9.8X,2H.8.8X,2H.7

```

```

1,8X,2H.6,8X,2H.5,8X,2H.4,8X,2H.3,8X,2H.2,8X,2H.1,8X,2H.0/1X)
DO 6 I=1,NSPEC
6   IBUF(I)=0
C
C FINDS FIRST MAXIMUM
C
DO 1 I=1,NSPEC
DO 1 K=1,NSPEC
IF(K, EQ, I) GO TO 1
IPO=ILPOCU(I, K)
IF(SIM(IPO), LE, SMAX) GO TO 1
SMAX=SIM(IPO)
IMAX=I
KMAX=K
1   CONTINUE
IBUF(1)=IMAX
JBUF(2)=KMAX
IFOUND=1
IACEGAT=IACEGAT+1
IPOX=ILPOCU(IMAX, KMAX)
VALMAX=SIM(IPOX)
WRITE(6,100) IMAX, KMAX, VALMAX, ISPEC(IMAX), ISPEC(KMAX), (IORD(IP), IP
I=1,10)
100 FORMAT(1X,2I4,G12.5,2I4,10A10)
SIM(IPOX)=-SIM(IPOX)
IMXM(IFOUND)=IMAX
KMXM(IFOUND)=KMAX
VMXM(IFOUND)=VALMAX
C
C SCANS THE ROWS OF ALREADY FOUND MAXIMA TO FIND
C THE NEXT MAXIMUM
5   SMAX=-1.E-6
IMAX=0
KMAX=0
DO 2 M=1,NSPEC
IF(IBUF(M), LE, 0) GO TO 3
IRIG=IBUF(M)
DO 2 K=1,NSPEC
IF(K, EQ, IRIG) GO TO 2
IPOG=ILPOCU(IRIG, K)
IF(SIM(IPOG), LE, SMAX) GO TO 2
SMAX=SIM(IPOG)
IMAX=IRIG
KMAX=K
2   CONTINUE
3   IPOX=ILPOCU(IMAX, KMAX)
VALMAX=SIM(IPOX)
IACEGAT=IACEGAT+1
SIM(IPOX)=-SIM(IPOX)
IF(IACEGAT, GE, IEFATTO) GO TO 11
JU=0
JE=0
DO 4 J=1,NSPEC
IF(IBUF(J), EQ, IMAX) JU=1
IF(IBUF(J), EQ, KMAX) JE=1
4   CONTINUE
IF(JU, EQ, 1, AND, JE, EQ, 1) GO TO 8

```

```

C
C STORES NEWLY FOUND MAXIMUM
C
      DO 7 M=1,NSPEC
      IF(IBUF(M).GT.0) GO TO 7
      IF(JU.EQ.1) IBUF(M)=KMAX
      IF(JE.EQ.1) IBUF(M)=IMAX
      IFOUND=IFOUND+1
      IMXM(IFOUND)=IMAX
      KMXM(IFOUND)=KMAX
      VMXM(IFOUND)=VALMAX
      IF(MOD(IFOUND,10).EQ.0) GO TO 13
      WRITE(6,100) IMAX,KMAX,VALMAX,ISPEC(IMAX),ISPEC(KMAX)
      GO TO 8
13     WRITE(6,100) IMAX,KMAX,VALMAX,ISPEC(IMAX),ISPEC(KMAX),(IORD(IP),IP
1=1,10)
      GO TO 8
7     CONTINUE
8     IF(IBUF(NSPEC).EQ.0) GO TO 5
11    CONTINUE
      IF(ITREE.LT.0)RETURN
      CALL MISPAT(IMXM,KMXM,NSPEC,VMXM,IBUF)
      PRINT 600,(IBUF(IUX),IUX=1,NSPEC)
600   FORMAT(' MST-SEQUENCE'/(1X,20I4))
      RETURN
      END
      SUBROUTINE GRAND(VEC,NQUAD,NSPECM,MASPE,I)
      DIMENSION VEC(1)
      REAL MASPE(100)
      XMI=0.
      XMA=0.
      DO 1 J=1,NQUAD
      XMI=VEC(J)
      IF(XMI.GT.XMA)XMA=XMI
1     CONTINUE
      IF(XMA.EQ.0.)XMA=-100.
      MASPE(I)=XMA
      RETURN
      END
      SUBROUTINE MISPAT(IMX,KMX,NS,VMX,IBUF)
      DIMENSION IMX(100),KMX(100),VMX(100),LEPRIM(100),NUMG(100),
      1LMIN(100),IBUF(100),ILEAF(100),IPIVOT(100,3),MST(100,4),
      2IPUN(100)
C---CLEARS ARRAYS
      DO 1 I=1,NS
      LEPRIM(I)=0
      NUMG(I)=0
      LMIN(I)=0
      ILEAF(I)=0
      MST(I,4)=10H
      DO 1 J=1,3
      IPIVOT(I,J)=0
1     MST(I,J)=0
C---SHIFTS ONE PLACE DOWNWARDS VECTORS OF DENDROGRAM TABLE
      NS1=NS-1
      DO 22 I=1,NS1
      IMX(NS-I+1)=IMX(NS-I)

```

```

      KMX(NS-I+1)=KMX(NS-I)
22   VMX(NS-I+1)=VMX(NS-I)
      KMX(1)=IMX(2)
      IMX(1)=0
      VMX(1)=0.
C---LOOKS FOR LEAF-LIKE ELEMENTS
      PRINT*, 'OLEAF-LIKE SPECIES JOIN ONLY ONCE IN DENDR.TABLE'
      NLEAF=0
      DO 3 I=2,NS
      IACI=KMX(I-1)
      NONCE=1
      DO 4 J=I,NS
      IF(J.EQ.2)GO TO 4
      IF(IMX(J).NE.IACI) GOTO 4
      NONCE=0
4     CONTINUE
      IF(NONCE.EQ.0)GOTO 3
      NLEAF=NLEAF+1
      PRINT 9002,NLEAF,IACI
9002  FORMAT(10X,' LEAF N.',I4,5X,I4)
      ILEAF(NLEAF)=IACI
3     CONTINUE
      NLEAF=NLEAF+1
      ILEAF(NLEAF)=KMX(NS)
      PRINT 9002,NLEAF,ILEAF(NLEAF)
C---LOOKS FOR PIVOTAL PAIRS
      PRINT*, 'PIVOTAL PAIRS SIGNAL GROUPS - IF FINAL N.OF'
      PRINT*, ' GROUPS IS LOWER THAN THAT OF PIV.PAIRS. THEN'
      PRINT*, ' SOME CONTIGUOUS GROUPS HAVE BEEN GROUPED INTO'
      PRINT*, ' A LARGER ONE - THIS SHOULD NOT AFFECT THE FI-'
      PRINT*, ' NAL TABLE, SINCE THE GROUPS ARE HOMOGENEOUS'
      IPIVOT(1,1)=IMX(2)
      IPIVOT(1,2)=VMX(2)*1000.+.5
      IPIVOT(1,3)=KMX(2)
      NPIVOT=1
      PRINT 7,NPIVOT,(IPIVOT(1,JK),JK=1,3)
      NS2=NS-2
      DO 5 I=2,NS2
      SIM1=VMX(I)
      SIM2=VMX(I+1)
      SIM3=VMX(I+2)
      IF(SIM1.LT.SIM2.AND.SIM3.LT.SIM2)GOTO 6
      GOTO 5
6     NPIVOT=NPIVOT+1
      IPIVOT(NPIVOT,1)=IMX(I+1)
      IPIVOT(NPIVOT,2)=SIM2*1000.+.5
      IPIVOT(NPIVOT,3)=KMX(I+1)
      PRINT 7,NPIVOT,(IPIVOT(NPIVOT,JK),JK=1,3)
7     FORMAT(' PIV.PAIR N.',I4,' : ',I4,'(---',I4,'---)',I4)
5     CONTINUE
      IF(VMX(NS-1).GT.VMX(NS))GO TO 8
      NPIVOT=NPIVOT+1
      IPIVOT(NPIVOT,1)=IMX(NS)
      IPIVOT(NPIVOT,2)=VMX(NS)*1000.+.5
      IPIVOT(NPIVOT,3)=KMX(NS)
      PRINT 7,NPIVOT,(IPIVOT(NPIVOT,JK),JK=1,3)
C---SCANS THE DENDROGRAM TABLE TO FIND OUT M.S.T. GROUPS

```

```

8   KOG=2
    MST(1,1)=IMX(2)
    MST(1,2)=VMX(2)*1000+.5
    MST(1,3)=KMX(2)
    MILEG=3000
    KG=1
    NG=1
    LEPRIM(NG)=IMX(2)
    IPUN(NG)=1
    I=1
    K=1
    KAFEL=0
    KIRK=0
    IRK=0
    N=MST(K,1)
    K=K-1
    GO TO 70
30  N=MST(K,3)
    IF(N.EQ.0)GOTO 60
    IF(N.LT.0)GOTO 50
    IF(MST(K,4).EQ.10H   LEAF)GOTO 50
70  DO 10 J=2,NS
    IF(K.EQ.0.AND.J.EQ.2)GOTO 10
    IF(N.NE.IMX(J))GOTO 10
    I=I+1
    IF(K.NE.IRK)GO TO 9
    IF(KIRK.EQ.1)GO TO 11
    KAFEL=1
    GO TO 11
9   IRK=0
    KAFEL=0
11  KOG=KOG+1
    KIRK=KIRK-1
    MST(I,1)=IMX(J)
    MST(I,2)=VMX(J)*1000+.5
    MST(I,3)=KMX(J)
    LE=LEAF(NLEAF,KMX(J),ILEAF)
    IF(LE.NE.0)MST(I,4)=10H   LEAF
    N1=IMX(J)
    N2=KMX(J)
    MI=MINUSC(NS,N1,N2,IMX,KMX,VMX,J)
    IF(KAFEL.GT.0)MI=LATG(NS,N1,N2,IMX,KMX,VMX,J)
    IZI=MPIV(N1,N2,PIVOT,IPVGT)
    IF(MI.EQ.0.AND.IZI.EQ.0)GOTO 10
    NG=NG+1
    LEPRIM(NG)=MST(I,3)
    LMIN(NG)=MST(I,2)
    MST(I,3)=-MST(I,3)
    IF(MST(I,2).LT.MILEG)MILEG=MST(I,2)
    KOG=KOG-1
    MST(I,4)=10H  B-CARRIER
10  CONTINUE
50  K=K+1
    IF(K.GE.NS)GOTO 60
    GOTO 30
60  KG=KG+1
    NUMG(KG-1)=KOG

```

```

      KOG=1
      N=LEPRIM(KG)
      IRK=N
      KIRK=1
      IPUN(KG)=K
      LMIN(KG-1)=MILEG
      MILEG=LMIN(KG)
      IF(K.GE.NS)GOTO 40
      K=K-1
      GOTO 70
C---EXIT FROM THE MAZE
  40  CONTINUE
      REWIND 1
      NUR=0
      NTOT=0
      DO 80 I=1,NG
      PRINT 100,I
  100 FORMAT('OGRROUP N.',I4)
      IUK=IPUN(I)
      IAK=IPUN(I+1)-1
      IF(I.EQ.NG)IAK=NS1
      IACI=0
      DO 90 J=IAK,IAK
      MOST=MST(J,1)
      MEST=IABS(MST(J,3))
      IOK=IPIV(MOST,MEST,NPIVOT,IPIVOT)
      IF(IOK.NE.0.AND.IACI.EQ.0) IACI=IOK
      PRINT 110,I,(MST(J,3)),JJ=1,4)
  110 FORMAT(5X,2I4,'(---',I4,'---',I4,5X,A10)
      WRITE(1)1,(MST(J,3)),JJ=1,4)
      NUR=NUR+1
  90  CONTINUE
      NTOT=NTOT+NUMG(I)
  80  PRINT 120,NUMG(I),LMIN(I),(IPIVOT(IACI,II),II=1,3),NTOT
  120 FORMAT('OGR.COMP.',I4,' MIN.OUT-LINK ',I4,' PIVOTAL PAIR',I4,
      1'(--',I4,'-')',I4,' ADDED VARIABLES N.',I4)
C
C---FINDS OUT KIND OF ALL SPECIES
C
      KONT=0
      DO 2 I=1,NG
      REWIND 1
      PRINT 100,I
      ILGR=0
      DO 21 J=1,NUR
      ITOP=1H
      ITIP=7HNUCLEAR
      READ(1)IG,IACI,LEG,IOCI
      IF(IG.NE.I)GO TO 21
      ILGR=ILGR+1
      IF(IOCI.LT.0)ITIP=9H8-CARRIER
      IF(LEG.LT.LMIN(I))ITIP=7HORBITAL
      IF(IOCI.LT.0)GO TO 222
      IF(ILGR.NE.1)GO TO 7782
      KONT=KONT+1
      IRUF(KONT)=IACI
      IF(IACI.NE.LEPRIM(1))ITOP=9H8-CARRIER

```

```

7782 KONT=KONT+1
      IBUF(KONT)=IOCI
222  IAK=IOCI
      IF(IGCI,LT,0)IAK=IACI
      IF(ILGR,EQ,1)PRINT 7778,IACI,ITOP
      PRINT 7778,IAK,ITIF
21   CONTINUE
7778 FORMAT(' SPECIES',I4,' IS ',A10)
2    CONTINUE
      RETURN
      END
      FUNCTION LEAF(NS,N,ILEAF)
      DIMENSION ILEAF(1)
      LEAF=0
      DO 1 I=1,NS
        IF(N,EQ,ILEAF(I))GOTO 2
1     CONTINUE
      RETURN
2    LEAF=N
      RETURN
      END
      FUNCTION IPIV(N1,N2,NS,IPIVOT)
      DIMENSION IPIVOT(100,3)
      IPIV=0
      DO 1 I=1,NS
        IF(N1,EQ,IPIVOT(I,1).AND,N2,EQ,IPIVOT(I,3))GOTO 2
1     CONTINUE
      RETURN
2    IPIV=I
      RETURN
      END
      FUNCTION MPIV(N1,N2,NS,IPIVOT)
      DIMENSION IPIVOT(100,3)
      MPIV=0
      DO 1 I=1,NS
        IF(N1,EQ,IPIVOT(I,1).OR,N1,ER,IPIVOT(I,3))GOTO 2
1     CONTINUE
      RETURN
2    K=I
      DO 3 I=1,NS
        IF(N2,EQ,IPIVOT(I,1).OR,N2,EQ,IPIVOT(I,3))GOTO 4
3     CONTINUE
      RETURN
4    IF(K,NE,I)MPIV=1
      RETURN
      END
      FUNCTION MINUSC(NS,N1,N2,IMX,KMX,VMX,I)
      DIMENSION IMX(1),KMX(1),VMX(1)
      MINUSC=0
      K=I
4    K=K-1
      IF(K,LT,1)RETURN
      IF(N1,EQ,KMX(K))GOTO 30
      GOTO 4
30   L=I
7    L=L+1
      IF(L,GT,NS)RETURN

```

```

      IF(N2,EQ,IMX(L))GOTO 5
      GOTO 7
5     SIM1=VMX(K)
      SIM2=VMX(I)
      SIM3=VMX(L)
      IF(SIM2.LT.SIM1.AND.SIM2.LT.SIM3)MIMUSC=N2
      RETURN
      END
      FUNCTION LATG(NS,N1,N2,IMX,KMX,VMX,I)
      DIMENSION IMX(1),EMX(1),VMX(1)
      LATG=0
      K=I
4     K=K-1
      IF(K.LT.1)RETURN
      IF(N1,EN,IMX(K))GO TO 30
      GO TO 4
30    L=I
7     L=L+1
      IF(L.GT.NS)RETURN
      IF(N2,EQ,IMX(L))GO TO 5
      GO TO 7
5     SIM1=VMX(K)
      SIM2=VMX(I)
      SIM3=VMX(L)
      IF(SIM2.LT.SIM1.AND.SIM2.LT.SIM3)LATG=N2
      RETURN
      END

```

The following sample produces 10 functions and 20 releves randomly generated. Besides, 1000 sampling units are generated for the perfect measurement simulation. The 10x20 table has a 20% level noise. The meaning of the remaining parameters can be easily deduced by looking at the sample output.

```

SAMPLE CASE FOR SPAGHET
10,20,45,9,12,-1,0,0,20,0,1000
      ←LAST CARD,FIRST 10 CHAR.BLANK

```

```

OIN HEADLINE-4A10
OIN NS,HREL,NOOH,MAXALT,IRANGE,IPL0T,IFIS,IFIR,NOISE
LSLP AND N. OF RELEVES FOR THEOR.VALUE OF SIMRATIO COMPUTATION
15SAMPLE CASE FOR SPAGHET
FUNCT.N. 10
RELEVES N. 20
INITIAL RANF N 45
MAX.ALT.CURVE 9
RANGE COENOCLINE 12
IPL0T -1
OPTION ON FUNCTIONS 0
OPTION ON RELEVES 0
NOISE LEVEL(%) 20
JACCA NUMBER 1000
LASOLP 0

```

	TYPE	MODA	MEAN V.	SIGMA	MAX.VAL.					
FUNCT.N.	1 POISSON	7.094	2.799	1.673	8.374					
FUNCT.N.	2 POISSON	9.984	2.275	1.508	6.423					
FUNCT.N.	3 GAUSS	4.338	4.338	1.106	4.027					
FUNCT.N.	4 POISSON	3.752	3.199	1.789	5.082					
FUNCT.N.	5 POISSON	4.638	2.209	1.486	6.681					
FUNCT.N.	6 MIRROIRPOIS	7.697	2.028	1.424	8.631					
FUNCT.N.	7 BIMODAL	7.251	7.251	.7375	5.609					
FUNCT.N.	8 GAUSS	6.865	6.865	2.012	5.712					
FUNCT.N.	9 BIMODAL	5.431	5.431	1.723	7.435					
FUNCT.N.	10 POISSON	6.195	3.140	1.772	6.616					
OREL.	1 X = 6.1									
	8.	0.	1.	1.	3.	6.	2.	5.	7.	6.
OREL.	2 X = 10.2									
	1.	5.	0.	0.	0.	0.	5.	1.	0.	1.
OREL.	3 X = 9.8									
	3.	6.	0.	0.	0.	4.	5.	2.	0.	1.
OREL.	4 X = 9.2									
	3.	5.	0.	0.	0.	5.	2.	3.	1.	2.
OREL.	5 X = 11.0									
	1.	5.	0.	0.	0.	0.	3.	1.	0.	0.
OREL.	6 X = 5.5									
	5.	0.	2.	2.	5.	0.	0.	4.	7.	5.
OREL.	7 X = 8.9									
	3.	6.	0.	0.	0.	4.	1.	4.	1.	2.
OREL.	8 X = 11.5									
	1.	3.	0.	0.	0.	0.	1.	0.	0.	0.
OREL.	9 X = 5.3									
	5.	0.	3.	2.	5.	6.	0.	5.	7.	5.
OREL.	10 X = 3.7									
	2.	0.	3.	4.	6.	1.	0.	2.	4.	3.
OREL.	11 X = 2.6									
	0.	0.	1.	4.	3.	0.	0.	1.	2.	1.
OREL.	12 X = 4.9									
	5.	0.	4.	3.	7.	3.	0.	4.	7.	5.
OREL.	13 X = 7.3									
	7.	3.	0.	1.	1.	8.	5.	5.	4.	4.
OREL.	14 X = 2.2									
	0.	0.	1.	4.	3.	0.	0.	0.	2.	1.
OREL.	15 X = 3.3									
	2.	0.	2.	4.	6.	1.	0.	1.	3.	1.
OREL.	16 X = 2.5									
	0.	0.	1.	4.	3.	0.	0.	0.	3.	1.
OREL.	17 X = 9.9									
	1.	7.	0.	0.	0.	4.	5.	2.	0.	1.
OREL.	18 X = 5.0									
	5.	0.	3.	3.	5.	3.	0.	4.	7.	5.
OREL.	19 X = 11.3									
	1.	3.	0.	0.	0.	0.	2.	0.	0.	0.
OREL.	20 X = 7.0									
	7.	3.	0.	1.	1.	8.	5.	5.	5.	4.
DENDROGRAM TABLE										
		1	.9	.8	.7	.6	.5	.4	.3	.2
1	8 .94534	1	8.							

```

1 6 .91189      1 6
8 10 .88999     8 10
10 9 .81234     10 9
9 5 .77325     9 5
5 3 .91681     5 3
5 4 .88641     5 4
6 7 .64572     6 7
7 2 .79717     7 2
GROUP-LEADING SPEC.AND EXT.LINK
1 646
5 773
7 646
DGROUP N. 1
1<-- 945--- 8
1<-- 912--- 6
8<-- 890--- 10
6<-- 646--- -7
10<-- 812--- 9
9<-- 773--- -5
DGR.COMP. 5 MIN.OUT-LINK 646 MAX.LINK 945 BETWEEN 1(---) 8
TOT.SP.N. 5
DGROUP N. 2
5<-- 917--- 3
5<-- 886--- 4
DGR.COMP. 3 MIN.OUT-LINK 773 MAX.LINK 917 BETWEEN 5(---) 3
TOT.SP.N. 8
DGROUP N. 3
7<-- 797--- 2
DGR.COMP. 2 MIN.OUT-LINK 646 MAX.LINK 797 BETWEEN 7(---) 2
TOT.SP.N. 10
DGROUP N. 1
SPECIES 1 IS
SPECIES 8 IS NUCLEAR
SPECIES 6 IS NUCLEAR
SPECIES 10 IS NUCLEAR
SPECIES 6 IS B-CARRIER
SPECIES 9 IS NUCLEAR
SPECIES 9 IS B-CARRIER
DGROUP N. 2
SPECIES 5 IS B-CARRIER
SPECIES 3 IS NUCLEAR
SPECIES 4 IS NUCLEAR
DGROUP N. 3
SPECIES 7 IS B-CARRIER
SPECIES 2 IS NUCLEAR
HST-SEQUENCE
1 8 6 10 9 5 3 4 7 2
OIN HEADLINE-4A10

```

1 COENOCLINES READY TO COOK

Appendix B — BASIC listing for OLIVETTI M20ST (160 kbyte-PCOS 2.0).

```

10 REM-oli20spaghet
20 ON ERROR GOTO 990
30 OPTION BASE 1
40 INPUT"give n,species,n.releves ";NS,NR
50 DIM H(NS),XM(NS),SG(NS),RP(NR),QUAD(NR,NS)
60 INPUT"give range for x ";RX
70 INPUT"give max.resp.funct.value,noise(Z)";HALT,HOPC
80 NOFC=NOFC/100
90 INPUT"random gen.-y/n ";YX
100 IF YX="y" THEN 150
110FOR I=1 TO NS : PRINT"sp.n.,";I;" give h,mode,sigma"
120 INPUT H(I),XM(I),SG(I)
130 NEXT I
140 GOTO 220
150 MX5=RX/5 : MN5=RX/20
160 DMNX5=MX5-MN5
170 FOR I=1 TO NS
180 H(I)=HALT*(.2+.6*RND(1))
190 XM(I)=RX*RND(1)
200 SG(I)=MN5+RND(1)*DMNX5
210 NEXT I
220 IF YX="y" THEN 270
230 FOR I=1 TO NR
240 INPUT"give a pos.for rel. ";RP(I)
250 NEXT I
260 GOTO 310
270 INPUT"theoecenoc.-y/n ";TEOX : IF TEOX="n" THEN 290
280 FOR I=1 TO NR : RP(I)=RX/NR*I : NEXT I : GOTO 310
290 FOR I=1 TO NR : RP(I)=RND(1)*RX
300 NEXT I
310 REM-printout of cenoc.characteristics
320 FOR I=1 TO NS : LPRINT "sp.,";I;" h=";H(I);" mean=";XM(I);" sigma=";SG(I)
330 NEXT I
340 NAFPC=NOFC*100 : LPRINT "relevs table-noise(Z)=";NAFPC
350 FOR I=1 TO NR : LPRINT"rel.n.,";I;" rel.x=";RP(I) : NEXT I
360 REM-table to file
370 INPUT "table to file-y/n ";YYX
380 FOR I=1 TO NR : FOR J=1 TO NS
390 QUAD(I,J)=0
400 DX=ABS(RP(I)-XM(J))
410 IF DX > 3*SG(J) THEN 460
420 DUS=2*SG(J)^2 : D2X=DX^2
430 DES=-D2X/DUS
440 QUAD(I,J)=H(J)*(1+NOFC*(RND(1)-1))*EXP(DES)
450 QUAD(I,J)=INT(QUAD(I,J)+.5)
460 NEXT J : NEXT I
470 REM-print table
480 FOR I=1 TO NR : FOR J=1 TO NS
490 LPRINT QUAD(I,J);" "; : NEXT J
500 LPRINT : NEXT I
510 REM-file option
520 IF YYX="n" THEN 610
530 INPUT"full filename ";FX
540 INPUT"does it already exist-y/n ";ZX

```

```

550 IF Z#="n" THEN 570
560 KILL M#
570 OPEN "0",M1,N#
580 FOR I=1 TO NR : FOR J=1 TO NS
590 PRINT#1,QUAD(I,J) : NEXT J : NEXT I
600 CLOSE#1
610 CLS : COLOR 1,0
620 FX=400/RX : FY=200/HAUT
630 LPRINT "fx=";FX;" fy=";FY : LPRINT
640 FSET(0,200)
650 LINE (0,200)-(0,0) : LINE (0,0)-(400,0)
660 LINE (400,0)-(400,200) : LINE (400,200)-(0,200)
670 XO=0 : YO=0 : FSET(XO,YO)
680 X1=0 : Y1=0
690 FOR J=1 TO NS
700 XO=0 : YO=0
710 Y=0 : SW=0
720 FOR K=0 TO 400 STEP 5
730 KX=K/FX
740 DX=ABS(KX-XH(J))
750 T5=4*SG(J)
760 IF DX > T5 THEN 870
770 T5=T5/4
780 T25=T5^2 : E5=-.5*(DX^2)/T25
790 Y=M(J)*EXP(E5)*FY
800 X=K
810 IF Y > 200 OR Y < 0 THEN 880
820 IF X > 400 OR X < 0 THEN 880
830 IF SW = 0 THEN PSET(X1,Y1),1
840 PSET(X,Y),0 : LINE (XO,YO)-(X,Y) : XO=X : YO=Y
850 SW=1
860 GOTO 880
870 SW=0
880 NEXT K
890 FSET(0,0)
900 NEXT J
910 FOR I=1 TO NR : PUF=RP(I)*FX
920 FSET(PUF,0) : LINE (PUF,0)-(PUF,110)
930 NEXT I
940 INPUT "plot to printer-y/n ";Y#
950 IF Y#="n" THEN 970
960 EXEC^sp
970 CLS
980 END
990 PRINT "kapelmeister" : GOTO 980

```

Appendix C — BASIC Listing of OLIMISPAT (Olivetti Minimum Spanning Tree).

```

10 REM-OLIMISPAT(M.Lagonegro-1984)
30 INPUT"n.of data points ";C
40 INPUT"max.n.of comp.";NC
50 DIM MIN(NC),MAX(NC),C(NC,C),Y1(C),X1(C),SEQ(C),XQ(C),Z1(C),D(C,C)
60 INPUT"data file ";NA%
70 INPUT"print coordinates-y/n ";AX%
80 INPUT"print distance-y/n ";CO%
90 OPEN "I",#1,NA%
100 FOR I=1 TO NC : TT=0 : FOR J=1 TO C
110 INPUT#1,C(I,J) : TT=TT+C(I,J) : NEXT J
120 FOR J=1 TO C : C(I,J)=C(I,J)-TT/C : NEXT J
130 NEXT I
140 CLOSE#1
150 FOR I=1 TO NC : MIN(I)=C(I,1) : MAX(I)=C(I,1)
160 FOR J=1 TO C-1 : IF MIN(I) < C(I,J+1) THEN 180
170 MIN(I)=C(I,J+1)
180 IF MAX(I) > C(I,J+1) THEN 200
190 MAX(I)=C(I,J+1)
200 NEXT J
210 IF MIN(I) > 0 THEN MIN(I)=.000001
220 NEXT I
230 INPUT"first,second and third axes tag-to stop give 0,0,0 ",X1,Y1,Z1
240 IF X1*Y1*Z1=0 THEN END
250 ALFA=15 : REM-x axis perspective angle
260 LPRINT "axes x=X",X1;" y=X",Y1;" z=X",Z1
270 ALFR=ALFA*1.74533E-02
280 FOR I=1 TO C : X1(I)=C(X1,I) : Y1(I)=C(Y1,I)
290 Z1(I)=C(Z1,I)
300 NEXT I
310 GOSUB 1140
320 IF CO%="n" THEN 350
330 FOR I=1 TO C : LPRINT"row ";I : FOR J=1 TO C
340 LPRINT D(I,J);" " : NEXT J : LPRINT : NEXT I
350 FX=(MAX(X1)-MIN(X1))/350 : FY=(MAX(Y1)-MIN(Y1))/350 : FZ=(MAX(Z1)-MIN(Z1))/190
360 FOR I=1 TO C : SEQ(I)=I : XQ(I)=X1(I) : NEXT I
370 NSCMB=0 : FOR I=1 TO C-1 : IF XQ(I) <= XQ(I+1) THEN 400
380 BUF=XQ(I) : XQ(I)=XQ(I+1) : XQ(I+1)=BUF
390 BUF=SEQ(I) : SEQ(I)=SEQ(I+1) : SEQ(I+1)=BUF : NSCMB=1
400 NEXT I
410 IF NSCMB < 0 THEN 370
420 LPRINT"horiz.sequence-x axis,from neg.to pos." : FOR I=1 TO C : LPRINT SEQ(I);" "
430 NEXT I : LPRINT
440 CLS : COLOR 1,0
450 IF FX < FY THEN FX=FY
460 IF FY < FX THEN FY=FX
470 IF FX\FZ THEN 490
480 FX=FZ : FY=FZ : GOTO 500
490 FZ=FX
500 REM-starts drawing axes
510 XO=200 : YO=110 : PSET(C,O) : LINE (O,YO)-(400,YO) : PSET(XO,0) : LINE (XO,0)-(XO,220)
520 PSET(O,YO-XO*TAN(ALFR)) : LINE (O,YO-XO*TAN(ALFR))-(400,YO-XO*TAN(ALFR))
530 FOR I=1 TO C : X=X1(I)/FX : Y=Y1(I)/FY : Z=Z1(I)/FZ
540 IF AX%="y" THEN LPRINT"x";I;"=";X1(I);" y";I;"=";Y1(I);" z";I;"=";Z1(I)
550 X1(I)=X : Y1(I)=Y : Z1(I)=Z
560 XD1=XO-X*CO5(ALFR)+Y : YD1=YO-X*51N(ALFR)+Z : XQ(I)=XD1 : SEQ(I)=YD1 : NEXT I
570 MIX=XQ(1) : MAX=MIX : MIY=SEQ(1) : MAY=MIY
580 FOR J=2 TO C
590 IF XQ(J)<MIX THEN MIX=XQ(J)
600 IF XQ(J)>MAX THEN MAX=XQ(J)
610 IF SEQ(J)<MIY THEN MIY=SEQ(J)

```

```

620 IF SEQ(J)MAY THEN MAY=SEQ(J)
630 NEXT J : IF MIX)=0 THEN MIX=.001
640 IF MIY)=0 THEN MIY=.001
650 FX=(MAX-MIX)/400 : FY=(MAY-MIY)/220
660 IF FX)FY THEN FY=FX
670 IF FY)FX THEN FX=FY
680 FOR I=1 TO C : X=X1(I)/FX : Y=Y1(I)/FX : Z=Z1(I)/FX
690 XDIS=Y0-X*COS(ALFR)+Y : YDIS=Y0-X*SIN(ALFR)+Z
700 PSET(XDIS,Y0-X*SIN(ALFR))
710 LINE (XDIS,Y0-X*SIN(ALFR))-(XDIS,YDIS)
720 XB=X0-X*COS(ALFR) : YB=Y0-X*SIN(ALFR)
730 PSET(XDIS,YB)
740 LINE (XDIS,YB)-(XB,YB)
750 X1(I)=X : Y1(I)=Y : Z1(I)=Z
760 PSET(XDIS,YDIS) : CIRCLE(XDIS,YDIS),2 : NEXT I
770 X#="1a 'X',1,41" : Y#="1a 'Y',390,100" : Z#="1a 'Z',205,210" : EXEC X# : EXEC Y# : EXEC Z#
780 NT=C : FOR I=1 TO NT : XQ(I)=I : NEXT I : KUI=1 : GOSUB 1020
790 XQ(1)=IM : SEQ(1)=JM : XQ(0)=JM
800 FOR I=2 TO C : NT=I-1
810 KUI=0 : GOSUB 1020
820 NT=NT+1 : XQ(NT)=IM : FOR I2=0 TO NT-1 : IF XQ(I2)(<)IM THEN 840
830 GOTO 860
840 NEXT I2
850 GOTO 900
860 XQ(NT)=JM : FOR I2=0 TO NT-1 : IF XQ(I2)(<)JM THEN 880
870 NT=NT-1 : GOTO 810
880 NEXT I2
890 SEQ(NT)=IM : GOTO 910
900 SEQ(NT)=JM
910 IF NT)=C-1 THEN 914
912 NEXT I
914 LPRINT"nearest neighb. sequence"
920 FOR I=0 TO C-1 : LPRINT XQ(I);" " : NEXT I : LPRINT : LPRINT
930 FOR J=1 TO C-1 : IM=XQ(J) : JM=SEQ(I) : GOSUB 1120
940 LPRINT"dist.=",ABS(D(IM,JM));" pair ",IM," ",JM : NEXT I
950 LPRINT : LPRINT
960 INPUT"plot to printer-y/n ";P# : IF P#="n" THEN 990
970 EXEC"sp
980 LPRINT : LPRINT
990 CLS
1000 GOTO 230
1010 PRINT"kapelmeister" : LPRINT "kapelshuler" : END
1020 REM-finds min.dist.in residual matrix
1030 MIND=1E+30 : FOR IUK=KUI TO NT : FOR JUK=1 TO C
1040 II=XQ(IUK) : IF JUK=II THEN 1090
1050 IF D(II,JUK)(<) THEN 1090
1060 IF D(II,JUK))=MIND THEN 1090
1070 MIND=D(II,JUK) : IM=II : JM=JUK
1080 IF D(II,JUK)=0 THEN D(II,JUK)=1E-09
1090 NEXT JUK : NEXT IUK
1100 D(IM,JM)=-D(IM,JM) : D(JM,IM)=D(IM,JM)
1110 RETURN
1120 REM-draws M.S.T. branch
1130 XA=X0-X1(IM)*COS(ALFR)+Y1(IM) : YA=Y0-X1(IM)*SIN(ALFR)+Z1(IM)
1140 XC=X0-X1(JM)*COS(ALFR)+Y1(JM) : YC=Y0-X1(JM)*SIN(ALFR)+Z1(JM)
1150 PSET(XA,YA) : LINE (XA,YA)-(XC,YC) : RETURN
1160 REM-computes euc.dist. for data
1170 FOR IAK=1 TO C : D(IAK,IAK)=0 : FOR JAK=IAK+1 TO C
1180 DX2=(X1(JAK)-X1(IAK))^2
1190 DY2=(Y1(JAK)-Y1(IAK))^2
1200 DZ2=(Z1(IAK)-Z1(JAK))^2
1210 D(IAK,JAK)=SQR(DX2+DY2+DZ2) : D(JAK,IAK)=D(IAK,JAK)
1220 NEXT JAK : NEXT IAK : RETURN

```


EFFECTS OF SAMPLING INTENSITY AND RANDOM NOISE ON DETECTION OF SPECIES GROUPS BY INTERSECTION ANALYSIS

Enrico FEOLI and Mario LAGONEGRO

Keywords: intersection, noise, sampling, simulation, vegetation

Abstract. The efficiency of Intersection Analysis in producing species groups at different noise and sampling intensity levels has been tested on the basis of a simulated coenocline. The results suggest that Intersection Analysis is a robust method for detecting species groups and that it could be used in field surveys to find out the sampling intensity sufficient to describe the vegetation under study.

Introduction

Intersection analysis has been introduced by Feoli (1977) and Feoli & Lagonegro (1979) to analyse phytosociological data. The method defines species groups according to the criterion of maximal intersection between sets of relevés defined by the presence of single species. The intersection between the sets of relevés is computed by the well known Jaccard's function, which in terms of set theory is the ratio between the intersection and the union of two sets. If one considers a relevé as a point in the multidimensional ecological space, the intersection between the sets computed by the Jaccard's function can be considered as an estimation of the relative intersection between niches according to the Hutchinson's definition (see Hurlbert, 1981 for other definitions and for a deep discussion). The intersection should be considered relative for two reasons: firstly, a sample set of relevés could not include all the hypervolume of a niche (Petraitis, 1979; 1982; Smith, 1982 among others); secondly the function relativizes the intersection of the union of the sets. In other terms, the intersection estimated by the Jaccard function, within a sample, is an estimation of the probability to find two species together in the universe represented by the sample, given independently one of the two species.

If the response of the species is considered, i.e. the quantities of the species in the relevés, the Jaccard function can be formulated by the following expression: $I(X, Y) = S_{xy} / (S_x^2 + S_y^2 - S_{xy})$, in which x means a single score of species X , y a single score of species Y , and S means the sum over the number of relevés. This

function estimates the similarity of the species responses in the ecological space rather than the intersection between niches. However if the resource use is considered proportional to the species response, it could be considered as an indirect estimator of the niche overlap in the sense of McArthur and Levins (1967), for which some statistical inference methods have been described by Maurer (1982).

The use of species groups (sociological groups, when defined on the basis of phytosociological tables, following Doing, 1969) for the description of plant communities allows to reduce the dimensionality of the sample space (Orlòci, 1978) and in some cases the classifications based on average scores of species groups proved to be more predictive than those based on species (Feoli, Lagonegro & Biondani, 1981; Feoli & Lagonegro, 1982). The explanation is to be found in the fact that the use of species groups reduces the effect of many low- or non-predictive species when the predictive species are few, and in the fact that the use of average values of species groups smothers the effect of random variation of the single species. The utility to find species groups is also related to the problem to make objective extrapolations of ecological indicator values (Ellenberg, 1974; Landolt, 1977).

The definition of species groups within a vegetation system depends on the intensity of sampling and on the noise level. In the present paper we test the effects of these two factors in the definition of species groups by intersection analysis and we suggest to use intersection analysis to find out the sampling intensity sufficient to describe the vegetation under study. Noise is here considered as a consequence of random fluctuations or dispersion, and of errors in identification or evaluation of species response.

Methods

The effects of sample size and noise level have been tested on data sets generated by a coenocline simulator (program SPAGHET: Lagonegro, 1984). Simulated coenoclines have been already used to test the performances of ordination and classification methods (see Gauch, 1982a, for references). Gauch (1982b) uses simulated coenoclines and coenoplanes to test the effect of noise upon eigenvector ordinations.

SPAGHET allows to generate coenoclines with response curves of Gaussian profile, bimodal profile (resulting from merging two gaussian responses curves) and Poisson profile, with maximum on the right or on the left side. The coenocline may be completely defined by the user through the position and the dispersion parameters, or generated completely at random, by giving only the number of species and the relative length of the x -axis. This is chosen by the user according to the wanted average density of modes for each arbitrary length unit. Such a unit is $1/n$ of the arbitrary length n . If for example we want an average density of 2 for 60 species the length must be 30.

The level of noise can be set by an option which adds or subtracts a number from the scores given by the response functions. The higher the noise level the wider the range of possible values of such a number. This is a random percentage of the

response value itself, up to a maximum equal to half the noise level chosen by the user. However, the program avoids to reach values of response greater than the maximum value of the single species response (established by user's scale). The user can chose between several scales, binary included. It must be clear that binary data ignore the species response and offer information only about species tolerance. If a user decides to normalize the data, the information of the position of species optima is added to the information about the tolerance, however the difference in quantities between species are neglected.

Coenoclines may be generated in infinite ways for testing the effects of different reasonable situations on methods of data analysis.

In the present paper we rely on a random coenocline. The reason is that if phytosociological data are used, it is impossible to forecast the niche breadth and the response function for all the species. Results based on field data (e.g. Feoli, Biondani & Lagonegro, 1982; Feoli-Chiapella, 1983) suggest that a random simulated coenocline with also bimodal curves, and with maximum responses on the right or on the left side of the curve may simulate closely the ecological responses of the species as in a real field data. Furthermore, the results of the papers by Austin (1976a,b; 1980) and Austin & Austin (1980) suggest that the Gaussian response is rarely met even under experimental conditions.

We decided to simulate a random coenocline with 60 species and density 2. 60 is a rough approximation of the average number of relevant species found in phytosociological tables of European grassland or woodland vegetation. Density 2 has been chosen in order to avoid the possibility to have disjoint data matrices.

Since in a real situation we cannot know the position of the relevés in the ecological multidimensional space, the relevés have been selected at random along the simulated coenocline. Mohler (1983) tried to evaluate the effect of sampling pattern on estimation of species distribution along gradients by concentrating relevés in different ways along the simulated coenocline. This is a good exercise, but applicable only under limited circumstances in direct gradient analysis when at least the effects of some measurable factors can be a priori presumed.

In order to test the effects of sampling intensity and random noise on detection of species groups, the species groups defined at different level of noise and sampling intensity have been compared by the theoretical species groups. These have been defined by selecting from the coenocline sets of relevés (150, 500, 1500 and 3000 respectively) at regular intervals. Intersection analysis has been applied to the relevés and the species groups have been compared. The species group defined from 500 relevés are perfectly identical to those defined from 1500 and 3000 relevés and different kind of data (binary, cover, normalized data). This fact is important in that the sampling intensity, when high may compensate for differences in the type of data.

The data to test the effects of noise level and sampling intensity are given in tables of relevés, randomly selected from the same coenocline at three noise level, 0, 20, 40%, and 4 sampling intensity 30, 110, 200 and 300 (corresponding to four levels of sampling density 1, 4, 7, 10). The resulting species groups have been

compared through contingency tables, by the program CLACOMP (Feoli, Lagonetro & Orlóci, 1984), which decomposes the mutual information of the tables into components and finds the corresponding chi-square probabilities.

Results and conclusions

The chi-square probabilities of the comparisons between the species groups obtained on the basis of different data (binary, normalized, cover) and the theoretical species groups are presented in Table 1. Only in the case of the comparisons between the species groups obtained from 30 relevés and the theoretical species groups the probability is regularly decreasing as the noise increases. In the other cases there is not such a clear trend. From the matrices in Table 1 we can see that in some cases the probability is increasing as the noise increases. In the cases of binary and normalized data the average values of probabilities are decreasing as the noise increases (Table 2). In the case of cover data the probability is more or less constant. If the standard deviation of probability is considered, it is always increasing as the noise increases. It is increasing more intensively in the case of binary data and lesser in the case of cover data (Table 3).

Table 1 — Chi square probability of the comparisons between species groups obtained at different level of noise and sampling density (1, 4, 7, 10 and T , T = theoretical). A : Binary data; B : normalized data; C : cover data. M = average probability in the tables. s = standard deviation of m , MT = average probability in the comparisons with the "theoretic species groups", sT = standard deviation of MT .

Binary data:
Noise 0%:

	4	7	10	T
1	99.2	99.8	100.0	94.7
4		100.0	100.0	90.9
7			100.0	96.9
10				99.4

$M = 98.09$ $s = 3.07$ $MT = 95.48$ $sT = 3.6$

Noise 20%:

	4	7	10	T
1	99.6	94.2	98.7	92.5
4		99.8	100.0	93.5
7			99.8	66.1
10				88.9

$M = 93.31$ $s = 10.32$ $MT = 82.25$ $sT = 12.92$

Noise 40%

	4	7	10	T
1	99.4	64.8	81.6	42.5
4		100.0	100.0	99.4
7			99.8	69.5
10				90.5

$M = 85.45$ $s = 19.94$ $MT = 75.48$ $sT = 25.31$

Normalized data
Noise 0%

	4	7	10	T
1	99.9	100.0	100.0	99.6
4		100.0	100.0	99.9
7			100.0	100.0
10				99.9

M = 99.93 s = .12 MT = 99.85 sT = .17

Noise 20%

	4	7	10	T
1	100.0	100.0	100.0	99.1
4		100.0	100.0	100.0
7			100.0	100.0
10				100.0

M = 99.91 s = .28 MT = 99.78 sT = .45

Noise 40%

	4	7	10	T
1	100.0	100.0	99.9	97.3
4		100.0	100.0	100.0
7			100.0	99.9
10				99.9

M = 99.70 s = .85 MT = 99.28 sT = 1.32

Cover data:

Noise 0%

	4	7	10	T
1	94.4	99.2	99.0	93.3
4		99.5	99.2	97.8
7			100.0	96.6
10				94.7

M = 97.37 s = 2.45 MT = 95.60 sT = 1.99

Noise 20%

	4	7	10	T
1	99.8	99.7	99.8	91.8
4		100.0	99.7	92.6
7			100.0	98.2
10				97.3

M = 97.89 s = 3.13 MT = 94.98 sT = 3.24

Noise 40%

	4	7	10	T
1	100.0	96.7	99.5	86.6
4		100.0	100.0	99.8
7			100.0	95.9
10				98.7

M = 97.71 s = 4.19 MT = 95.25 sT = 5.99

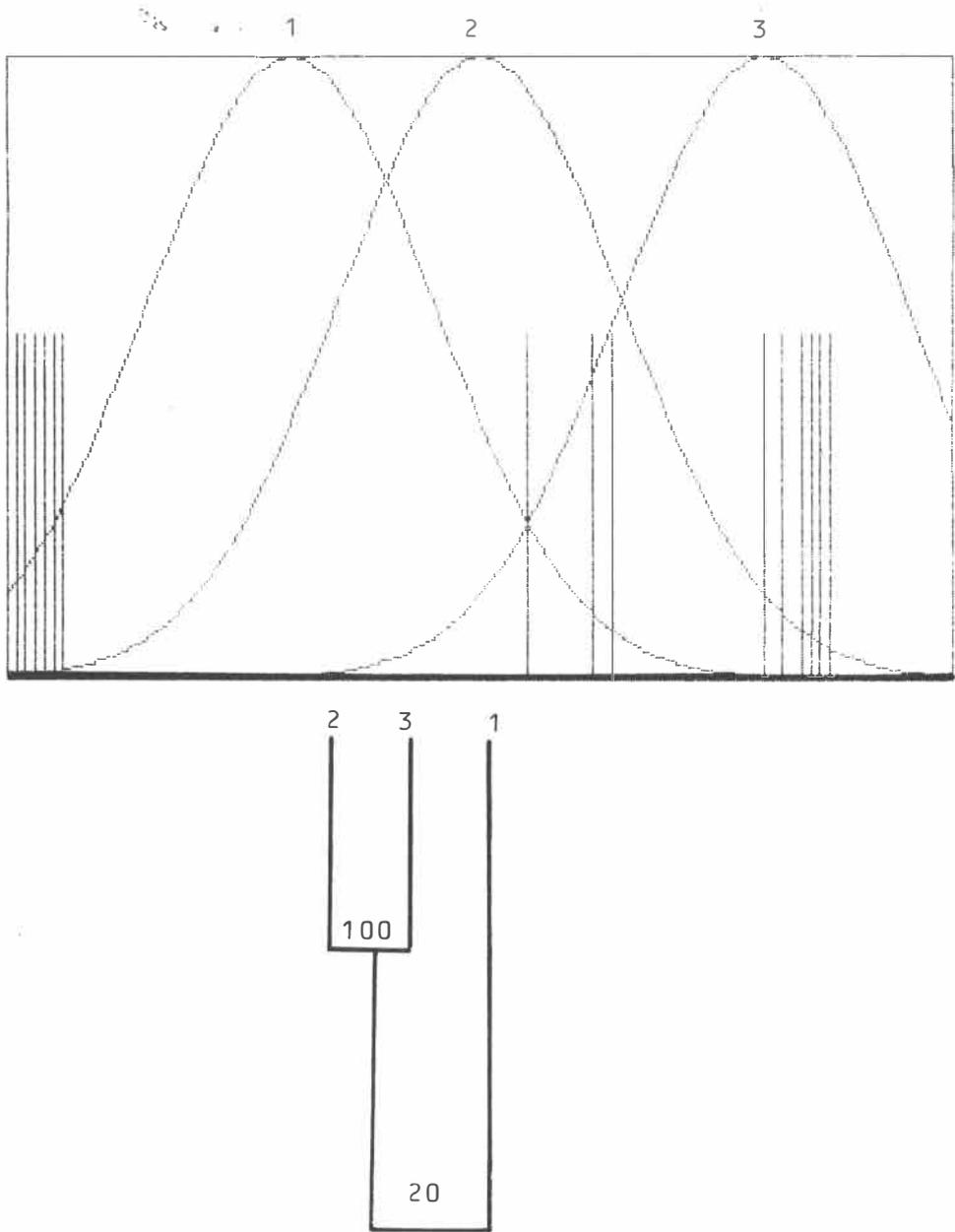


Fig. 1 — Simulated coenocline with 3 species and 15 relevés irregularly sampled. On the basis of presence absence data, species 2 and 3 result identical, while it is evident from the figure that the intersection between species 1 and 2 is higher than the intersection between species 2 and 3. The dendrogram below the simulated coenocline indicates the fusion level of the three species based on the relevés marked by the vertical lines. The Jaccard coefficient is multiplied by 100. The fusion criterion is single linkage.

Table 2 — Linear regression functions between averages chi square probabilities (M and MT) and noise, and between standard deviations of M and MT and noise (n).

Binary data

$$\begin{aligned} M &= 98.603 - 0.316n & s &= 2.675 + 0.422n \\ MT &= 95.400 - 0.500n & sT &= 3.092 + 0.542n \end{aligned}$$

Normalized data

$$\begin{aligned} M &= 99.962 - 0.006n & s &= 0.058 + 0.018n \\ MT &= 99.920 - 0.014n & sT &= 0.075 + 0.029n \end{aligned}$$

Cover data

$$\begin{aligned} M &= 97.487 + 0.009n & s &= 2.390 + 0.043n \\ MT &= 95.450 - 0.009n & sT &= 1.744 + 0.100n \end{aligned}$$

The species groups obtained on the basis of 30 relevés, binary and cover data are never so similar to the theoretical species groups as those based on normalized data (Table 1). From these results we can conclude that binary data are the most sensible to the noise effects. In this case the noise is mainly due to errors in species identification therefore when binary data are used a careful identification of the species is necessary. The cover data are less affected by noise and sampling intensity than binary data, however the results most close to the theoretical ones are those obtained with normalized data. If the probability of the comparisons within the same noise level and between different sampling intensity is considered, the most stable results are always obtained by the normalized data. The fact that there is not a clear improvement of the similarity with the theoretical species groups by increasing intensity of sampling is due to the fact that the relevés are not sampled on regular intervals. A possible effect of non regularly sampling is presented in Fig. 1. This figure suggests that if we are interested in find species groups (sociological) the suggestions of Mohler (1983) are dangerous, notwithstanding their usefulness in his particular circumstance.

Intersection analysis looks to be a robust technique, especially if applied to normalized data. It can be used to detect sociological species groups and also to define the sampling intensity sufficient to give a stable description of the vegetation under study. A user can apply intersection analysis iteratively to an increasing number of relevés until he starts to get stable species groups. By using intersection analysis the user can work with a method very little sensitive to noise and sampling density.

Riassunto. Il simulatore di cenoclini SPAGHET è stato impiegato per valutare l'efficienza della Analisi dell'Intersezione nel definire gruppi di specie a diversi livelli di "noise" e di intensità di campionamento. L'Analisi dell'intersezione si è rivelato un metodo molto affidabile, avendo dato risultati molto simili nelle diverse situazioni simulate.

Acknowledgements. The work has been supported by CNR, "Gruppo Biologia Naturalistica" and M.P.I. 40%. We are grateful to Prof. L. Orlóci for reading and correcting the text.

References

- Austin M.P. (1976a) - *On non-linear species response models in ordination*. *Vegetatio* 33:33-41.
- Austin M.P. (1976b) - *Performance of four ordination techniques assuming different non-linear species response models*. *Vegetatio* 33:43-49.
- Austin M.P. & Austin B.O. (1980) - *Behaviour of experimental plant communities along a nutrient gradient*. *J. Ecol.* 68:891-918.
- Doing H. (1969) - *Sociological species groups*. *Acta Bot. Neerl.* 18:398-400.
- Ellenberg E. (1974) - *Zeigewerte der Gefaesspflanzen Mitteleuropas*. Verlag Erich Goltze KG, Göttingen.
- Feoli Chiapella L. (1983) - *Prodrone numerico della vegetazione dei brecciai appenninici*. CNR, AQ/5/40. pp. 99, Roma.
- Feoli E. (1977) - *A criterion for monothetic classification of phytosociological entities on the basis of species ordination*. *Vegetatio* 33:147-152.
- Feoli E. & Lagonegro M. (1979) - *Intersection analysis in phytosociology: computer program and application*. *Vegetatio* 40:55-59.
- Feoli E. & Lagonegro M. (1982) - *Syntaxonomical analysis of beech woods in the Appennines (Italy) using the program package IAHOPA*. *Vegetatio* 50:129-173.
- Feoli E. & Lagonegro M. (1982) - *Syntaxonomical analysis of beech woods in the Appennines (Italy) using the program package IAHOPA*. *Vegetatio* 50:129-173.
- Feoli E., Biondani F. & Lagonegro M. (1981) - *Individuazione di cenoclini nell'analisi indiretta di gradienti*. In A. Moroni, O. Ravera e A. Anelli (eds.) "Ecologia. Atti del primo Congresso Nazionale della Società Italiana di Ecologia", pp. 207-211, Edizioni Zara.
- Feoli E., Lagonegro M. & Biondani F. (1981) - *Strategies in syntaxonomy: a discussion on two classifications of grasslands of Friuli (Italy)*. In H. Dierschke ed. "Syntaxonomie", pp. 95-107. Cramer, Vaduz.
- Feoli E., Lagonegro M. & Orlóci L. (1981) - *Information analysis of vegetation data*. H. Lieth & H. Mooney eds. *Tasks for Vegetation Science* 10. pp. 143. Junk, The Hague, Boston.
- Gauch H.G. (1982a) - *Multivariate analysis in community ecology*. Cambridge University Press, Cambridge.
- Gauch H.G. - *Noise reduction by eigenvector ordinations*. *Ecology* 63:1643-1649.
- Lagonegro M. (1984) - *SPAGHET: a coenocline simulator to calibrate software tools*. *Studia Geobotanica*.
- Hurlbert S.H. (1981) - *A gentle depilation of the nice: Dicean resource sets in resource hyperspace*. In Mav, R.M. (ed.) *Evolutionary theory*, 5: 177-184. The University of Chicago.
- Landolt E. (1977) - *Ökologische Zeigewerte zur Schweizer Flora*. *Ber. Geobot. Inst. ETH.* 64:64-207.
- Mac Arthur R.H. & Levins R. (1967) - *The limiting similarity, convergence and divergence of coexisting species*. *Am. Naturalist* 101:377-385.
- Maurer B.A. (1982) - *Statistical inference for Mac Arthur-Levins niche overlap*. *Ecology* 63:1712-1719.
- Mohler C.L. (1983) - *Effect of sampling pattern on estimation of species distributions along gradients*. *Vegetatio* 54:97-102.
- Orlóci L. (1978) - *Multivariate analysis in vegetation research*. 2nd ed., Junk, The Hague, Boston.
- Petraitis P.S. (1979) - *Likelihood measures of niche breadth and overlap*. *Ecology* 60:703-710.
- Petraitis P.S. (1981) - *Algebraic and graphical relationships among niche breadth measures*. *Ecology* 62:545-548.
- Smith E.P. (1982) - *Niche breadth, resource availability and inference*. *Ecology* 63:1675-1681.

Enrico Feoli & Mario Lagonegro
Dipartimento di Biologia
Università degli Studi di Trieste
34100 Trieste, Italia.

PHYTOSOCIOLOGY, ECOLOGY AND PHYTOGEOGRAPHY OF EPIPHYTIC LICHEN VEGETATION IN THE CALAMONE LAKE AREA (N-APENNINES, ITALY)

Pier Luigi NIMIS

Keywords: Lichens, Epiphytes, Apennines, Vegetation.

Abstract. Six community types of epiphytic lichen vegetation are reported from the Calamone Lake area (N-Apennines). Data analysis is based on multivariate methods. The ecological interpretation of the compositional variation was based on indirect gradient analysis. Each of the communities is well characterized in floristical, ecological and phytogeographical terms.

Introduction

This paper presents the results of a study on epiphytic lichen vegetation in the Calamone Lake area (Northern Apennines, province of Reggio Emilia, Italy). The main aims of the study are:

- i) to analyze the floristical variation of epiphytic lichen vegetation in the survey area.
- ii) to relate floristical variation to the variation of ecological factors.
- iii) to study the correlation between ecology of epiphytic lichens and their distribution patterns in Europe.

The study is based on phytosociological relevés of epiphytic lichen vegetation. These have been submitted to methods of multivariate analysis (ordination and classification). The ecological interpretation of the elaboration of floristical data is based on indirect gradient analysis, with the indicator values proposed by Wirth (1980).

Description of the survey area

The survey area is located in the Northern Apennines, Province of Reggio Emilia, and corresponds with the immediate surroundings of the Calamone Lake, in the high Enza Valley. The lake, of glacial origin, is located at an elevation of 1408 m.

Palinological studies have been performed in the lake area (Bertolani-Marchetti et al., 1983). A brief history of previous biological research in the area is in Manzini (1983). No phytosociological study has been yet performed on the vegetation surrounding the lake, and a climatological station has been set up only in recent

times, so that reliable climatical data are not yet available. The woody vegetation surrounding the lake consists of almost pure *Fagus*-stands. Grazing by sheep, cattle and horses is frequent around the lake, and anthropic pressure by tourists is increasing in recent times (Chiessi, 1983). The relevés for the present study were taken all on *Fagus*, in open or closed stands, between 1350 and 1550 m.

Data and methods

The data for the present study are 38 phytosociological relevés of epiphytic lichen vegetation (Tab. 1). They have been all taken on *Fagus*, as follows:

- isolated trees, base of the boles
- isolated trees, trunk at breast height.
- isolated trees, old crown branches.
- isolated trees, young branches.
- trees in woody stands, base of the boles.
- trees in woody stands, old crown branches.
- trees in woody stands, young branches.

Two relevés were taken on each bole, respectively at the north and south side of the trunk.

A further data source, utilized for the ecological and phytogeographical interpretation, are the indicator values and the phytogeographical diagnoses for the single species given by Wirth (1980).

Data analysis occurred in the following steps:

- a) numerical classification of relevés and of species, in order to obtain floristically similar releve groups.
- b) ordination of relevés, to detect compositional gradients.
- c) concentration analysis of matrices of ecological data and relevé groups, in order to analyze the correlation between compositional variation in the data set and the variation of some main ecological factors.
- d) concentration analysis of the matrix of phytogeographical data and relevé groups, to analyze the correlation between compositional/ecological variation in the data set, and the variation of phytogeographical affinities of the relevé groups.
- e) reciprocal ordering of relevés and species, to extract a reduced number of indicator species.

Classification is based on Complete Linkage Clustering (Anderberg, 1973) and Correlation Coefficient (Orloci, 1978). Ordination is based on Principal Component Analysis (see Orloci, 1978). For Concentration Analysis see Feoli & Orloci (1979). For data analysis, I used the package of programs by Wildi & Orloci (1980).

Results

The dendrograms of relevés and species are respectively in Fig. 1 and Fig. 2. In the dendrogram of relevés (Fig. 1) 6 main releve groups are formed at a value of the Correlation Coefficient of 0.1. In the dendrogram of species (Fig. 2), 9 species groups are formed at a value of the Correlation Coefficient of -0.3 . The results of

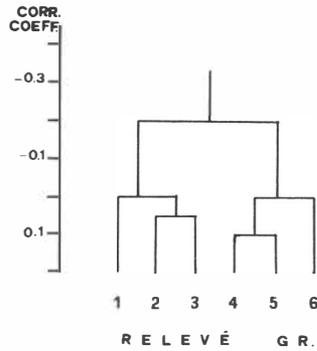


Fig. 1 — Dendrogram of the relevé groups.

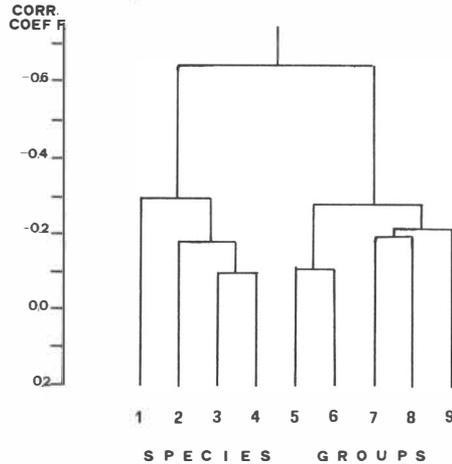


Fig. 2 — Dendrogram of the species groups.

AOC performed on the contingency table of relevé groups and species groups are visualized in Fig. 3. All of the relevé groups are significantly associated with at least one species group. This indicates that the six relevé groups may be interpreted as distinct vegetation types, each of them defined by a set of differential species.

The results of PCA performed on the data in Tab. 1 are in Fig. 4. The clustering of relevés obtained by the classification method (Fig. 1) is still recognizable in the ordination results. The first two Principal Components clearly separate relevé groups 1,2 and 3 (positive scores on the 1st Principal Component) from relevé groups 4 and 5 (negative scores). Relevé group 6 is separated from all the others on the 3rd Principal Component.

Tab. 2 (a-d) contains the occupancy rates of the species in classes of pH (a), light intensity (b), eutrophication of the substrate (c) and degree of humidity of the

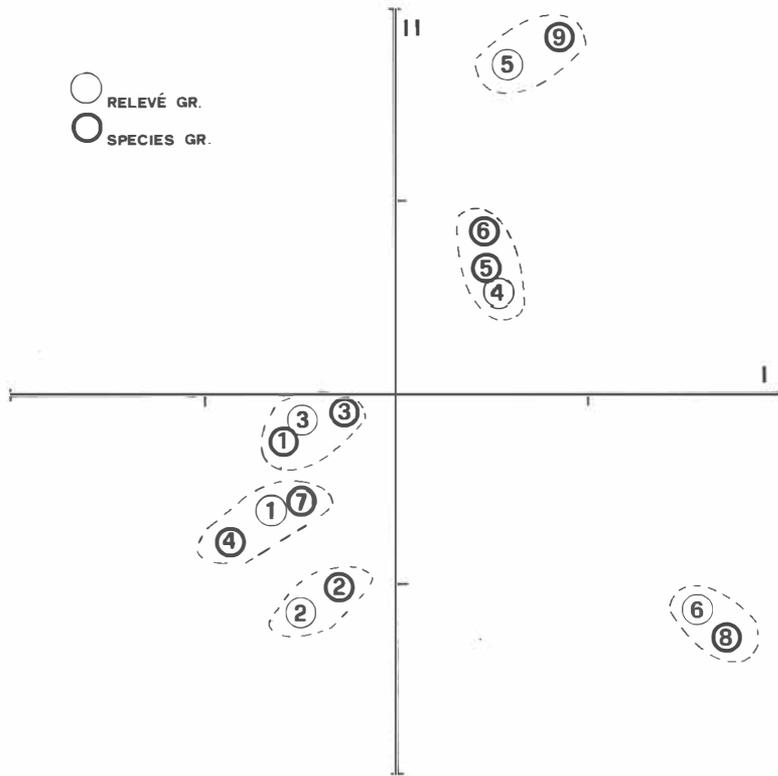


Fig. 3 — Arrangement of relevé and species group points according to the two Principal Components of AOC performed on the contingency table of species and relevé groups.

substrate (d), subdivided by relevé groups. The indicator values of the single species, that have been utilized to calculate the data in Tab. 2, are as in Wirth (1980). The data in Tab. 2 (a-d) have been submitted to AOC, in order to quantify the degree of correlation between relevé groups and some main ecological factors. The results are visualized in Fig. 5 (pH), 6 (light), 7 (nitrogen) and 8 (humidity). They may be summarized as follows: the relevé groups defined on floristical basis are strongly correlated with the variation of the considered ecological factors. They may be ecologically characterized as follows:

- Relevé group 1: neutrophytic, photophytic, little nitrophytic, rather xerophytic.
- Relevé group 2: neutro-basiphytic, rather photophytic, nitrophytic, xerophytic.
- Relevé group 3: subneutrophytic, little photophytic, rather nitrophytic, xerophytic.
- Relevé group 4: subacidophytic, rather skiophytic, little nitrophytic, rather higrophytic.
- Relevé group 5: subacidophytic, skiophytic, anitrophytic, higrophytic.
- Relevé group 6: acidophytic, rather photophytic, nitrophobic, mesophytic.

On the basis of these results, it is possible to interpret the ordination of Fig. 4 in

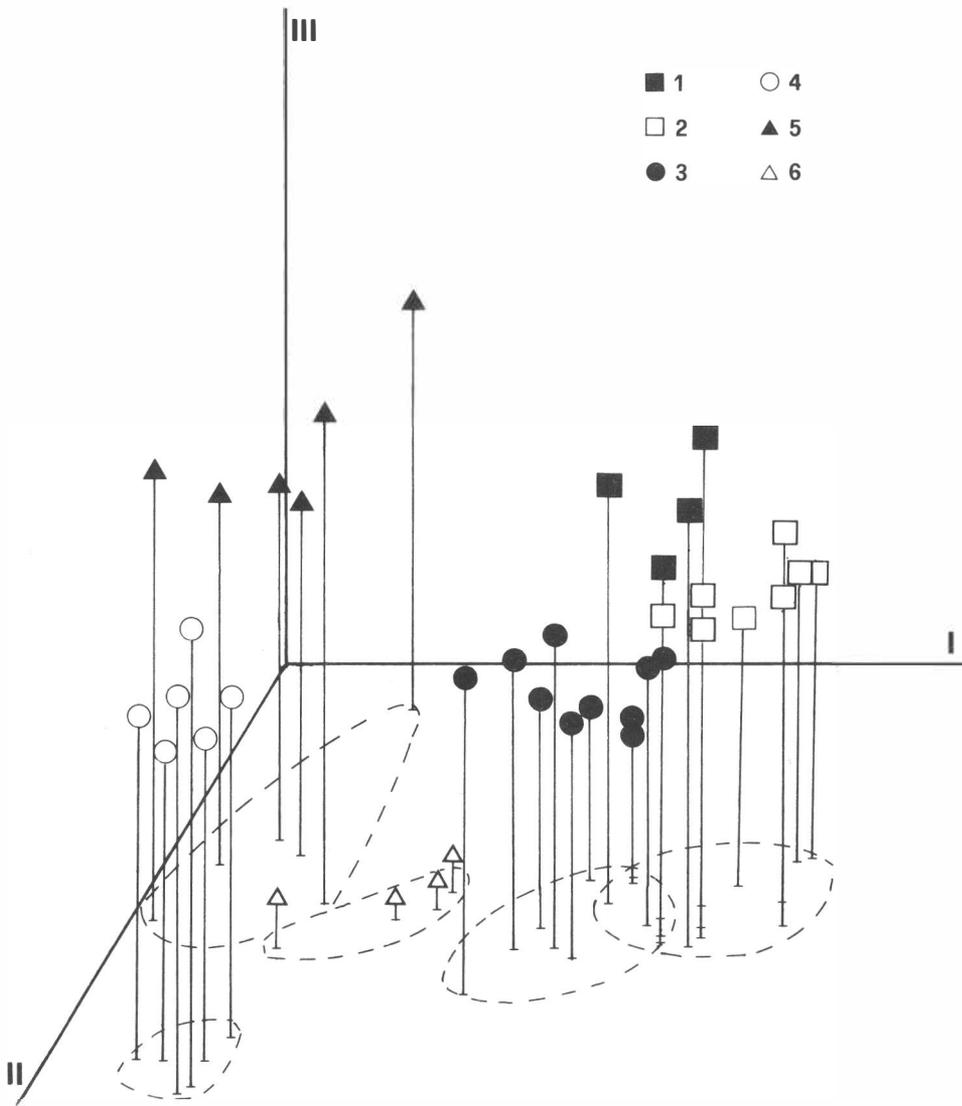


Fig. 4 — Arrangement of the relevé points according to the first three principal components of PCA performed on the data of Tab. 1. Symbols refer to relevé groups, numbered as in Tab. 1.

RELEVÉ GROUP	Nr.	1	2	3	4	5	6
a)							
pH 3.4-4.0		9.0	....	1.2	8.6	69.5	15.7
pH 4.1-4.8		20.4	21.5	35.8	24.0	86.9	31.4
pH 4.9-5.6		77.2	58.8	74.0	99.0	74.0	88.5
pH 5.7-7.0		70.4	71.1	62.0	22.4	....	24.2
pH 7.1-8.5		11.3	26.4	2.4	....	....	....
b)							
Photophytic		52.2	44.0	18.5	4.1	5.3	8.6
Moderately photoph.		86.3	74.0	69.1	75.7	82.1	91.3
Slightly photoph.		45.5	64.0	77.7	65.7	78.5	91.3
Moderately skiophytic		4.9	31.5	36.3	8.6
c)							
Nitrophytic		4.5	33.3	3.7	....	....	....
Moderately nitroph.		50.0	69.3	65.4	30.4	19.6	8.6
Slightly nitroph.		97.7	96.0	72.8	56.5	62.5	39.1
Not nitrophytic		56.8	29.3	37.0	71.0	76.7	91.3
d)							
Moderately xerophytic		65.6	70.1	63.2	10.4	6.6	....
Slightly xerophytic		20.9	67.1	46.0	18.7	28.8	88.0
Mesophytic		15.6	14.9	10.2	47.9	66.6	47.2
Moderately hygrophytic		6.2	5.9	2.9	50.0	86.6	35.2

Tab. 2 — Occupancy rates in the classes of ecological factors, calculated as percents of the total occupancies in each relevé group. a) pH-classes; b) light intensity-classes; c) eutrophication classes; d) moisture classes.

ecological terms: the first Principal Component separates neutro- photo- nitro- and xerophytic stands (relevé groups 1, 2, 3) from acido-, skio-, anitro- and hygrophytic stands (relevé groups 4, 5). In general, acidity and eutrophication, are inversely correlated, whereas light intensity, degree of xerophytism, and eutrophication are positively correlated. The correlation between high light intensity and xerophytism is obviously due to higher evapotranspiration rates. The one between acidity and low light intensity is less obvious. The average acidity of *Fagus*-bark in natural conditions is 5.39 (Barkman, 1958). In the study area grazing by sheep, cattle and horses is frequent, and more intense in not-forested sites. This ensures a continuous apport of nitrogen to isolated trees, that is the main reason for higher pH values in photophytic stands. The separation of relevé group 6 from the others on the 3rd Principal Component is justified also in ecological terms: this relevé group is characterized by strongly acidiphytic species, that however, are rather photophytic and mesophytic. These results are in good agreement with the location of the relevés on the porophyte, that is as follows:

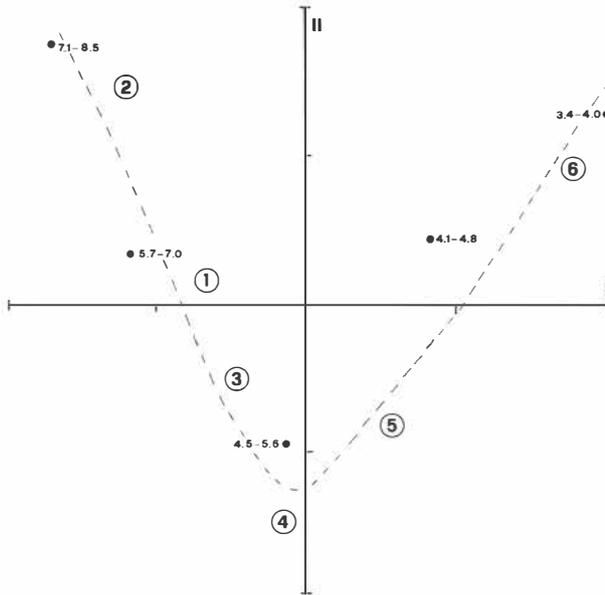


Fig. 5 — Arrangement of relevé group - and pH class - points according to the two first Canonical Variates in AOC performed on the data of Tab. 2a.

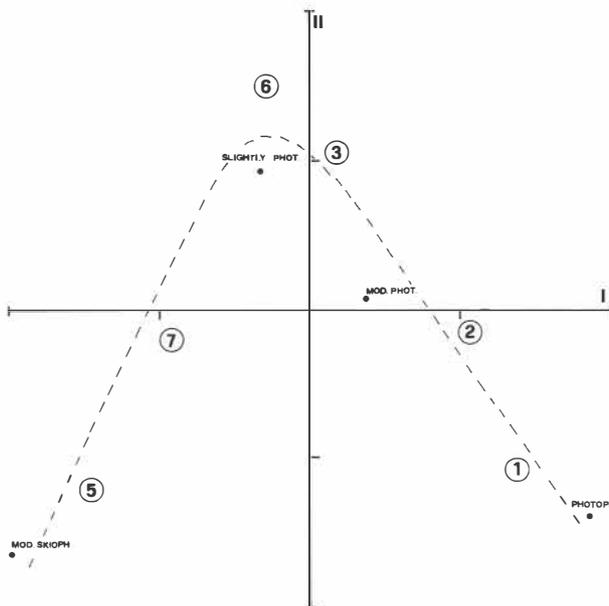


Fig. 6 — Arrangement of relevé group - and light intensity class - points according to the two first Canonical Variates of AOC performed on the data of Tab. 2b.

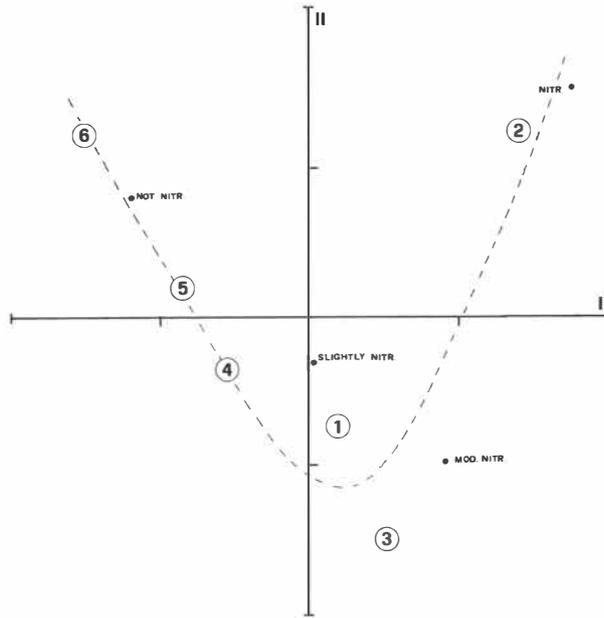


Fig. 7 — Arrangement of relevé group - and eutrophication class - points according to the two first Canonical Variates of AOC, performed on the data of Tab. 2c.

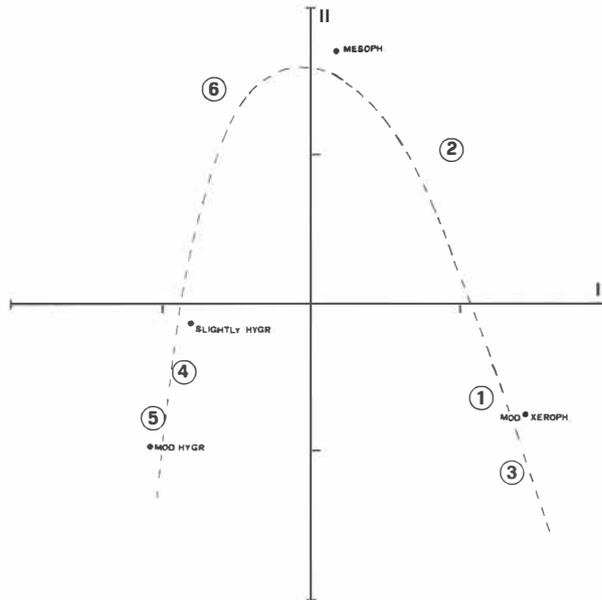


Fig. 8 — Arrangement of relevé group - and moisture class - points according to the first two Canonical Variates of AOC performed on the data of Tab. 2d.

- Relevé group 1: old outer branches of isolated trees, mostly near the lake.
- Relevé group 2: bole of isolated trees, near the base (higher accumulation of nitrogen), south-exposed...
- Relevé group 3: young branches (smooth bark), mostly of isolated trees; indifferent to exposure.
- Relevé group 4: bole of isolated trees (north exposed, at 1-2.5 m of height) or bole of trees in rather open stands (and then indifferent to exposure).
- Relevé group 5: only on the bole old trees in woody stands, indifferent to exposure, mostly on epiphytic mosses (higher water availability).
- Relevé group 6: Branches (indifferent to exposure) and high portions of the boles (at the north side) of isolated trees in strongly wind-exposed sites (near ridges).

The results of the reciprocal ordering of relevés and species are in Fig. 9 (a and b). Also in this case the relevé groups obtained by classification are recognizable in the ordination (Fig. 9a). The relevé points are arranged along a horse-shoe; their sequence is as follows: relevé groups 1, 2, 3, 4, 5, 6. It is not possible to interpret this sequence only on the basis of the variation of ecological factors. Fig. 10 reports the percentages in each relevé of 6 main growth form types (as in Barkman, 1958); the relevés are arranged according to their angular scores in Fig. 9a. The crustose growth form type (Fig. 10) is predominant at the center of the gradient, and decreases left- and rightwards. The *Physcia*-type (narrow-lobed, foliose) and the *Ramalina*-type (fruticose) tend to increase towards the left side of the gradient, whereas the *Lobaria*-type (broad-lobed, foliose) and the *Anaptychia*-type (fruticose) increase at the right side of the gradient. The crustose type is characteristic of pioneer stands, the fruticose type of well developed, mature stands. The arrangement of the relevés in Fig. 9a reflects two successional trends, that occur in different ecological conditions. Relevé group 3 represents the pioneer lichen vegetation on young branches with smooth bark. On isolated trees (high light intensity, hence dominance of the narrow lobed foliose form) the succession evolves towards relevé group 2 where nitrogen accumulation is high (base of the boles), or towards relevé group 1 where this does not occur (high, old branches). On trees located in woody stands, where light intensity is lower (dominance of the broad lobed foliose type), the succession evolves towards relevé group 4 (boles, directly on bark) and relevé group 5 (boles, mostly on epiphytic mosses). Relevé group 6 could be considered as the expression of an azonal vegetation in the study area, bound to habitats with peculiar ecological conditions (exposure to strong winds). Fig. 11 reports the frequency of apothecia bearing species in the relevés arranged as in the ordination of Fig. 9a. Reproduction by spores is maximal in xerophytic, neutrobisphytic and photophytic communities.

The results of the reciprocal ordering of species are in Fig. 9b. Most of the species in Fig. 9b have low scores on the two first canonical variates: they are either low-frequency species or species that are not strongly correlated with the successional-ecological gradient of Fig. 9a. In Fig. 9b only those species are named, that have high scores on the first two canonical variates. This allows to extract 23

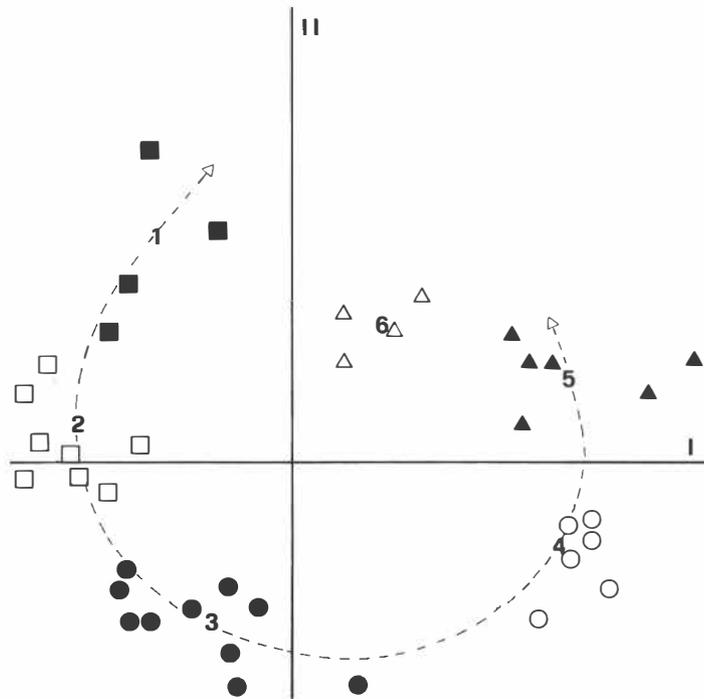


Fig. 9a — Arrangement of relevé points in the reciprocal ordering of relevés and species based on the data in Tab. 1. Symbols refer to relevé groups, as in Fig. 3.

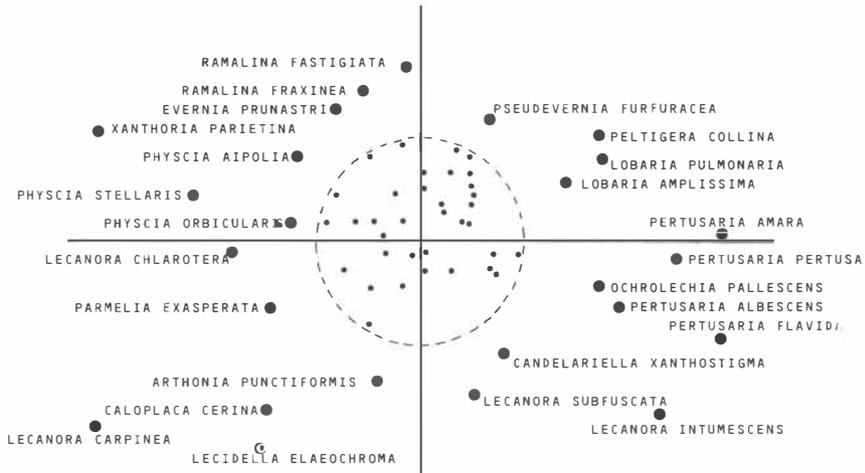


Fig. 9b — Arrangement of species points in the reciprocal ordering of relevés and species based on the data in Tab. 1. Only those species are named, that have high scores on the first two Canonical Variates.

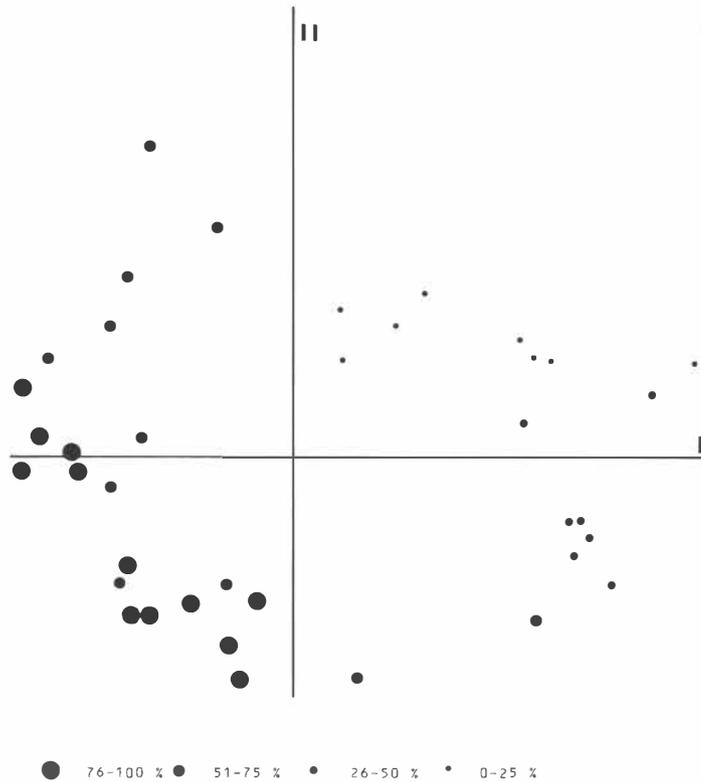


Fig. 10 — Frequency classes of apothecia-bearing species in the relevés. The relevés are arranged as in Fig. 9a.

indicator species out of a total of 64. The indicator value of each species can be inferred from its position in respect with the relevé groups in Fig. 9a, and with the ecological characterization of the relevé groups given above.

Tab. 3 contains the occupancy rates of the species in the geographical subdivisions of Europe proposed by Wirth (1980), calculated as percents of the total occupancies for each relevé group. The data in Tab. 3 have been submitted to AOC in order to analyze the phytogeographical affinities of the relevé groups. The results are visualized in Fig. 12, where two main trends are evident:

- a) the first canonical variate clearly reflects a trend in increasing aerohygrophytism, from relevé groups with high incidence of subcontinental species (relevé group 6) to relevé groups with high incidence of subatlantic and atlantic species (relevé groups 4,5). Noteworthy is the fact that in relevé groups 4 and 5 most of the species whose ranges extend from boreal or central western Europe also occur in the mediterranean region, where, however are restricted to high elevations (Tab. 3). This is mainly due to the suboceanic conditions that characterize the montane belt of the mediterranean region (Walter & Straka, 1970).

Oper. Geogr. Unit	R E L E V E			G R O U P		N R.
	1	2	3	4	5	6
ARCTIC	7.8	4.4	20.0	8.0	12.5	24.0
BOREAL ATL.	.....	.....	.....	.....	14.2	.....
BOREAL SUBATL.	2.6	2.2	4.3	6.6	21.4	.....
BOREAL SUBCONT.	.....	.....	.....	.....	.....	16.0
BOREAL	62.3	48.8	75.7	32.0	26.7	80.0
SOUTH BOREAL ATL.	.....	.....	.....	.....	14.2	.....
SOUTH BOREAL SUBATL.	3.9	4.4	4.3	6.6	21.4	4.0
SOUTH BOREAL SUBCONT.	.....	.....	.....	.....	.....	16.0
C-EUROP. SUBATL.	10.3	11.1	4.3	24.0	50.0	4.0
C-EUROP. SUBCONT.	.....	.....	.....	.....	.....	16.0
C-EUROP. MONTANE	.....	2.2	.....	.....	.....	.....
C-EUROP.	89.6	86.6	95.7	54.6	35.7	80.0
SOUTH C-EUR. SUBATL.	7.8	8.8	4.3	24.0	48.2	4.0
SOUTH C-EUR. SUBCONT.	.....	.....	.....	.....	.....	8.0
SOUTH C-EUR. MONTANE	.....	2.2	5.7	9.3	1.8	36.0
SOUTH C-EUR.	92.2	88.8	90.0	53.3	50.0	60.0
SUBMEDIT. SUBATL.	2.6	8.8	4.3	17.3	21.4	.....
SUBMEDIT. MONTANE	3.9	4.4	5.7	18.6	32.1	56.0
SUBMEDIT.	93.5	86.6	90.0	50.6	42.8	44.0
MEDIT. SUBATL.	.....	.....	.....	.....	1.8	.....
MEDIT. MONTANE	7.8	20.0	10.0	32.0	55.3	36.0
MEDIT.	90.9	75.5	88.6	50.6	37.5	44.0

Tab. 3 — Percents of species occurring in different geographical subdivisions of Europe, calculated over the total occupancies of each relevé group.

b) The second canonical variate reflects a trend from high (negative scores) to low (positive scores) temperatures. At the negative extreme is the mediterranean region, at the positive extreme the subcontinental parts of boreal Europe. Relevé group 2 is the one whose species most extend into the mediterranean region,

relevé group is 6 the one whose species are mostly restricted to northern or Central Europe.

If interpreted on the basis of the previous ecological characterization of the relevé groups, these results show that there is a strong correlation between ecological requirements of the species and their distribution patterns. Relevé groups 4 and 5, taken in shady sites have the highest frequency of suboceanic species, whereas relevé groups 1, 2, 3, taken in strongly illuminated sites, have the highest incidence of southern species; relevé group 6, occurring on branches in wind-swept stations, is mostly composed by northern species.

We can conclude that the epiphytic lichen flora of an area tends to be organized in community-types with different ecology, in which species with similar distribution patterns are associated according to the prevailing ecological conditions.

Phytosociological interpretation

Relevé group 1: this relevé group corresponds well with the union *Ramalinetum fastigiatae* Duvigneaud (1942). The three faithful species, *Ramalina fraxinea*, *R.*

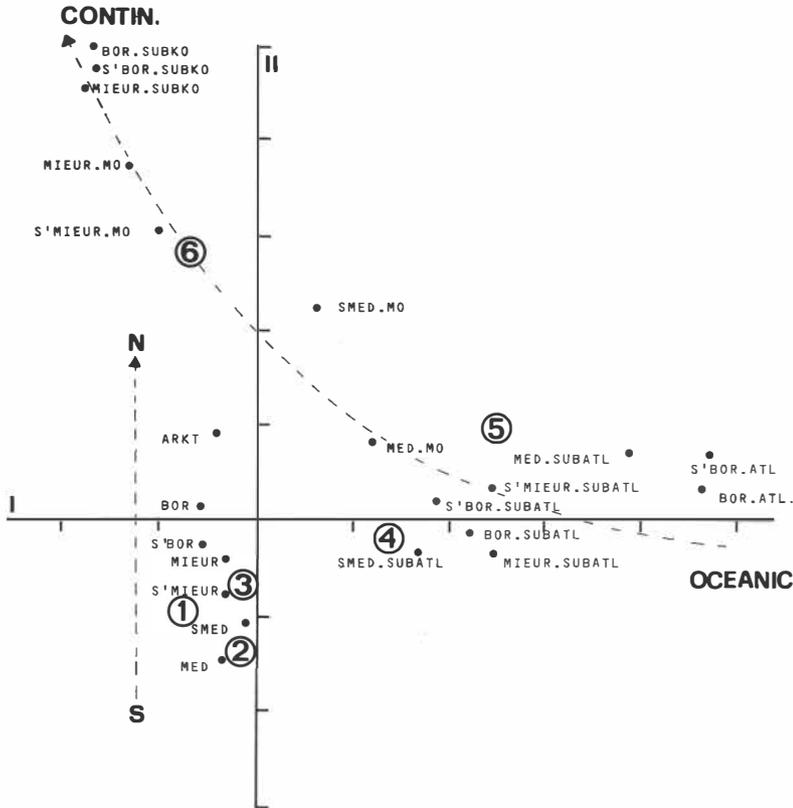


Fig. 12 — Arrangement of relevé group points and of geographical subdivisions of Europe according to the two first Canonical Variates of AOC, based on the data of Tab. 3.

fastigiata and *R. farinacea* are all constant in our data set. *Evernia prunastri* is considered by Barkman (1958) as differential within the Order *Physcietalia adscendentis* Mattick (1951) em. Barkman (1958). The ecological characterization given by Barkman (1958) for this union corresponds well with the one presented in the results. The union is known from Scotland and South Finland (Barkman, 1958) in Northern Europe, to South France (Rondon, 1951, 1953) and North East Italy (Nimis, 1983) in Southern Europe. I frequently observed well developed stands of the *Ramalinetum fastigiatae* in the montane belt of Central and Southern Italy.

Relevé group 2: this relevé group corresponds with the union *Physcietum adscendentis* Frey and Ochsner (1926). Of the faithful species (Barkman, 1958), the following are present in our data set: *Physcia aipolia*, *Physconia pulverulacea*, *Physcia stellaris*. Several variants of this union have been described (Barkman, 1958; Nimis & De Faveri, 1981). Our relevés belong to the var. *Parmeliosum glabrae* Barkman (1958), characterized by the constant presence of *Physcia stellaris*. This variant is known for the lowland and colline zones of Central and Eastern Europe.

Relevé group 3: this relevé group belongs to the *Lecanoretum carpineae* s.l. The union *Lecanoretum carpineae* was subdivided by Barkman (1958) into three unions, that are considered as geographical vicariants. This subdivision has been criticized by Kalb (1970), above all as far as the choice of the differential species is concerned. Actually, it is impossible to include our relevés in any of the unions proposed by Barkman, since they contain species that are considered by Barkman as differential of all of the three unions. They are: *Lecanora pallida*, *Caloplaca cerina* (*Lecanoretum carpineae continentale*), *Candelariella xanthostigma*, *Lecanora intumescens* (*Lecanoretum carpineae montanum*), *Arthopyrenia punctiformis* (*Lecanoretum carpineae atlanticum*).

Relevé group 4: this relevé group corresponds well with the *Pertusarietum hemisphaericae* Klement (1955) (Syn.: *Pertusarietum amaræ* Hilitzer, 1925 em. Barkman, 1958). The following faithful species are present in our data set: *Pertusaria hemisphaerica*, *Fuscidea cyathoides*, *Pertusaria pertusa*. The union has a subatlantic distribution in Europe, being known for South Scandinavia, Brittany, the Netherlands (Barkman, 1958) and Germany (Klement, 1955). It has been recorded by Nimis (1983) in the Trieste Karst (NE Italy), where it is confined to deep dolines with a particularly humid microclimate. I frequently observed stands referable to this union in the montane belt of southern Italy, so that its total distribution is probably subatlantic-mediterranean montane.

Relevé group 5: this relevé group fully corresponds with the *Lobarietum pulmonariae* Hilitzer (1925). Of the faithful species, the following are present in our data set: *Lobaria pulmonaria*, *Lobaria amplissima*, *Nephroma resupinatum*, *Peltigera collina*, *Cetrelia cetrarioides*, *Peltigera polydactyla* and *Parmeliella plumbea*. The distribution of this union in Europe is subatlantic-mediterranean montane (Nimis, 1982).

Relevé group 6: this relevé group corresponds with the *Pseudevernetum furfuraceae* Hilitzer (1925). This union is common in central Europe, mainly in the montane-subalpine belts, where it occurs on a variety of trees, mostly conifers. In

the study area the *Pseudevernetum* is rare and localized in stations exposed to strong winds, and should be considered as azonal in respect with the prevailing climatical conditions.

Concluding remarks

The compositional variation of epiphytic lichen vegetation in the study area is strongly correlated with the variation of ecological factors. This is in its turn correlated with a variation of the frequencies of lichen species with given distribution patterns. Phytosociology, ecology and phytogeography may provide complementary tools to the causal approach in the study of epiphytic lichen vegetation.

Riassunto. La vegetazione lichenica epifita della zona del Lago Calamone (Appennino Settentrionale, Provincia di Reggio Emilia) è stata studiata sulla base di rilievi fitosociologici sottoposti a metodi di analisi multivariata. Sono state individuate le seguenti unioni di licheni epifiti:

- a) *Ramalinetum fastigiatae*, sui rami di faggi isolati.
- b) *Physcietum adscendentis*, alla base dei tronchi di faggi isolati.
- c) *Lecanoretum carpineae*, su giovani rami di faggio.
- d) *Pertusarietum hemisphaericae*: sui tronchi di faggi isolati in esposizione Nord, sui tronchi di faggi in bosco, indifferente all'esposizione.
- e) *Lobarietum pulmonariae*: sui tronchi di faggi in bosco, per lo più su muschi epifiti.
- f) *Pseudevernetum furfuraceae*: su rami di faggio in zone fortemente esposte al vento.

Ogni comunità è stata caratterizzata ecologicamente sulla base di un'analisi indiretta di gradiente. I dati per l'interpretazione ecologica sono gli indici ecologici proposti da Wirth (1980). I risultati dell'analisi fitogeografica mostrano una forte correlazione tra ecologia ed affinità fitogeografiche delle varie comunità licheniche epifite.

Acknowledgements. I would like to thank Prof. D. Bertolani Marchetti (University of Modena) who invited me to carry out the present study, Dr. E. Chiessi and the Amministrazione Provinciale di Reggio Emilia for the kind assistance and financial support. The work has been supported also by a CNR grant to "Gruppo Biologia Naturalistica".

References

- Anderberg M.R. (1973) - *Cluster analysis for applications*. Academic Press. New York.
- Barkman J.J. (1958) - *Phytosociology and ecology of cryptogamic epiphytes*. Assen, 628 pp.
- Bertolani-Marchetti D. et al. (1983) - *Ricerche geobotaniche, ecologiche, faunistiche al lago Calamone (Monte Ventasso, Appennino Reggiano)*. Gior. Bot. Ital., 117, suppl. 1: 33-37.
- Chiessi E. (1983) - *Una proposta per l'uso e la tutela dell'area Ventasso-Laghi*. Giorn. Bot. Ital., 117, suppl. 1: 38-39.
- Duvigneaud P. (1942) - *Les associations épiphytiques de la Belgique*. Bull. Soc. Roy. Bot. Belg., 71: 99-114.
- Feoli E. & Feoli Chiapella L. (1980) - *Evaluation of ordination methods through simulated coenoclines: some comments*. Vegetatio 42: 35-41.
- Feoli E. & Orlóci L. (1979) - *Analysis of concentration and detection of underlying factors in structured tables*. Vegetatio 40: 49-54.
- Kalb K. (1970) - *Flechtengesellschaften der vorderen Öztaler Alpen*. Dissert. Bot., 9, Lehre, 118 pp.
- Klement O. (1955) - *Prodromus der mitteleuropäischen Flechtengesellschaften*. Feddes Rep. Beih., 135: 5-194.
- Masini P. (1983) - *Lineamenti storici ed ecologici del lago di Ventasso*. Giorn. Bot. Ital., 117, suppl. 1: 42-43.
- Mattick F. (1951) - *Wuchs- und Lebensformen, Bestand- und Gesellschaftsbildung der Flechten*. Engler's Bot. Jahrb., 75,3: 378-423.
- Nimis P.L. & De Faveri R. (1981) - *Numerical classification of Xanthorion communities in north eastern Italy*. Gortania, 2: 91-110.
- Nimis P.L. (1983) - *The epiphytic lichen vegetation of the Trieste province (north eastern Italy)*. Studia Geobot., 2: 169-191.
- Ochsner F. (1928) - *Studien über die Epiphytenvegetation der Schweiz*. Jahrb. St. Gall Naturwiss. Ges., 63,2: 1-106.
- Orlóci L. (1978) - *Multivariate analysis in vegetation research*. 2nd ed. Junk, The Hague, 451 pp.
- Rondon Y. (1951) - *Une station des lichens pinicoles au Mont-Ventoux*. Feuille des Natur., 6: 71-74.
- Rondon Y. (1953) - *Les lichens corticoles de Cedrus atlantica au Mont-Ventoux*. Cahier des Natur. Bull. des N.P., 8: 13.
- Walter H. & Straka H. (1970) - *Arealkunde, Floristisch-historische Geobotanik*. Ulmer, Stuttgart, 478 pp.
- Wildi O. & Orlóci L. (1980) - *Management and multivariate analysis of vegetation data*. Swiss Fed. Inst. For. Res. Rep. Nr. 215, Birmensdorf, 68 pp.
- Wirth W. (1980) - *Flechtenflora*. Stuttgart, 552 pp.

Pier Luigi Nimis
Dipartimento di Biologia, Università degli Studi di Trieste
34100 Trieste.

TWO EXAMPLES OF THE USE OF NUMERICAL CLASSIFICATION AND ORDINATION METHODS IN THE ANALYSIS OF STRUCTURE AND CHOROLOGY OF VEGETATION TYPES

Carlo BLASI

Keywords: classification, chorology, ordination, texture, vegetation types.

Abstract. Two examples of application of numerical classification and ordination methods to textural and chorological data of vegetation types defined with the Braun-Blanquet approach are presented.

Introduction

Vegetation data can be classified on the basis of different criteria: physionomic, dynamic, floristic etc. (Westhoff & van der Maarel, 1978), therefore many classifications could be proposed which may give information about vegetation diversity (see Feoli, 1983). Comparison between different classifications and ordination of the same phytosociological data is always a useful tool in understanding correlations and making interpretations for compositional changes (see Orłóci, 1978). Feoli, Lagonegro & Biondani (1981) present an example of classification evaluation on the basis of external variables. The same can be done with internal characteristics of vegetation such as structure and chorology. In the present paper I give two examples on the use of classification and ordination methods to investigate the structure and chorology of vegetation types defined with the Braun-Blanquet approach. I would like to stress that the vegetation types should be the basis for the structural and functional studies of vegetation.

Example 1

With this example I show an application of cluster analysis to answer the following question: are floristically defined vegetation types distinguishable also in terms of texture (see Barkman, 1978)?

The example is taken out from a previous paper (Blasi & Scoppola, 1981). Two well defined associations and some types without syntaxonomical interpretation are compared by their weighted life form spectra. These have been computed on the basis of phytosociological tables of relevés from different areas in the Central Apennines:

- a) M. Velino (Avena & Blasi, 1980)
 - 1) Saturejo montanae-Brometum erecti
 - 2) Seslerio nitidae-Brometum erecti
 - 3) A type of Mesobromion s.l. of difficult syntaxonomical interpretation.
- b) Central Apennines (different mountains) (Avena & Blasi, 1979)
 - 4) Saturejo montanae-Brometum erecti
 - 5) Transitional type (facies) between Saturejo montanae-Brometum erecti and Seslerio nitidae-Brometum erecti.
- c) Valsorda (Umbria) (Bruno & Covarelli, 1968)
 - 6) Seslerio nitidae-Brometum erecti em. Biondi & Blasi (1982)
 - 7) Seslerio nitidae-Brometum erecti sesleriëtosum apenninae
 - 8) Seslerio nitidae-Brometum erecti var. with Bromus erectus and Koeleria splendens.

In order to answer the question, the method of average linkage clustering (Anderberg, 1973) has been applied to the similarity matrix between the weighted life form spectra of the 8 phytosociological tables. The similarity between the spectra has been computed by the similarity ratio coefficient (see Westhoff & van

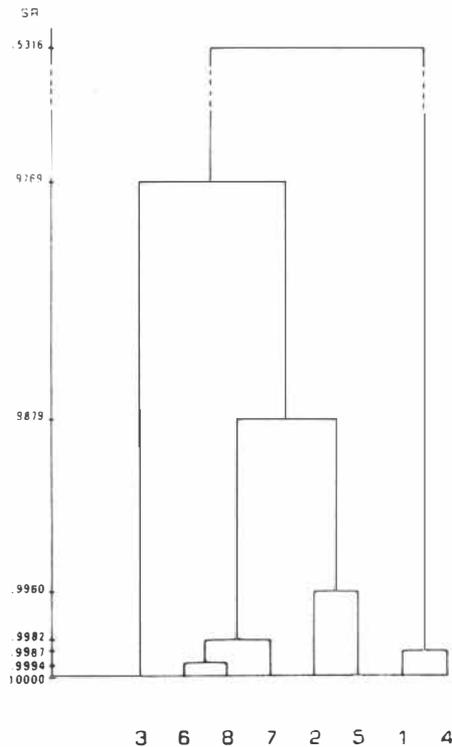


Fig. 1 — Dendrogram of similarity between the phytosociological units on the basis of weighted life form spectra (Blasi, Scoppola 1981).

der Maarel, 1978). The resulting dendrogram is presented in Figure 1. It defines two main clusters (3, 6, 8, 7, 2, 5) and (1, 4) respectively including the spectra of *Seslerio nitidae-Brometum erecti* and those of *Saturejo montanae-Brometum erecti*. The hierarchical structure proves that the transitional facies 5 is, texturally, more similar to the former than to the latter and also that the type 3 has a texture more similar to *Seslerio nitidae-Brometum erecti* than to *Saturejo montanae-Brometum erecti*. By rearranging the weighted life form spectra according to the sequence of the dendrogram:

	3	6	8	7	2	5	1	4
P	3.8	----	----	----	----	----	----	----
Ch	8.8	15.2	16.6	17.9	19.6	23.6	57.8	59.6
H	79.8	83.0	83.2	80.5	77.3	74.4	38.4	36.7
T	2.2	1.7	0.1	1.5	0.6	----	2.6	2.5
G	5.4	0.1	0.1	0.1	2.5	2.0	2.2	1.2

a clear pattern of variation is detectable. The trend concerns chamaephytes and

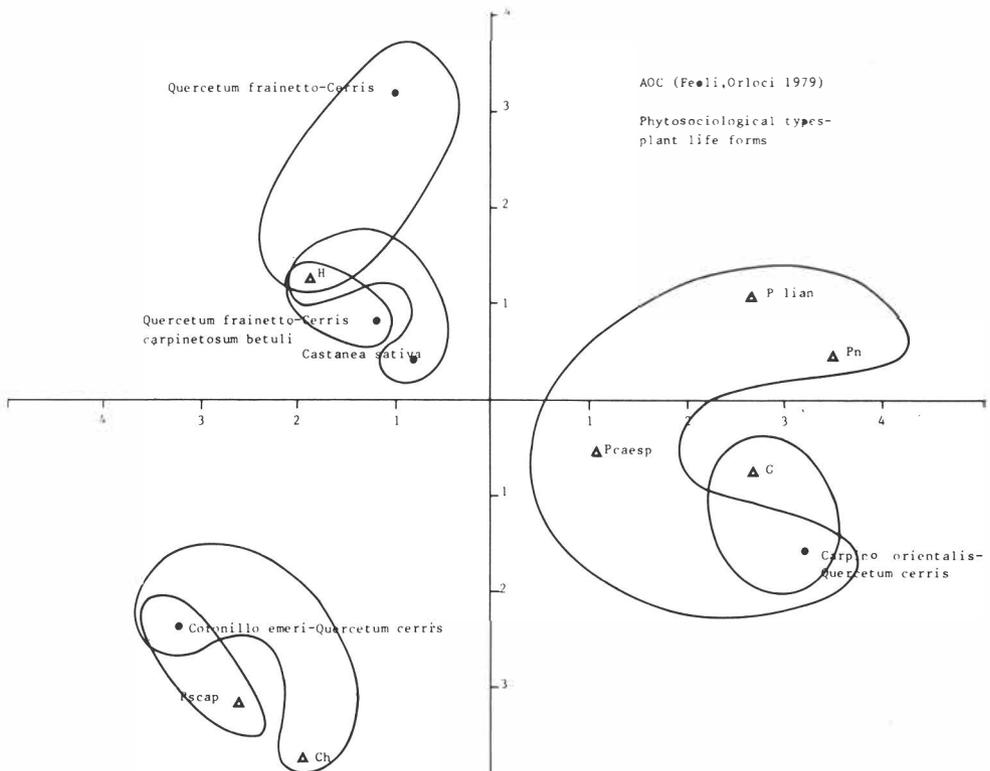


Fig. 2 — Ordination of the types and life-forms based on the first two canonical variates (Blasi 1984).

hemipterophytes only, the other life forms do not show any trend. From the table it is evident that the two associations have different texture, *Seslerio nitidae-Brometum* is dominated by Hemipterophytes while *Saturejo nitidae-Brometum* by Chamaephytes. This comparison could be done also without clustering techniques, however in this case no quantification of similarity would be possible. The fact that in the previous paper Avena & Blasi (1979) have considered the type 5 as a facies of *Saturejo montanae-Brometum erecti* it is not supported by the results of cluster analysis applied to textural data. This suggests to analyse again the floristic data with numerical methods both for classification and predictive analysis (see Orlóci, 1978; Feoli, 1983) in order to see if the differences are mainly due to species composition or to different proportions between species.

Example 2

In this example I present an application of analysis of concentration to weighted life forms and chorological spectra of vegetation types of oak woods of Lazio. The example is taken out from Blasi (1984). The analysis of concentration has been used to order the types on the basis of their spectra and also to quantify the relationships between the different life forms and chorological elements and the types as suggested by Feoli & Lagonegro (1982). The method when applied to cover data has not the same statistical meaning as in case of occupancy counts data (Feoli & Orlóci, 1979), however it can be used to obtain values for deterministic comparisons.

The life form and chorological spectra have been computed on the basis of phytosociological tables of the following types (Blasi, 1984):

- 1) *Quercetum frainetto-cerris* Oberd. 1948 em. Horvat 1959.
- 2) *Quercetum frainetto-cerris carpinetosum betuli* Blasi 1984
- 3) *Coronillo emeri-Quercetum cerris* Blasi 1984
- 4) *Carpino orientalis-Quercetum cerris* Blasi 1984
- 5) Type with *Castanea sativa* (Blasi, 1984).

The ordination of life forms and the types is presented in Figure 2. The maximal influence levels in respect to the first canonical variate are marked with lines including the types and the life forms. The figure indicates that the types 1, 2, 5 are texturally characterized by high frequency and cover of hemipterophytes, the type 3 by high frequency and cover of scapose phanerophytes and chamaephytes while *Carpino orientalis-Quercetum cerris* by high frequency and cover of geophytes, caespitose phanerophytes, lianose phanerophytes and nano-phanerophytes.

The joint ordination of the types and chorological elements is presented in Figure 3. Also in this case the lines include the types and chorological elements with the highest influence level with respect to the first canonical variate (first factor). Since in Europe there is a strong relationship between the climate and the range of the species especially if the mediterranean element is considered, the first canonical variate can be interpreted as a climatic factor. In fact the North-European element and the Stenomediterranean element are on the opposite sides on the canonical variate. *Coronillo emeri-Quercetum cerris* is characterized by high frequency and cover of the North European and Mediterranean montane elements. *Quercetum frainetto-cerris* its subassociation and the type with *Castanea sativa* are

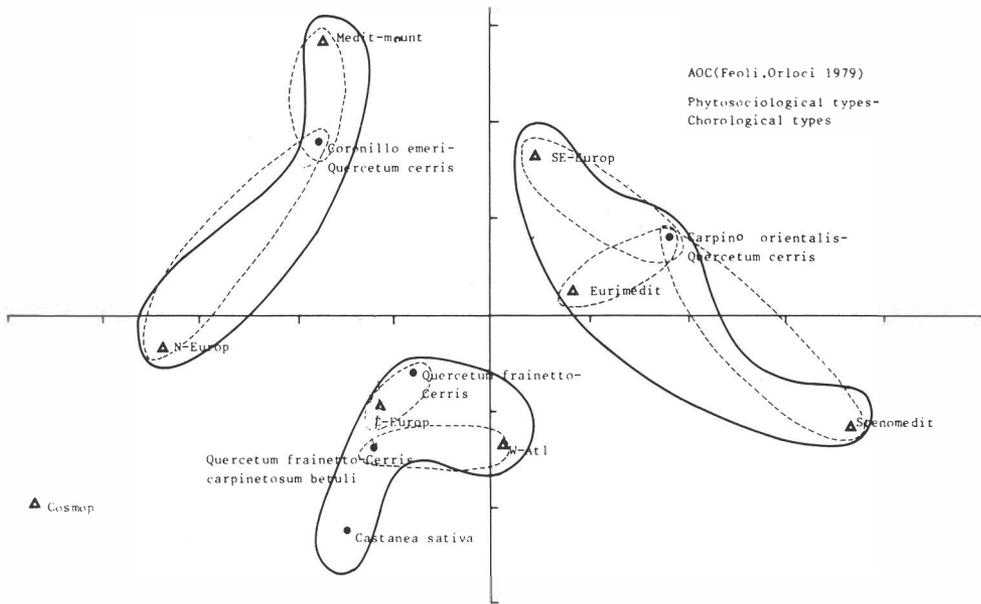


Fig. 3 — Ordination of phytosociological and chorological types based on the first two canonical variates of AOC (Blasi 1984).

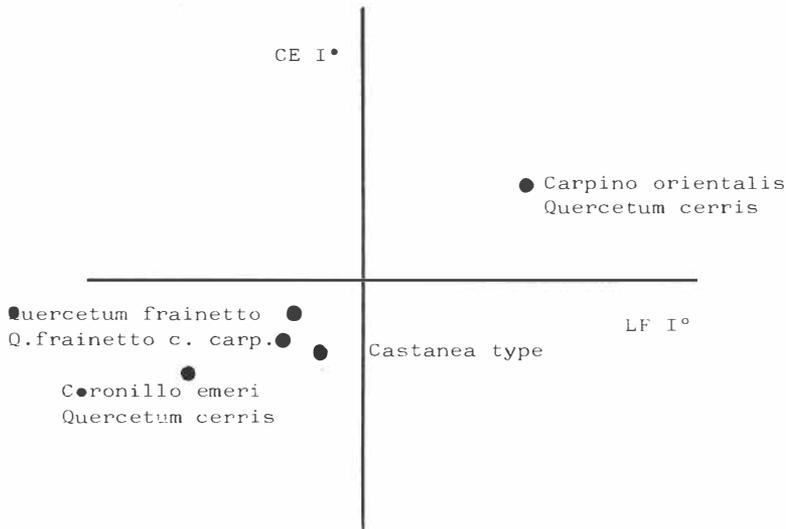


Fig. 4 — Correlation between the first canonical variates of AOC on the basis of life form spectra (LFI) and on the basis of chorological spectra (CE I).

all characterized by high frequency and cover of the Central European element and West-Atlantic element; *Carpino orientalis-Quercetum cerris* is characterized by high frequency or cover of SE-European, Eurimediterranean and Stenomediteranean elements. If the first canonical variates of the two ordinations are used to construct a correlation diagram (Figure 4) a linear relationship between them can be deduced. This suggests that a linear relationship can be presumed between the textural and chorological variation of the vegetation of oak woods of Lazio. The three figures should also suggest that in the woods under study the Stenomediterranean, Eurimediterranean and SE-European elements are mainly caespitose phanerophytes, lianose phanerophytes, nano-phanerophytes and geophytes, the Central European and W-Atlantic species are mainly hemycryptophytes and that the Mediterranean montanae are mainly scapose phanerophytes and chamaephytes. The analysis proves to be informative about the relationships between chorology and structure of vegetation types which according to Westhoff & van der Maarel (1978) should constitute the main criteria for vegetation classification.

Conclusions

The examples show how the correlation between floristic data, structural and chorological data can be verified on the basis of phytosociological types defined according to the Braun-Blanquet approach. The floristically defined types offer the frame to formulate hypotheses about vegetation structure and chorology; they can be considered as tools on which develop further biological researches on vegetation. The types do not need to have precise syntaxonomical definition, they have to be considered just abstract classes useful to present and illustrate the multidimensional variation of vegetation.

Riassunto. Alcuni tipi di vegetazione definiti con il metodo di Braun-Blanquet sono stati confrontati sulla base dei loro spettri biologici e corologici ponderati. Vengono presentati due esempi di applicazione di metodi numerici. Nel primo (pascoli dell'Appennino) la classificazione numerica viene usata per valutare per via indiretta la correlazione tra i dati floristici (i tipi sono definiti su base floristica!) e i dati strutturali. Nel secondo caso l'analisi della concentrazione viene usata per stimare in modo diretto la correlazione fra forme biologiche ed elementi corologici e i tipi di vegetazione. In entrambi i casi risulta evidente l'utilità della tipificazione fitosociologica indipendentemente da un preciso inquadramento sintassonomico. I tipi dovrebbero essere considerati come insiemi che forniscono la struttura logica (classificazione) per misure di correlazione.

References

- Anderberg M.R. (1973) - *Cluster analysis for applications*. Academic Press, New York, London.
- Avena G.C. & Blasi C. (1980) - *Carta della vegetazione del Massiccio del Monte Velino - Appennino Abruzzese*. CNR serie AQ/1/55.
- Avena G.C. & Blasi C. (1979) - *Saturejo montanae-Brometum erecti* ass. nova dei settori pedemontani dell'Appennino calcareo centrale. Arch. Bot. e Biog. Ital., 55-1/2: 34-43.
- Blasi C. (1984) - *Quercus cerris and Quercus frainetto woods in Latium region (Central Italy)*. Ann. Bot. (Roma), 42: 7-19.
- Blasi C. & Scoppola A. (1981) - *Sull'uso delle forme biologiche nella classificazione fitosociologica e nella verifica sintassonomica di alcuni aspetti degli xero-brometi appenninici*. Giorn. Bot. Ital., 115, n. 4-5: 197-209.
- Bruno F. & Covarelli G. (1968) - *I pascoli e i prati falciabili della Valsorda (Appennino Umbro)*. Not. Fitosoc. 5: 47-65.
- Feoli E. (1983) - *Predictive use of classification and ordination methods in plant community ecology*. In Ferrari et al. (eds.) "Le comunità vegetali come indicatori ecologici". Studi e Documentazioni Reg. Emilia Romagna 30: 83-108.
- Feoli E. & Lagonegro M. (1982) - *Syntaxonomical analysis of beech woods of Apennines based on the program package IAHOPA*. Vegetatio 50: 130-173.
- Feoli E., Lagonegro M. & Biondani F. (1981) - *Strategies in syntaxonomy: a discussion of two classification of grasslands of Friuli (Italy)*. In H. Dierschke (ed): Syntaxonomie, pp. 95-107, Cramer, Vaduz.
- Feoli E. & Orłóci L. (1979) - *Analysis of concentration and detection of underlying factors in structured tables*. Vegetatio 40: 49-54.
- Orłóci L. (1978) - *Multivariate analysis in vegetatio research*. 2nd ed. Junk, The Hague.
- Westhoff V. & Maarel E. van der (1978) - *The Braun-Blanquet approach*. 2nd ed. - In: Wittaker R.H. (ed.): Classification of plant communities pp. 287-399. The Hague.

Carlo Blasi
Dipartimento di Biologia
Vegetale, Università
di Roma Italia

COMPARISON OF ORDINATIONS OF SOME APENNINE FOREST COMMUNITIES BASED ON DIFFERENT CHARACTERS AND METHODS

E. FEOLI, L. ORLÓCI and M. SCIMONE

Keywords: character sets, comparisons, cluster analysis, methodology, ordinations.

Abstract. In the course of numerical ordinations of Apennines woodlands, the problem arose of different performance of ordination methods, using different character sets and methods. To reveal underlying trends and relationships, 47 ordinations are jointly examined, corresponding to combinations of 6 methods and 8 character types. The Spearman formula has been used to measure the similarity between different ordinations. The ordinations based on families are, on the average, the most similar to the other ones irrespective to the method used. The ordination based on detailed life forms (growth forms) are the least similar to the other ordinations. Ordinations based on the same character set and different methods could be different as well as ordinations based on different character sets and the same method. The suggested procedure can be the basis to select among different ordinations those explaining complementary informations.

Introduction

The ordination methods are all based on algorithms which reduce the dimensionality of the space under study. The aim is to describe synthetically the relationships of similarity between the objects and the correlation between the characters describing the objects. Different methods applied to the same data set may give different results, i.e. informations which remain unexplained by one method can be revealed by another one. Furthermore the same set of objects may be described by different characters with the aim to investigate different biological phenomena. The characters may be redundant, because of correlation (see Orłóci, 1975) or hierarchical relationships (see Feoli, 1984). The comparison of ordinations of the same sets of objects based on different methods and descriptions should be useful to select among several ordinations those which are supposed to reveal complementary informations. The problem is addressed with regard to 4 character sets with a hierarchical structure:

- (I) Taxonomic (species, genera, families)
 - (II) Structural (growth-form, life-form)
 - (III) Syntethic (species groups)
 - (IV) Chorological (chorology, subchorology)
- and different ordination methods:

(I) MDSCAL (Brambilla & Salzano, 1981; Fewster & Orlóci, 1983)

(II) AOC (Feoli & Orlóci, 1979)

(III) SIPLO (Feoli & Feoli Chiapella, 1980).

The use of these is contemplated in the analysis of the data from a broader survey (Feoli, Ganis & Scimone, in prep.).

The modus operandi of the study is relatively simple: repeat an ordination by character sets at different hierarchical levels, proceeding from low (higher information level) to high (lower information level). When the ordinations are completed, classify and ordinate the ordinations and study the resulting dendrogram and scattergram for patterns and trends. The data, method and results are discussed in the following sections.

Data

The set of data consists of 17 types of woods of Apennines obtained by clustering procedures applied to synthetic tables structured in a data bank (Lagonegro et al., 1982) which will be described in detail by Feoli, Ganis & Scimone (in prep.). In Tab. 1 some informations about the types are given.

Table 1 — Characterization of the 17 types of the woods of Apennines used for the analysis according to the number of synthetic tables from which they were obtained, the regional distribution and the main tree composition.

Group	n. of synthetic tables	Localities from	Constant trees
1	8	Toscana/Liguria/Puglia	Quercus ilex, Arbutus unedo, Quercus suber
2	2	Lazio	Myrtus communis, Pistacia lentiscus
3	8	Liguria/Toscana/Marche/ Umbria	Quercus cerris, Quercus frainetto
4	11	Umbria/Marche/Liguria	Quercus petraea, Quercus cerris
5	2	Marche	Sorbus domestica, Juniperus communis, Quercus cerris
6	10	Toscana/Marche/Umbria	Ostrya carpinifolia, Quercus ilex
7	7	Umbria/Lazio/Abruzzo	Quercus cerris, Acer campestre, Ostrya carpinifolia
8	8	Umbria/Marche/Abruzzo	Acer campestre, Quercus cerris, Carpinus betulus
9	9	Campania/Lazio/Basilicata	Ostrya carpinifolia, Acer obtusatum
10	6	Liguria/Toscana	Quercus pubescens, Acer campestre
11	5	Abruzzo/Lazio	Quercus pubescens, Carpinus orientalis, Acer campestre, Ostrya carpinifolia
12	7	Liguria/Toscana/Marche	Ostrya carpinifolia, Acer pseudoplatanus
13	2	Lazio/Abruzzo	Quercus pubescens, Juniperus communis
14	13	Liguria/Toscana/Lazio/ Umbria	Ostrya carpinifolia, Acer obtusatum, Quercus pubescens, Juniperus communis, Quercus cerris
15	9	Puglia/Abruzzo/Campania/ Calabria	Fagus sylvatica
16	5	Liguria/Emilia/Toscana/ Abruzzo	Fagus sylvatica
17	3	Liguria/Abruzzo/Toscana	Fagus sylvatica

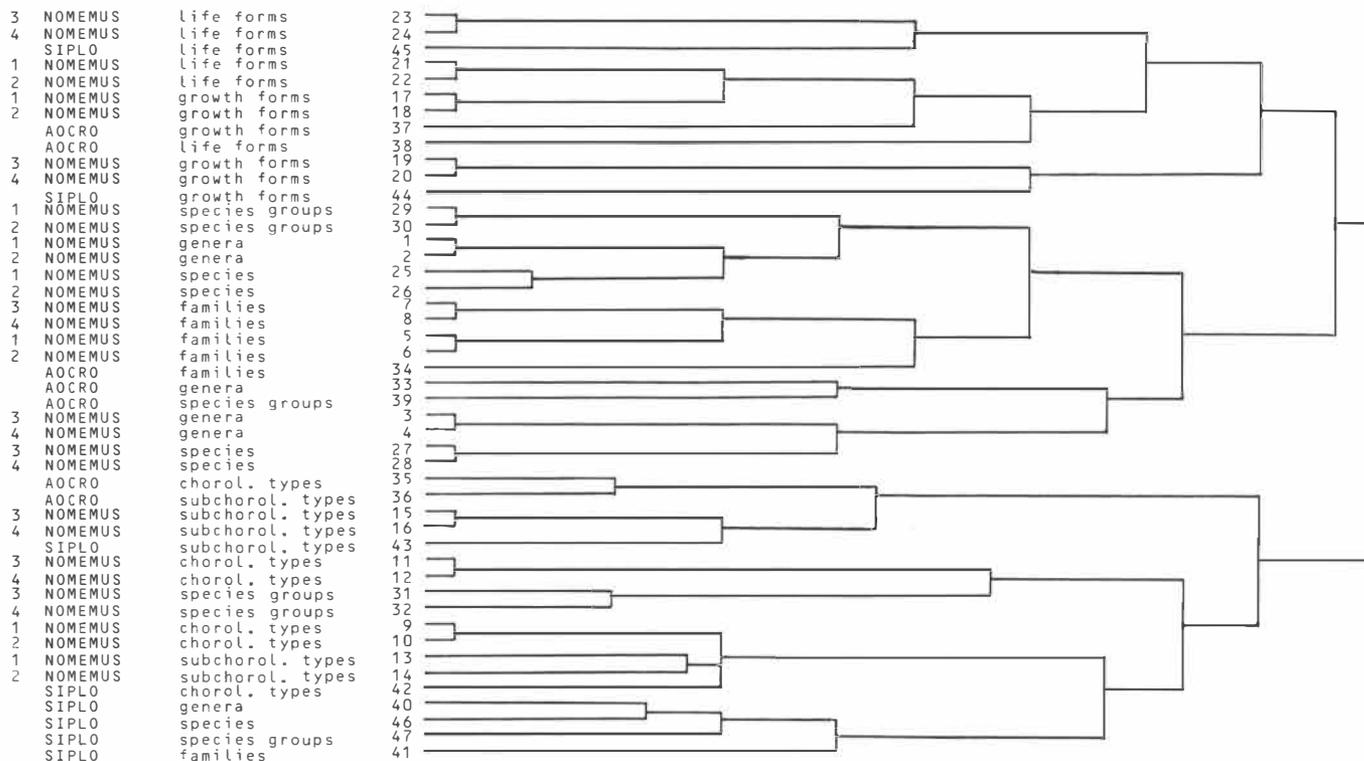


Fig. 1 — Average linkage clustering of 47 ordinations. The symbols identify ordination method and occupancy variable: N - MDSAL, a modification of the Kruskal & Carmone (1971) algorithm. N1 - random initial configuration, Orłóci's internal distance. N2 - random initial configuration, Euclidean distance. N3 - minimum variance option, Orłóci's internal distance. N4 - minimum variance option, Euclidean distance. S - SIPLO ordination. A - AOC ordination. SPE - species. GEN - genera. FAM - familv. SG - species groups. LF - life-form. GF - growth-form. CHORT - chorological type. SUBCHORT - sub-chorological type.

Method of analysis

The occupancy matrices were subjected to ordinations by 6 methods (see legend to Figure 1) and correlations were calculated between the ordinations among axes by the Spearman formula. The correlations were averaged for the first three axes and arranged in a 47x47 symmetric matrix (S) which, in turn, was subjected to cluster analysis and ordination. The order 47 comes from 6x8 minus one combination (AOC on species has not been computed). The clustering method was average linkage and the ordination was based on eigenvectors of S. The program used for MDSCAL is NOMEMUS which have been adapted by M. Lagonegro to the method suggested by Orlóci (1978) and Fewster & Orlóci (1983). AOCRO is the program for AOC and SIPLO the program for SIPLO.

Results and discussion

Fig. 1 contains the dendrogram by average linkage clustering and Figs. 2 and 3

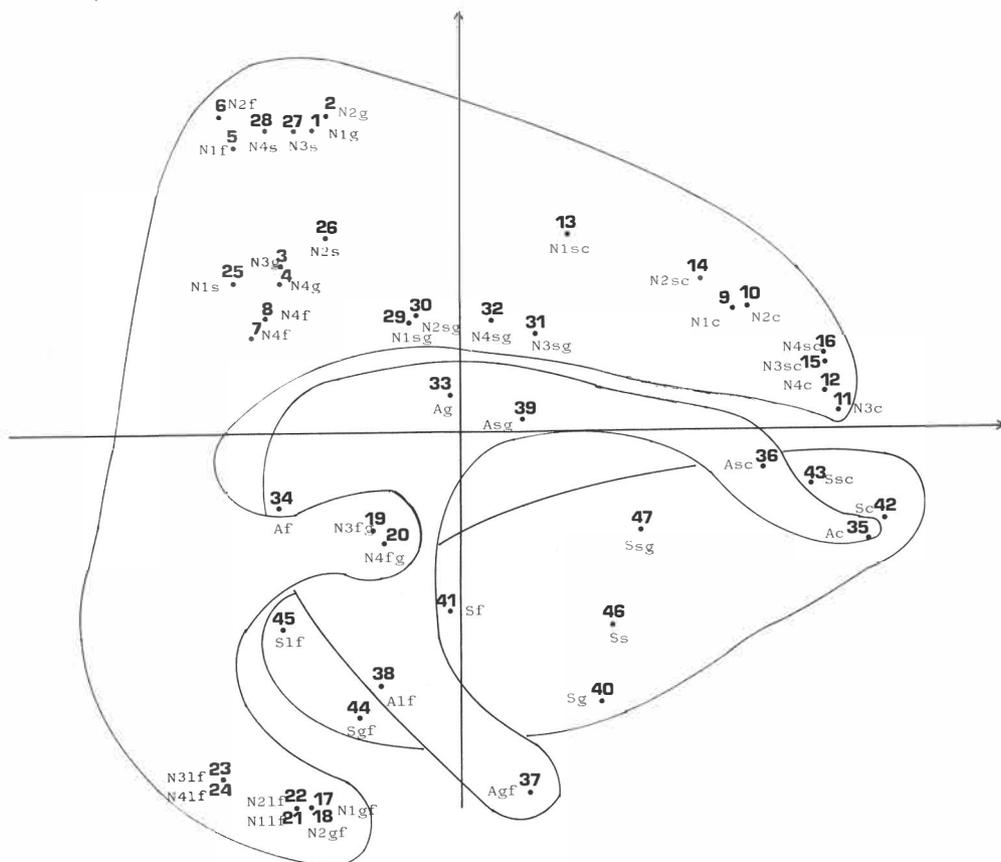


Fig. 2 – Ordination of the 47 ordinations by the 2nd and the 3rd eigenvectors of the matrix of Spearman coefficients. Top horseshoe - MDSCALE. Middle horseshoe - AOC. Straight cluster - SIPLO. Symbols are explained in the title of Fig. 1.

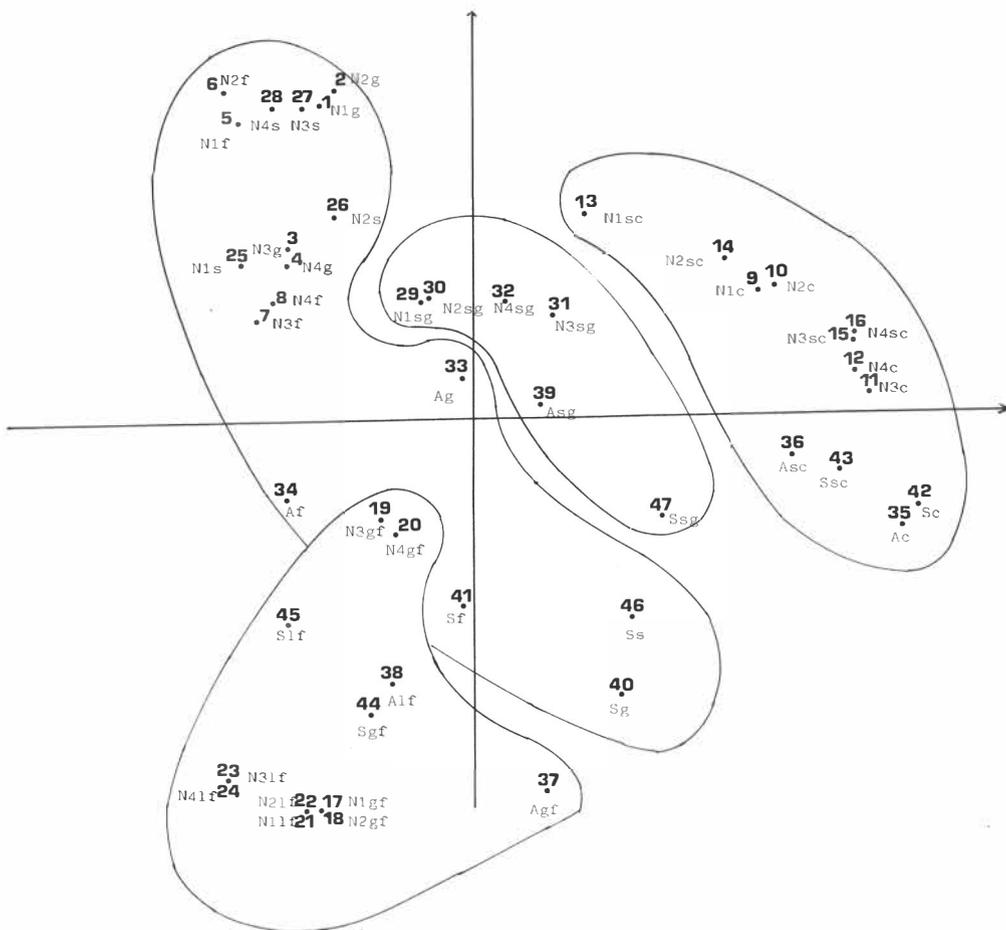


Fig. 3 — Ordination of 47 ordinations as in Fig. 2. Groups of characters are included in lines. Symbols are explained in the title of Fig. 1.

the ordination based on matrix S. Some statistics describing the 47 ordinations are given in Table 2.

Table 2a — Stress values in ordination by MDSAL. Explanations in Fig. 1.

Axis	N1			N2			N3			N4		
	1	2	3	1	2	3	1	2	3	1	2	3
Species	.30	.13	.11	.37	.17	.15	.35	.15	.11	.33	.15	.11
Species groups	.37	.13	.09	.43	.15	.09	.30	.13	.09	.44	.13	.09
Genera	.41	.17	.17	.44	.13	.17	.37	.15	.09	.35	.15	.09
Families	.19	.11	.09	.48	.11	.09	.19	.11	.07	.19	.11	.07
Chorological types	.28	.17	.11	.28	.19	.11	.16	.15	.07	.28	.15	.07
Subchorological types	.48	.13	.11	.24	.13	.13	.26	.13	.09	.26	.15	.09
Growth-forms	.15	.09	.06	.15	.11	.06	.15	.09	.06	.15	.09	.06
Life-forms	.44	.11	.07	.16	.22	.07	.31	.17	.04	.31	.17	.04

Table 2b — Cumulative percent of variance explained by three axes in ordinations of character groups by SIPLO.

Axes	1	2	3
Species	53.4	82.7	88.6
Species groups	60.8	82.3	88.7
Families	61.9	79.5	88.7
Genera	51.4	82.1	88.3
Chorological types	51.1	69.4	87.0
Subchorological types	65.0	80.9	91.5
Growth-forms	88.5	95.8	97.4
Life-forms	95.1	97.7	99.1

Table 2c — Cumulative percent of total chi-square explained by canonical axes of AOC in different character groups.

Axes	1	2	3
Species groups	21.8	39.5	51.1
Genera	21.4	37.5	46.6
Families	33.6	53.6	61.7
Chorological types	38.3	61.3	76.9
Subchorological types	41.8	57.9	69.9
Growth-forms	36.2	54.0	69.2
Life-forms	58.7	84.8	95.5

Three main groups can be seen in the dendrogram (Fig. 1). The first includes the ordinations corresponding to structural characters of life-form and growth-form. The second group contains the ordination based on taxonomic characters, and the third group consists of the remaining ordinations based on the chorology and subchorology characters. A smaller group, attached to the third contains ordination of SIPLO based on taxonomic characters and species groups. By-and-large it is apparent that the group structure of the 47 ordinations is dominated by character differences rather than by differences in ordination method.

An examination of Figs. 2 and 3 reveals additional patterns. The figures are based on the same axes, but different groups of the 47 ordinations (each point is one ordination). In Fig. 2 the clusters of the three methods occupy distinct locations. They also have different shapes. Considering the AOC cluster, its shape is an horseshoe. What follows logically is that the ordinations based on AOC are non-linearly related among the character groups. The same apply to the MDSCAL cluster, but not to SIPLO. In the case of SIPLO, the cluster is straight, suggesting only proportional differences among the ordinations of the character groups. SIPLO is more efficient in handling non-linear relationships among the characters than each of the other methods. The sequence of the ordinations are more or less the same along the curves fitting the dispersion within the cloud of the same method, i.e.

life-form + growth-form < families < genera < species < species groups < chorology + subchorology. This pattern suggests a good correlation between the ordination given by life forms and families and a high independence of the life forms in respect to the chorology. The detailed pattern of correlation between the first axes of ordinations based on the Spearman formula is given in Table 3, while in Table 4 a summary of the results is presented. The ordinations with the highest number of significant correlations are those obtained by NOMEMUS based on euclidean distance, the internal function suggested by Orlóci (1978) and Fewster & Orlóci (1983) and the starting by a random configuration (see Brambilla & Salzano, 1981). If the character type is considered, the ordination with the highest number of significant correlations are those based on families, followed by those based on life forms. The ordinations based on detailed life forms have the least number of significant correlations. This means that this character is the least correlated with the others. Within the same character the ordinations based on families have all significant correlations irrespective to the method used. Also the ordinations based on life forms are very similar irrespective to the method. The characters more sensitive to the method are the genus and the chorology.

Table 4 — Number of significant correlations ($p < 0.05$) between the first ordination axes of the different methods. Columns indicate the significant correlations for the methods, rows for the characters. T = totals, P = number of significant correlations within the character types irrespective of the method, N1-N4 see Fig. 1

	N1	N2	N3	N4	AOC	SIPLO	T	P
Genera	24	24	16	16	16	25	121	7
Families	21	21	29	29	29	27	156	15
Chorology	14	14	17	17	16	23	101	11
Subchorology	21	13	18	15	15	23	105	10
Growth-form	25	25	6	6	15	3	80	11
Life-forms	25	25	20	20	27	20	137	12
Species	27	30	10	14	—	27	108	8
Species groups	26	24	16	25	21	28	140	11
Totals	183	176	132	142	139	176	949	85

Conclusions

The results suggest that the character choice is more critical than the choice of the method, different methods may give similar or dissimilar results in relation of the character set used. SIPLO resulted the least affected by the choice of characters, only the ordinations based on life forms are quite different from the others. The procedure that we suggest can be easily performed for different ordinations (computer programs are available on request to M. Scimone) and will certainly help in the choice of the ordinations which are dissimilar. The dendrogram of Fig. 1 and the Table 4 could be used to select the ordination which potentially should give complementary informations (i.e. the non-correlated ordinations).

Riassunto. Viene usato il coefficiente di correlazione di Spearman per confrontare ordinamenti ottenuti con metodi diversi e basati su caratteri diversi, applicati allo stesso insieme di dati vegetazionali. I risultati dimostrano come gli ordinamenti siano più dipendenti dal tipo di descrizione, piuttosto che dal metodo impiegato.

Acknowledgements. The work has been supported by Italian C.N.R. and Canadian N.S.E.R.C.. Thanks are due also to prof. M. Lagonegro for adaptations on program NOMEMUS.

References

- Brambilla C. & Salzano G. (1981) - *A non-metric multidimensional scaling method for non-linear dimension reduction. Theory and computer program.* Istituto per le Applicazioni del Calcolo, Consiglio Nazionale delle Ricerche, Serie III - N. 121. Roma.
- Feoli E. (1984) - *Some aspects of classification and ordination of vegetation data in perspective.* Studia Geobotanica: 4: 7-21.
- Feoli E. & Orłóci L. (1979) - *Analysis of concentration and detection of underlying factors in structured tables.* Vegetatio 40: 49-54.
- Fewster P.H. & Orłóci L. (1983) - *On choosing a resemblance measure for non-linear predictive ordinations.* Vegetatio 54: 27-35.
- Kruskal J.B. & Carmone F. (1971) - *How to use M D SCAL (version 5M) and other useful information.* (Mimeographed).
- Orłóci L. (1978) - *Multivariate analysis for vegetation research.* 2nd ed. Junk, The Hague.
- Orłóci L. (1979) - *Types of data structures and their description.* In Orłóci L., Rao C.R. and Stiteler W.M. (eds.), *Multivariate Methods in Ecological Work*, pp. 191-202. International Co-operative Publishing House, Burtonsville, Maryland.
- Lagonegro M., Ganis P., Feoli E., Poldini L. & Canavese T. (1982) - *Un software per banche dati di flore territoriali. estendibile alla vegetazione.* CNR AQ/5/38, Roma. Udine.

Dr. E. Feoli
Dr. M. Scimone
Dipartimento di Biologia
Università di Trieste
Italy i-34100

Dr. L. Orłóci
Department of Plant Sciences
University of Western Ontario, London
Ontario, Canada N6A 5B7

Finito di stampare
nel mese di ottobre 1984



Studia Geobotanica Vol. 4 1984

CONTENTS

E. Feoli. Some aspects of classification and ordination of vegetation data in perspective.	7
G. Cristofolini. Un punto di vista sulla classificazione della vegetazione.	23
R. Gerdol, & M. Tomaselli. Evaluation of vegetation classifications from peatlands in the dolomites (S-Alps).	25
C. Ferrari & M. Speranza. Ecological inferences from phytosociological data in an alluvial forest on the Po Plain (Northern Italy).	41
P.L. Nimis. Contributions to quantitative phytogeography of Sicily. II. Correlation between phytogeographical categories and elevation.	49
M. Lagonegro. Spaghet: a coenocline simulator useful to calibrate software detectors.	63
E. Feoli & M. Lagonegro. Effects of sampling intensity and random noise on detection of species groups by intersection analysis.	101
P.L. Nimis. Phytosociology, Ecology and phytogeography of epiphytic lichen vegetation in the Calamone lake area (N-Apennines, Italy).	109
C. Blasi. Two examples of the use of numerical classification and ordination methods in the analysis of structure and chorology of vegetation types.	129
E. Feoli, L. Orloci & M. Scimone. Comparison of ordinations of some Apennine forest communities based on different characters and methods.	137