The Phytosociological Database "SOPHY"
Part I: Calibration of indicator plants
Part II: Socio-ecological classification of the relevés

(english version)

H. BRISSE, P. DE RUFFRAY, G. GRANDJOUAN, M. HOFF

(1) UAM III, Faculté de Saint Jérôme, IMEP Laboratoire de Botanique et Ecologie méditerranéenne Case 461, F 13397 Marseille Cedex 20, (2) IBMP, rue du Général Zimmer, F 67000 Strasbourg, (3) UM II, USTL, Laboratoire de Palynologie, Place Eugène Bataillon, F 34095 Montpellier Cedex, (4) ULP, Institut de Botanique, 28, rue Goethe F 67083 Strasbourg Cedex

ABSTRACT. – Two computerized tools are used to identify the environment according to the flora: a phytosociological data bank and a calibration of plants. 1) The data bank brings large ecological and floristical gradients, and makes them obvious. Our data bank «SOPHY» covers all France and includes 5.626 plants in 63.640 stands. 2) The calibration computes the fidelities of plants towards plants, and defines a multidimensional space of the fidelities, in which an axis shows the index of a factor and a point represents the sociological behaviour of a plant. Calibration uses floristical data but gives ecological comparisons. Three examples use the plants which are registered in the bank, and which are localized in a space of 5.626 fidelities: 1) From 10 to 30 discriminant plants are enough to characterize, for a half, the socio-ecological peculiarity of a behaviour or of a relevé; 2) the increased indicator capacity of a species when it is abundant; 3) Maps localize the possible flora, besides the observed flora, and show the probable environments for a species or a group of species.

KEY WORDS – Phytosociological data bank, socio-ecology, fidelity, possible flora, indication plants, discriminatory capability.

1. INTRODUCTION: THE PHYTOSOCIOLOGICAL DATABASE

Phytosociology provides the link between floristics and ecology. With purely floristic relevés as the basis, it then deduces the ecological differences between these. To quantify this link, it can use two computerised tools, on the one hand a database which provides substantial ecological and floristic gradients and, on the other, a statistical procedure which is able to quantify ecology on the basis of sociology, known as the "socio-ecological" method. We propose first to present these two computerised tools, and then to describe their application to the calibration of indicator plants.

1.1 *Standardisation of the data*

Phytosociology rests on two sorts of standardisation, that of botanical systems and that of phytosociological relevés. Both enable a comparison to be made in the soil data between areas that are a considerable distance from one another, on condition that an inventory is made of such data and that a suitable statistical treatment is then applied to them, which is capable in particular of comparing relevés from different surface areas since the standardisation of different surfaces has varied.

1.2 *Compiling an inventory of data on extended gradients*

Over 17 years, 63,640 phytosociological relevés have been compiled from a thousand publications and brought under the same botanical nomenclature, that of the Flora of P. Fournier (1961). They have been located on large-scale maps and recorded in the "SOPHY" database (de Ruffray *et al.* 1989). They consist of 3, 585 taxa of specific or infra-specific rank and are recorded with their abundance-dominance (figure 1) (For the figures and tables see the French version).

On the local scale, the sampling of relevés, which depends on available publications, has geographical deficiencies. The sampling aims to cover not an area but ecological and floristic gradients. It considers a relevé as representative not of a locality but of an ecological situation, in other words as the example of coexistence between a flora and an environment. These relevés, being situated in all the regions of France, they effectively cover extensive ecological gradients (figure 2).

1.3 *The exploitation of floristic and ecological gradients*

The ecologist seeks to identify the environment by asking questions of the flora. The ecologist who studies an area may find answers outside of this area. This "outside" has always meant the erudition of the botanist who reasons in the light of what he has seen during his travels. Today, we have an addition to this a quantitative erudition contributed by a database. However, databases are often used simply like libraries from which pieces of information are extracted independently of one another, whilst it is in fact possible to take advantage not only of the evolution of the data along the gradients but also of the coexistence of interdependent data in the relevés (figure 3).

2. Socio-ecological method of calibration of plants

The treatment proposed is the logical follow-on to the treatments used in classic phytosociology, and then in ecology. It generalises the notion of fidelity that Braun-Blanquet (1932) long ago showed to be fundamental.

2.1 *Fidelity of plants to groupings*

The plants which coexist in a locality enable one to identify the environment of the station. The relevé of these plants is like an identity card of their environment. The relevés are grouped in phytosociological units corresponding to types of environment. The multiplicity of plants, relevés and factors necessitates the use of statistical procedures. Most of these procedures calculate floristic similarities between relevés and consider that they directly express ecological similarities since the flora reflects its environment.

Now, it is not sufficient to count the common species in order to evaluate ecological similarity. It is also necessary to compare the ecology of the species and to calculate a slight difference between two species whose behaviour is closely-related and a strong difference between two species of widely-differing behaviour. This is what the founders of phytosociology did before computerisation became generalised. Thus, for Pavillard (1935), the essential thing was not to count plants, but to weigh them. Classic phytosociological reasoning implicitly balances a plant by its fidelity to the groupings in the phytosociological hierarchy of which it is a part. A species faithful to a grouping, that is to say which has allegiance to it, is a characteristic of the grouping. The species alone is sufficient to identify the grouping in order to map it.

2.2 *Fidelity of plants to ecological characteristics*

Ecology studies types of environment which correspond to vegetation groupings, and it distinguishes them no longer by species but by ecological characteristics. It then applies this same notion of fidelity to the characteristics of soil and climate (Brisse and Grandjouan 1977). Fidelity is here expressing the apparent dependence of the plant in relation to ecological characteristics, just as in phytosociology it expresses the apparent dependence of the plant in relation to vegetation grouping. In both cases, fidelity is calculated as a quotient of the frequency of the plant set in its grouping or its characeristic surroundings, divided by the total frequency of the species.

2.3 *Fidelity of plants to plants*

Only floristic data are available to phytosociology in any systematic way. It does not have at its disposal standardised data, for example on the level of limestone in the substrata. It cannot therefore calculate the fidelity of a plant to limestone. On the other hand, if it wants to obtain ecological information from floristic data, it is able to calculate the fidelity of a plant to a calcareous plant.

In general, this method considers every plant to be an indicator of an envrionment which is more or less strictly demarcated, and it calculates the fidelities of plants to plants. Without being able to identify the nature of the plant's environment, it nevertheless transforms a purely floristic characterisation into an implicit but quantitative ecological characterisation. It even considers a ubiquitous plant as being associated with an implicit environment, however vague this may be, although few plants are completely ubiquitous and thereby entirely devoid of value in terms of their information content, especially when they are observed over such extensive gradients. We shall see that this method of socio-ecological characterisation brings quantitative answers to the preoccupation of ecologists concerning the heterogeneity of species, as well as on the change in their significance according to the groupings where they are to be found.

This treatment considers the same plant, in turn, either as evidence of a factor of the environment, or as a behavioural sign which will feature in the whole of the relevés where the plant is present (Tables 1 and 2, figure 4). It defines a space for fidelities, having as many dimensions as there are indicator plants, that is to say 5,626 plants. In this space, an axis corresponds to an indicator plant and a dot stands for the behaviour of a plant. The dot has as its coordinates the fidelities of the plant's behaviour towards the indicator plants. Two plants of similar behaviour are represented by two dots next to one another; two ecologically differing plants are represented by dots far removed from one another. The characterisations of plants are thus balanced by ecology as the phytosociologists wished it (2.1). The table of fidelities constitutes the "brain" of the database for it allows an ecological interpretation of phytosociological data.

The behavioural fidelity of a plant A to an indicator plant B, noted as FID (A, B) is the probability of presence of A in the relevés including B. It has an inclusive value of between O and 100%. It expresses the apparent dependence of A towards B. In general, FID (A, B) FID (B, A).

2.4 *Socio-ecological characterisation of plants* (Tables 1 and 2)

a) **Comparison of plant behaviour:** The DEP difference between the behaviours of two plants is measured by the overall difference in their characterisations in the space for fidelities. The difference is thus quantifiable even for two plants which never meet in the same relevés. This measure of difference is at the basis of a socio-ecological classification of plants (Brisse *et al.* 1984). The DEP differences serve to regroup those plants showing similar behaviour and thus to establish a hierarchy of types of behaviour represented graphically by a dendrogram.

b) **Disciminatory capabilities of indicator plants (PDP):** They measure the relative importance of an indicator plant by the overall originality of its behaviour. This overall originality is measured by the distance between this behaviour and the total behavioural patterns listed in the database. Discrimatory capability can thus be calculated by the contribution of the indicator plant to the preceding distance, DEP. PDP serves to characterise the behaviour of a plant or of a group of plants. In respect of a given plant, disciminating plants constitute the original part of its succession of flora.

c) **Indicator capability of a plant (PIP):** It is measured by the concentration of the plant in the space for fidelities. The concentration is the quotient of two dispersions, on the one hand that of the relevés containing the plant, and on the other that of all the relevés. The nearer the relevés containing the plant are to each other within this space, the more their environments are similar and the more the plant appears to have allegiance to a homogeneous environment. PIP is applied to a group of plants just as to one single plant.

3. Applications of the socio-ecological calibration of plants

The space for fidelities founded on floristic data allows us to quanitfy their implicit ecological significance which we will illustrate by the following three applications.

3.1 *Indicator capability of abundant species*

A species bears witness to its environment more reliably when it is abundant. This empirical notion has been quantified for plants which are indicators of climate (Brisse and Grandjouan 1980). It is also quantifiable in phytosociology by calculating the indicator capability of PIP plants and making a comparison between PIPs of the same species at two levels of abundance. It is illustrated by a socio-ecological classification of plants drawn up in a small region of France, the Hautes-Vosges, which included in particular peat bogs and sessile-oak forests. The two parts of the dendrogram represented show the indicator capabilities of the PIP plants and of the PIG groups of plants (figure 5).

The first part of the dendrogram (lines 1 to 47) includes peat bog plants (1 to 15), then acid altitudinous environments (19 to 29). Note (line 27) the presence of *Deschampsia flexuosa* abundant (ab. $\geq$ 4) in this phytosociological element. The second part of this same dendrogram, lines 332 to 372, gathers together plants from groves of sessile oak and Scotch pine. On line 345 *Deschampsia flexuosa* figures whatever its abundance. These two plants of abundant levels thus figure in two distinct phytosociological elements corresponding to two different types of environment.

These results demonstrate the systematic superiority of the indicator capability of species when they are abundant, not only in attributing the two levels of a same species to two different phytosociological elements but also, within the same group, often separating the two levels of the same species (lines 363/332 for *Lonicera periclymenum*; lines 354/332 for *Quercus sessili-*

flora; lines 370/341 for *Poa nemoralis*, etc). Finally, the two levels of the same species, despite having little ecological difference, demonstrate this phenomenon once more (lines 4 for *Drosera rotundifolia*; lines 343 for *Veronica officinalis*; lines 349 for *Teucrium scorodonia*, etc.).

3.2 *Comparison of two species of similar distribution* (Figure 6)

Ruscus aculeatus and *Rubia peregrina* have mediterranean-atlantic distributions on a French scale (Dupont, 1990) and they also have in common a number of their discriminatory plants. However, their other disciminatory plants show differences in their ecological behaviour, which are on the whole cooler in one case, and more xerophilous in the other. Those which are specific to *Ruscus* have both atlantic and sub-atlantic affinities, silicicolous and sciadophilous (advantaged by shade) whilst, at the other extreme, those of *Rubia* have mediterranean and sub-mediterranean, calcicolous and heliophilous affinities.

3.3 *Observed flora and potential flora*

The average fidelity of a relevé with regard to a plant is none other than the probability of finding the plant in the relevé according to the indications given by the whole flora. The average fidelity to an indicator plant calculated for all the relevés in the database shows a coherent gradient. It expresses the probability of the presence of an environment favourable to the plant. It completes, in part, an intermittent geographical sampling, which includes only those stations where the species is actually observed (figure 7). This average fidelity shows the stations where a part of the environment, at least, would probably permit the presence of the species (figure 7 at the bottom and figure 8). The sole presence of a species, observed directly, is an environmental indicator comparable to a piece of equipment plagued by bad electrical contact; one moment it functions, the next it is silent. By contrast, the average fidelity of the relevé to the species is comparable to a piece of equipment "plugged in" to the environment by as many contact points as there are plants in the relevé; everywhere it gives a gradual indication of the environment.

4. Conclusion: phytosociology and socio-ecology

Socio-ecology is an aspect of phytosociology which measures information supplied by the flora about the environment. It respects the principles set out by the founding fathers of the discipline, such as: 1) analysing all the spontaneous flora; 2) considering the behaviour of a plant over quite a large area; 3) distinguishing a plant by its specialisation; 4) making a type of vegetation community correspond to a type of environment. Socio-ecology limits itself to translating these principles into statistical terms, in order to take advantage of the power and precision of computers.

It translates 'erudition' by 'database', 'specialisation' by 'fidelity', and 'correspondence between community and environment' by 'location of communities in a space for fidelities'. In short, it treats phytosociology like a simplified version of vegetation ecology in a natural environment, in which factors are only known through implicit but standardised signs: the indicator taxa. It obtains stable results and shows gradual geographical variations. Socio-ecology, applied to an already rich phytosociological database, promises precise information on the behaviour of thousands of taxa and on the distribution of the environments that they characterise in France.

The socio-ecological characterisation of plants which is the keystone of this treatment is only possible within a database of a phytosociological type, in which a relatively standardised observation procedure allows one to make sure that a list of plants corresponds to a strictly circumscribed environment. This excludes all other sources of botanical data, whether they come from maps, from lists of plant collections compiled in the field, or from dispersed herbarium data.

SUMMARY

Two computerised tools are used to characterise the environment according to the flora: a phytosociological database and a calibration of plants. 1) The database identifies substantial ecological and floristic gradients, and makes them manifest. Our database SOPHY covers the whole of France and includes 5,626 plants in 63,640 stands. 2) The calibration computes the fidelities of plants towards plants, and defines a multidimensional space for the fidelities, in which an axis shows the index of a factor and a dot represents the sociological behaviour of a plant. Calibration uses floristic data but gives ecological comparisons. Three examples use the plants which are registered in tbe database, and which are calibrated in a space of 5,626 fidelities to show: 1) that, in half of the cases, from 10 to 30 discriminatory plants are enough to characterise the socio-ecological peculiarity of a mode of behaviour or of a relevé; 2) the indicator capacity of a species increases when it is abundant; 3) that maps can locate the potential flora, besides the observed flora, and sbow the environments which are probably the most favourable for a species or a group of species.

The Phytosociological database SOPHY
Part II: Socio-ecological classification of the relevés

1. Introduction: Choice of a biological rather than a geographical or phytosociological approach.

In phytosociology, the observation unit is the station. However, the corresponding ecological variables are not necessarily noted and, in any case, they are not in theory used to determine groupings.

The only station variables observed in a systematic way are the plants themselves, considered as environmental indices and used as such to differentiate the stations and to distribute them between vegetation groupings. The plants are then themselves characterised by the vegetational groupings in which they are confined, that is to say by their fidelity to the groupings. It is accepted that a vegetational grouping corresponds to a type of environment.

For a long time now, phytosociology has had recourse to computers but, in doing so, it generally adopts a geographical approach, in the sense that it is essentially based on a classification of stations, a station group (or grouping) being analogous to an area which is more or less unconnected. Moreover, it does not take account, in traditional calculations, of ecological similarities between plants. When it uses correspondence analysis, for example, the distances between stations are calculated independently of the distances between plants, the latter being used as qualitative characteristics of the stations.

Very different is the approach and the perspective resulting from the introduction into phytosociology of an ecological type of calculation like the one advocated here. Indeed, one begins by calibrating the plants in relation to one another, just as in ecology the plants are calibrated in relation to the environment then used as indicators. The phytosociological calibrating of a plant therefore rests on its fidelities with regard to other plants, fidelity from one plant to another being calculated as the fidelity of that plant to an ecological type. A fidelity space is hence defined which includes as many dimensions as there are plants. The difference in fidelity between plants thus measures their distribution differences, which are themselves brought about by ecological differences. Still by means of a hierarchy produced by a dendrogram, these differences serve first of all to classify the plants into "phytosociological elements". They can then be taken into account in calculating the distances between relevés, that is to say between stations. Thus they serve in a way to balance each difference in flora against its ecological importance so that each station is placed at the centre of gravity of the plants it contains. In this way the calculation enables one to define groupings which are ecologically as homogeneous as possible whilst being base on floristic variables only.

2. Method of socio-ecological characterisation of the relevés (Tables 1 and 2 of the first part of this paper)

The plants which coexist in a relevé bear witness to their environment. The sum total of their behaviour characterises that environment. This sum total is symbolised, in the space for fidelities, by a dot situated at the centre of gravity of the species in the relevé (Grandjouan 1982). It has as its coordinate, on each of the axes, the FIM average fidelity of the relevé to the corresponding indicator plant (Table 3). A relevé is characterised by as many coordinates as there are indicator plants. Thus, a relevé from the database which contains 20 species possesses several thousands of coordinates which will enable the researcher to differentiate it from the other relevés. All the relevés in the database have the same number of coordinates.

Such a characterisation relies very little on the floristic richness of the relevé, and so it places little reliance on its surface area, as long as the behavioural proportions represented in the flora of the relevé remain similar. Thus, two relevés situated in the same environment, but carried out on different surface areas, have a richness and therefore a floristic characterisation which is systematically different, and yet they have similar socio-ecological characters. These no longer reflect differences due only to floristic richness.

A relevé or a group of relevés is situated in the same fidelity space as the plants and its characterisation takes a similar form to that of the plants. In this space, the DER distance of two relevés expresses their ecological difference. The distance between a relevé and the whole of the observations of the database expresses the overall originality of the relevé. Finally, the portion occupied by an indicator plant in this distance expresses the discrimination capability of that plant, with regard to the relevé.

The discriminatory capability of an indicator plant with regard to a grouping is modified by a sign, which is positive if the grouping is more faithful to the plant than are all the relevés, but negative in the opposite case. The sign of discrimination capability distinguishes those plants which are discriminant by their frequency in the grouping from those which are discriminant by their rarity and even their absence.

3. Application of the socio-ecological classification of relevés

3.1. *Form of the results*

3.1.1. Classification of the relevés in vegetational groupings

The hierarchy of similarities between the relevés is represented by a detailed dendrogram in which each relevé occupies a line indicating membership of the groupings to which it belongs. In its turn, the hierarchy of the groupings is represented by summarised dendrograms drawn from the preceding one with different levels of synthesis. The first level demonstrates the major phenomena constituted by groupings with the most numerous relevés and having the biggest differences between them. The subsequent levels show the secondary phenomena marked by the subdivisions of the first groupings. A grouping is represented on a line of the summarised dendrogram: it is conventionally identified by the aggregation number which constituted it and it is characterised by the size of the relevés, the plants and the observations of the grouping.

3.1.2. Characterisation of a grouping

A grouping is characterised by its discriminant plants, those which contribute the most to its originality measured by the distance between the grouping and the total of the relevés. These plants are ranked in order of their decreasing discrimination capability. Generally, fewer than thirty plants out of the total 5,626 plants used as references are sufficient to contribute to half of the distance. These reduced numbers illustrate the clarity of the plant distribution between groupings. The discriminant plants in socio-ecology are the equivalents of the characteristic species in classic phytosociology but they are defined quantitatively according to a gradual discrimination capability, and not by all or nothing. Their number results from an initial choice fixing at 50% the fraction of originality to be characterised. A discriminant plant is also characterised by its fidelity to and its consistency with the grouping. These two classic parameters do not have a role in the calculation but they help to depict the status of the plant within the grouping.

3.2. *Summary description of a few groupings*

3.2.1. Pedagogical sampling: classification of 45 relevés with no species in common

Despite its extreme nature, this pedagogical example illustrates the capacity of socio-ecology to rank relevés which have no species in common, whereas traditional floristic methods would be incapable of doing so. A methodical inventory was able to extract only 45 relevés having no species in common. They were characterised and classified as before, according to their average fidelities to the 5,626 plants in the database.

Certainly, amongst these curiously disparate relevés, almost half are divided between four groupings, including 8, 4, 3 and 6 relevés respectively (figure 10) whereas some are added one by one at the end of the hierarchy (figure 9). As a result of the special sampling, the discriminatory plants (figure 11) have a fidelity to the grouping which is either total or nil. A plant which is absent from a grouping may therefore be discriminant (*Hedera helix* and *Corylus avellana* even have the highest discrimination ability of the group G34).

To classify these ideas, we would propose a concise environmental description, from general knowledge of the flora and its ecology. The G7 grouping is found in coastal environments, saline or otherwise; the G10 grouping in very damp terrestrial environments; G19 includes *Calluna* and G34 deciduous forests outside the Mediterranean.

In the first place, the socio-ecological method allows us to calculate distances and thus to assess ecological similarities between relevés which have no species in common. Some relevés are close, others are more distant from one another. In the second place, it enables us to establish a hierarchy between relevés. This sampling is only a part of the classes of phytosociology: it nevertheless permits an identification of four important phytosociological units from aquatic environments to the leafy forests of temperate Europe. In the first unity, G7, there clearly appear discriminant species of salty aquatic terrains and environments and others of freshwater aquatic environments which of course do not belong to the same phytosociological classes.

This example demonstrates the ability of the socio-ecological method to compare disparate relevés belonging to separate phytosociological classes, as a prelude to the characterisation of super-classes.

3.2.2. Geographical sampling: assessment of the vegetation groupings in a region

The region about which information is to be obtained, in this case the Hautes-Vosges, in the east of France, is bordered by a broken line drawn between localities. An extraction programme identifies the 4,000 relevés in the database situated within the area. A socio-ecological treatment programme calibrates the plants present in these 417 relevés taking into account the total relevés in the database, not only with regard to the plants present in these relevés but to all the plants in the database.

The treatment proceeds by characterising the relevés, whilst taking account, thanks to the calibration, of the similarities between the plants. The treatment first classifies the relevés into four main groupings in the first level of synthesis, then it subdivides these groupings at the more detailed levels. Finally, it characterises each grouping by its discriminant plants.

A regional assessment answers a classic question of botanists in the field: What is the present state of knowledge in this region? The results present a kind of information screen in which the state of the vegetation of the region can be seen at a glance. Linked to a socio-ecological classification of the plants, the results can be completed by establishing phytosociological tables in which the relevés like the plants are arranged in order of their respective classification at the different levels of synthesis (Brisse and Grandjouan 1984). Moreover, the vegetation groupings as well as the phytosociological elements can be made into maps.

With regard to the analysis of the ranked groupings at different levels of synthesis, the method brings to light a succession of groupings organised around a central core. Thus the grouping G189 entitled oak-hornbeam groves includes four subdivisions of unequal importance: G105 with 106 relevés is the central core of the oak-hornbeam groves; C152 with 48 relevés corresponds to the limestone scrub; G175 with 23 relevés is close to the Alno-Padion, and finally G188 with 13 relevés corresponds to *Calluna* and acidophilous moorland. These apparently disparate groupings have more similarities between them than with all the other groupings with which they have been compared. The grouping 189 could thesefore be assimilated into a super-class bringing together these four subgroups belonging to four phytosociological classes. Finally, it is worthy of note that the socio-ecological method is capable of comparing groupings of very different sizes without the largest grouping (G105) overwhelming the smallest (G188).

At the third level, the first subdivided group G105 brings to light a mesophyllic grouping (to) *Quercus sessiflora* from which *Alnus glutinosa* and *Prunus padus* are absent and a meso-hygrophyllic grouping (to) *Quercus pedunculata* from which *Quercus sessiflora* is excluded. The second subdivided group, G152, separates the stages of scrub recolonisation of the sub-Vosgian chalk grasslands, and G136 the less advanced stages of recolonisation in which G151 *Bromus erectus* patches of grasss predominate. In this last example, it is of note that the species absent from the 16 relevés concerned (*Thymus serpyllum, Koeleria cristata, Asperula cynanchica, Hieracium pilosella* and *Geranium sanguineum*) are nevertheless discriminatory, which is a well-known phytosociological fact (Gaussen 1953). It is important that a general method should give prominence to all the known phytosociological facts without introducing artefacts.

As the groups become subdivided, the discriminatory capabilities tend to balance themselves out in the sub-groups. Thus, when one compares subgroups 136 and 151, DIS is worth 61 and 20 respectively for *Ligustrum vulgare*; further on, for *Euphorbia cypartissias,* DIS is worth. 11 and 46. This shows the transitional character of the groupings and underlines the difficulty for phytosociologists of finding exclusive characteristic species in them.

3.2.3. Phytosociological sampling: Reclassification of the relevés of Ononido-Rosmarinetea

The class of Ononido-Rosmarinetea is subdivided into two orders and four alliances (Guinochet and de Vilmorin 1973). The six corresponding syntaxa are identified by their characteristic species. Each of the syntaxa is in its turn characterised, like a relevé, by the behavioural average of its characteristic species. These characterisations can then be compared to those of the relevés and those relevés which show most similarity to one or other of these six syntaxa can be extracted from the database: 645 relevés were selected in this way. One can then carry out a socio-ecological classification of them in order to compare it with the subdivisions previously defined as two orders and four alliances.

At the first level of synthesis (figure 16) the 645 relevés are distributed clearly into two groupings which accord with the two phytosociological orders seen simply from the point of view of their discriminant species. However, the discriminatory plants are more numerous than their characteristic species and we would emphasise that they have a quantitative definition which is at the same time more objective and more subtle than a binary qualfification whilst at the same time integrating levels of abundance.

At the seond level of synthesis, the subdivisions show four groupings which seem to correspond to the four alliances, still from the point of view of their discriminatory species (figure 17).

A third level of synthesis is introduced with the tables of corresponding discriminating plants, without any comments, so as to leave people free to make their own interpretation (figures 18 and 19) in other words to find the constitutent associations for these groupings.

Thus, whilst the notion of grouping seems to be well defined by phytosociologists, the characteristic species, although allowing an identification of the groupings, are far from being the best choice of species by which to discriminate them, and hence to name them.

A general classification of the whole of the relevés listed in a data base such as the SOPHY database, would lead to a definition of a socio-ecological hierarchy incorporating very high levels of regroupings, which remain precise at the lower levels, linked to comparative tables of discriminant plants. The whole would provide a stable reference allowing a description to be made of French vegetation and its corresponding environments.

4. Conclusion: Quantitative catalogue of the vegetation groupings

The results presented have concerned relevés which are similar to one another as well as relevés belonging to a wide variety of classes. The socio-ecological method has thereby proved its efficiency in resolving two types of common difficulty situated at the two extremes of the synthesis; on the one hand by bringing precision to the detail, on the other by carrying out regroupings at the higher levels of classification.

As we have seen, the socio-ecological method takes up the principles established by the founding fathers of the discipline and it applies them to a database which is also founded upon the work and the publications of phytosociologists. The classification of relevés which number tens of thousands and which include in total several thousands of species, can no longer be based solely on visual groupings according to tables, maps, or even factorial graphics.

The programmes proposed constitute a continuous chain of operation whose options are explicitly fixed at the outset so as to clarify the significance of the results. These programmes compare the environment as it is expressed by the flora of a relevé with the environments of all the other relevés. They provide a catalogue of vegetational groupings ranked in decreasing importance from the largest to groupings which are as detailed as one could wish. They characterise a grouping from a specific portion of its discriminatory plants. A sort of phytosociological balance sheet is thus obtained.