REPEATABILITY OF THE FRENCH HIGHER VEGETATION TYPES ACCORDING TO SOCIO-ECOLOGICAL HIERARCHIES

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ABSTRACT - Higher vegetation types are generally determined by successive approximations and defined by a common consent. Instead, they might be statistically determined and repeated, according to a numerical method called 'socio-ecology'. This method deals only with floristical data, but gives them an ecological meaning by a previous calibration of the relations between plants, computed as ecological indices. It is applied to a pair of two homologous samples, each having 2.000 relevés and coming from the 60.000 relevés stored in the French data bank 'Sophy'. Each sample covers the main ecological gradients of the bank, it defines a hierarchy of vegetation types and it explains half the peculiarity of a type with only 10 to 30 discriminant plants, out of the 5.000 plants observed in the relevés. Results : 1) The discriminant plants may characterize the vegetation types, including the higher ones, in a coherent and readable form. 2) In the two independent classifications, having different structures, the same vegetation types are repeated. They are the reciprocal nearest types, in the socio-ecological space. Though the two classifications have no one relevé in common, the repeated types have nearly the same discriminant plants. 3) At the highest level, two clear-cut main types show the difference between light and shadow. The same herbaceous discriminant plants, for a type, and the ligneous or sciaphilous ones, for the other, have similar fidelities and constancies in the two classifications. 4) Such a numerical agreement, instead of common consent, appears again in the sub-types, which remind the classical ones, but which are repeatable.

KEY WORDS - Fidelity, Calibration, Discriminant plants.

INTRODUCTION

REPEATABILITY OF A VEGETATION TYPE

«The outstanding aims of numerical taxonomy are repeatability and objectivity» (Sokal & Sneath, 1963). We try to apply this principle to numerical taxonomy in vegetation science. In exact sciences, an experiment must be repeatable and give the same result again. Similarly, a vegetation type is reliable if it is repeatedly identical. A repeatable type may be irrelevant, but a relevant type must be repeatable. The repeatability is the possibility of determining the same vegetation types in two classifications based on two different samples of relevés covering the same gradients.

Actually, the higher vegetation types do not depend on numerical taxonomy, because the detailed data banks do not cover large enough gradients. These types are defined by successive approximations, and fixed by a common consent. So, we try a demonstration of repeatability on the scale of France, because we have a data bank «Sophy» which covers the main ecological and floristical gradients, with about 60.000 relevés.

The repetition of a vegetation type involves three steps : 1) To sample two batches of relevés covering the same gradients. 2) To classify the relevés in each batch, in order to have two independent classifications of vegetation types. 3) To define how two types are identical though they have no one relevé in common.

SAMPLING AND CLASSIFICATION OF RELEVES

1. Background of the sampling and the classification : transposition of ecology into sociology

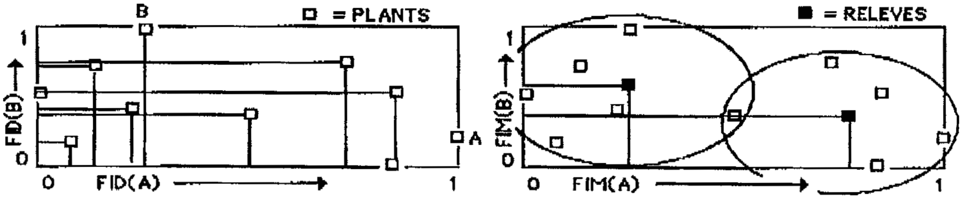
1.1. Socio-ecological characterization of plants.

This work depends on a data bank of 60.000 floristical relevés, collected in publications and located in France (Ruffray *et al.*, 1989). The standardized relevés, covering the main ecological gradients in France, enable us to quantify the ecological differences from the floristical differences, without using data about soil or climate (Brisse *et al.*, 1995). Here, let us just mention the meaning of the results. The method defines a statistical space where plants, as well as relevés, are located according to their ecology (Appendix 1). The method transposes a classical parameter, the fidelity of a plant to a type of community, which measures the seeming dependency of the plant on the corresponding environment. The socio-ecological space uses the fidelities of plants to plants. In that space : 1) An axis measures the fidelity to a plant. 2) A dot represents the behaviour of a plant. 3) The distance between two plants measures the difference between their behaviours. So, two plants having similar behaviours are represented by two close dots (fig. 1).

1.2. Socio-ecological characterization of the relevés by their probable flora.

In the space of the fidelities, a dot may also represent a relevé, located at the centre of gravity of its plants. The coordinates of the relevé are the average fidelities of its plants. The average fidelity of a relevé to a plant is nothing else than the probability for the plant to be in the relevé. The average fidelities express the probable flora of the relevé, according to the observed flora and the relations between that flora and all the other relevés. The distance between two relevés represents the difference between their ecological capabilities. In such a space, two relevés having different floras but similar environments are represented by two close dots. This quantification turns an intermittent floristical information into a gradual ecological information.

Fig. 1 - Localization of plants and relevés in the space of fidelities. The rectangular frame represents the socio-ecological space, reduced to 2 dimensions (instead of 5.000). Left : White squares representing plants, according to their fidelities FID to two plants A and B. Right : Two black squares representing



the relevés, according to their average fidelities FIM to A and B.

2. A DOUBLE SAMPLING OF RELEVÉS COVERING THE SAME GRADIENTS

2.1. Theoretical sampling : stratification of the relevés amongst neighbourhoods.

The sampling aims at selecting relevés in all the types of environment. The first idea has been to start with the holotypes relevés of the French plant associations, and to locate them in the socio-ecological space. But we do not yet have a file of the holotypes. So, we start with the distribution of the relevés in ecologically homogenous neighbourhoods. This stratification divides the space into the neighbourhoods, like a multidimensional grid. Inside each neighbourhood, it selects two relevés which are the reciprocal nearest neighbours, one to the other, and puts them in two batches. The two batches include relevés as equivalent as possible. Each of the two batches covers the whole gradient of the bank (fig. 2).

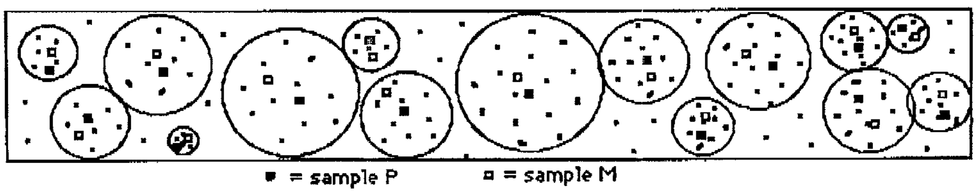


Fig. 2 - Scheme of the distribution of the relevés amongst neighbourhoods. The rectangular frame represents the socio-ecological space, with only 2 dimensions (instead of 5.000). A dot shows the location of a relevé. A circle symbolizes a neighbourhood. Inside a neighbourhood, two squares show the two close relevés which are sampled and distributed in two batches P and M.

2.2. Practical sampling: stratification of the relevés amongst the phytosociological tables then amongst the neighbourhoods.

At present time, the theoretical sampling would be time-consuming, because it computes and sorts 60.000 times 60.000 distances with 5.000 dimensions. A practical sampling uses a shorter computation, comprising two steps. 1) First, it uses the initial stratification of the data bank, according to the 6.000 phytosociological tables. The relevés coming from the same table come from the same type of plant community. They often come from similar environments. The first step selects two relevés in each table.

2) The second step computes the 12.000 resulting relevés in a simplified space, and distributes them amongst neibourhoods having about 10 relevés. At last, the effective of the selected relevés is proportional to the effective of the neighbourhood.

3. Hierarchy of the relevés and dendrograms of the vegetation types

The hierarchy is built from bottom to top, by aggregative clustering. It compares the plant communities step by step and goes from the small types to the large types. Once the hierarchy is built, then the classification divides it and shows the vegetation types from top to bottom. It begins with the main types, having the biggest effectives and the largest distances. Then, it shows the subtypes, through more and more detailed levels of synthesis. The two classications have different hierarchical structures, because the batches P and M allow some differences between the sampled relevés.

DETERMINATION AND CHARACTERIZATION OF THE REPEATED VEGETATION TYPES

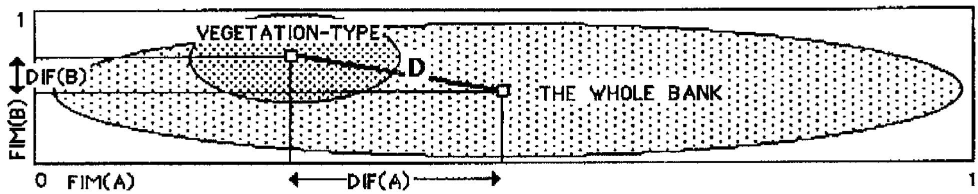
1. Numerical determination of the repeated types in the two classifications

The two sets of types are located in the same space. A type P repeats a type M if each of the two types is the nearest neighbour of the other. The square distance D between two types has a range from 0.01 to 10, proportionally from 1 to 1.000. Between two repeated types, D is about a few pour cent. Between two close types, but not reciprocal neighbours, D is about 10 times higher. Between the main different types, D is about 100 times higher. On the four main levels of synthesis, there are 94 types P, 64 types M, and 22 vegetation-types which are repeated in the two classifications P and M. At each level of synthesis, some types P repeat some types M, and correspond to the same environment. Some others types P are between a type M and its subdivision, not so large than the type, but larger than the subdivision. We are going to characterize the repeated types in a more expressive way than a simple distance.

2. Characterization of a vegetation type with its discriminant plants

The image of a vegetation type is the set of dots which represent the relevés belonging to the type. It is like a cloud in the space of fidelities. The centre of gravity of the cloud represents the average position of the type. The distance between the type and the centre of gravity of the whole bank determines the ecological peculiarity of the type. The plants which bring the greater contribution to the distance, characterize the peculiarity of the type (Appendix 1).

Fig. 3 - Scheme of the discriminant power DIS. The rectangular frame symbolizes the space of the fidelities, with only 2 dimensions, instead of 5.000. The white squares show the centres of gravity of the



whole bank, and the vegetation type. D is the distance between them.
$DIS(A) = DIF(A)^2 / D^2$ DIS is given the sign 'plus' if FIM is higher in the type than in the bank. DIS is given the sign 'minus' if FIM is lower.

Let us consider the most discriminant plants of a type, which contribute to half the distance between the type and the whole bank. Among the 5.000 plants of the bank, which are in the relevés and which define the socio-ecological space, a few dozen only attain to half the distance. So, a few dozen discriminant plants are enough to characterize the ecological peculiarity of a type, in that given proportion of 50 %. The discriminant plants are the quantitative homologues of the classical characteristic species in plant sociology. Two types having the same discriminant plants have the same ecology. This is the way we are going to show the repeatability of the higher types coming from two samples of relevés.

3. The discriminant plants at the first level of synthesis

On the scale of France, which kind of gradient explains the difference between the two main vegetation types ? In this classification, the main difference appears to be between light and shadow. The classification shows two main vegetation types whose discriminant plants are herbaceous and heliophilous, for one type, ligneous or sciaphilous for the other (fig. 4). The two types show a surprising clear-cut split, at such a high level of grouping, considering that most discriminant plants have fidelities above 90 %. There is also a third vegetation type, on the same level, with a smaller effective, discriminated by mediterranean plants (fig. 5).

PLANTES LES PLUS DISCRIMINANTES DU GROUPE 1070

DIS	FID	CST		A-D
11	92	25	LOTUS CORNICULATUS L.	1-6
8	96	23	THYMUS SERPYLLUM L.	1-6
8	96	22	PLANTAGO LANCEOLATA L.	1-5
5	97	13	BRIZA MEDIA L.	1-5
4	89	18	ACHILLEA MILLEFOLIUM L.	1-5
4	89	16	SANGUISORBA MINOR SCOP.	1-6
4	94	13	TRIFOLIUM PRATENSE L.	1-6
4	84	18	BROMUS ERECTUS HUDS.	1-6
4	**87**	**16**	**FESTUCA OVINA L.**	**1-6**
4	83	18	HIERACIUM PILOSELLA L.	1-6

PLANTES LES PLUS DISCRIMINANTES DU GROUPE 858

DIS	FID	CST		A-D
15	83	26	LOTUS CORNICULATUS L.	1-6
12	89	26	THYMUS SERPYLLUM L.	1-6
10	87	24	PLANTAGO LANCEOLATA L.	1-5
8	95	18	BRIZA MEDIA L.	1-5
7	77	23	BROMUS ERECTUS HUDS.	1-6
7	83	21	SANGUISORBA MINOR SCOP.	1-6
6	83	14	TRIFOLIUM PRATENSE L.	1-6
5	78	22	HIERACIUM PILOSELLA L.	1-6
5	78	19	ACHILLEA MILLEFOLIUM L.	1-5
5	**87**	**16**	**HIPPOCREPIS COMOSA L.**	**1-5**

PLANTES LES PLUS DISCRIMINANTES DU GROUPE 1688

DIS	FID	CST		A-D
42	89	48	CORYLUS AVELLANA L.	1-6
39	86	56	HEDERA HELIX L.	1-6

PLANTES LES PLUS DISCRIMINANTES DU GROUPE 1770

DIS	FID	CST		A-D
39	92	41	CORYLUS AVELLANA L.	1-6
37	95	36	FAGUS SILVATICA L.	1-6

34	92	40	FAGUS SILVATICA L.	1-6
27	97	35	CARPINUS BETULUS L.	1-6
26	82	37	QUERCUS PEDUNCULATA EHR	1-6
24	95	35	FRAXINUS EXCELSIOR L.	1-6
17	76	42	CRATAEGUS MONOGYNA JACQ	1-6
16	84	32	VIOLA SILVESTRIS (LAM.)	1-5
16	**87**	**37**	**CORNUS SANGUINEA L.**	**1-6**
15	91	23	ANEMONE NEMOROSA L.	1-6
13	**100**	**19**	**LAMIUM GALEOBDOLON (L.)**	**1-6**

36	90	48	HEDERA HELIX L.	1-6
27	90	39	QUERCUS PEDUNCULATA EHR	1-6
26	100	28	CARPINUS BETULUS L.	1-6
20	97	31	FRAXINUS EXCELSIOR L.	1-6
15	89	23	VIOLA SILVESTRIS (LAM.)	1-5
15	**98**	**31**	**LONICERA PERICLYMENUM L**	**1-6**
15	96	21	ANEMONE NEMOROSA L.	1-6
14	76	32	CRATAEGUS MONOGYNA JACQ	1-6

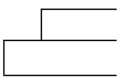
PLANTES LES PLUS DISCRIMINANTES DU GROUPE 1840

DIS	FID	CST		A-D
47	45	51	RUBIA PEREGRINA L.	1-6
37	77	50	BRACHYPODIUM RAMOSUM (L	1-6
35	55	44	THYMUS VULGARIS L.	1-5
34	51	44	QUERCUS ILEX L.	1-6
28	89	46	ASPARAGUS ACUTIFOLIUS L	1-6
24	90	42	SMILAX ASPERA L.	1-6
22	98	34	PISTACIA LENTISCUS L.	1-6
21	90	35	PINUS HALEPENSIS MILL.	1-6
17	**90**	**37**	**PHILLYREA ANGUSTIFOLIA**	**1-6**

PLANTES LES PLUS DISCRIMINANTES DU GROUPE 1042

DIS	FID	CST		A-D
44	51	52	RUBIA PEREGRINA L.	1-6
36	63	44	THYMUS VULGARIS L.	1-5
35	80	52	BRACHYPODIUM RAMOSUM (L	1-6
33	62	50	QUERCUS ILEX L.	1-6
24	89	36	ASPARAGUS ACUTIFOLIUS L	1-6
20	87	30	SMILAX ASPERA L.	1-6
19	93	29	PINUS HALEPENSIS MILL.	1-6
19	98	29	PISTACIA LENTISCUS L.	1-6

Fig. 4 - Discriminant plants of the three French main vegetation types showing their repeatability. From top to bottom : 1) The herbaceous type P-1070 and M-858. 2) The ligneous or sciaphilous type P-1688 and M-1770. 3) The mediterranean type P-1840 and M-1042. Left, the type P. Right, the type M. On one line : the discriminant power, DIS, per 1.000, the fidelity FID and the constancy CST, per cent, the name of the taxon and its range of abundance A-D. The plants are ordered according to their decreasing discriminant powers. The list of plants is abridged to 25 % (instead of 50 %) of the peculiarity of the type. When the main discriminant powers are negative, the list is limited to the 10 plants which have the highest positive discriminant powers.



Classif. P		Classif. M	Dist.		
Num.	Eff.	Num.	Eff.	socio.	
1070	1071	858	859	0.02	Herbaceous and heliophilous type
1688	619	1770	712	0.03	Ligneous and sciaphilous type
1840	152	1042	185	0.03	Mediterranean forests and garrigues

Fig. 5 - Scheme of the 3 French main vegetation types. Num. = Number of the type in the classification. Eff = Effective of relevés. Dist. Socio. = Square distance, in the socio-ecological space, between the two repeated types of the classifications P and M.

4. The 3 repeated types at the first level of synthesis

Two repeated types are built with different relevés and they have strikingly similar lists of discriminant plants. Such a similarity is more obvious, for a botanist, but less accurate than a distance in a virtual space. The beginning of the list, which brings the highest contributions and shows the main characterization, is identical, for two repeated types. The plants are listed in similar orders, and with similar fidelities and constancies. But the end of the list depends on the conventional limit of 50 % of the distance. The same discriminant plant may be a little above the limit in a type, and a little below in the other. The similarity between the lists of discriminant plants, which characterize two repeated types, is remarkable because it gives to relevés, having variable floristical effectives, a non-variable floristical characterization, which reflects an environmental characterization.

EXAMPLES OF REPEATED VEGETATION TYPES

1. Repetition of the 7 main French types on level 2

1.1. Outlook of the 7 main types (fig. 6)

On this level of synthesis, the vegetation types are still above the size of phytosociological classes. However, the discriminant plants divide clearly the types, considering that the plants have huge differences of fidelity between the types. The summarized table of discriminant plants is enough to give to a botanist an outlook of the types and their corresponding environments. The fidelities often differ from 80 to zero, except between the related types, as between the Northern meadows P-624 and the weeds P-1055, and between the Northern forests P-1554 and the submediterranean forests P-1867, for half the list, and of course between the two mediterranean types P-1750 and 1805, here again for half the list.

NOM DES PLANTES		GPMENT **624**			GPMENT **980**			GPMENT **1055**		
		DIS	FID	CST	DIS	FID	CST	DIS	FID	CST
PLANTES DISCRIMINANTES DU GROUPEMENT NUMERO 624										
FESTUCA RUBRA L.	1-6	**8**	75	19	0	15	6	0	0	0
ANTHOXANTHUM ODORATUM L	1-6	**8**	61	20	0	11	7	-1	0	0
HOLCUS LANATUS L.	1-6	**6**	69	17	0	5	2	0	0	1
PLANTAGO LANCEOLATA L.	1-5	**6**	56	22	3	34	24	2	4	22
TRIFOLIUM REPENS L.	1-6	**4**	74	13	0	15	4	1	6	13
AGROSTIS VULGARIS WITH.	1-6	**4**	62	20	0	8	5	0	0	0
TRIFOLIUM PRATENSE L.	1-6	**4**	56	13	1	33	14	0	2	7
LUZULA CAMPESTRIS L.	1-5	**3**	66	12	0	12	3	0	0	0
HYPOCHOERIS RADICATA L.	1-5	**3**	75	13	0	14	4	0	0	1
RUMEX ACETOSA L.	1-5	**3**	75	9	0	9	2	0	2	3
PLANTES DISCRIMINANTES DU GROUPEMENT NUMERO 980										
BROMUS ERECTUS HUDS.	1-6	-5	11	4	**39**	72	48	-2	0	0
THYMUS SERPYLLUM L.	1-6	0	21	8	**35**	73	53	-2	0	0
BRACHYPODIUM PINNATUM (	1-6	-11	16	9	**31**	49	49	-5	0	0
TEUCRIUM CHAMAEDRYS L.	1-5	-16	0	0	**31**	64	43	-4	0	0
HIPPOCREPIS COMOSA L.	1-5	-3	7	2	**26**	80	40	-1	0	0
SANGUISORBA MINOR SCOP.	1-6	-1	15	4	**25**	70	38	0	3	11
ASPERULA CYNANCHICA (BA	1-4	-3	9	2	**24**	82	33	-1	0	0
LOTUS CORNICULATUS L.	1-6	0	42	19	**24**	49	40	-1	0	0

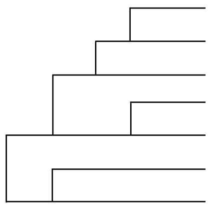
HIERACIUM PILOSELLA L.	1-6	0	29	11	**20**	53	36	-1	0	0
PLANTES DISCRIMINANTES DU GROUPEMENT NUMERO 1055										
POLYGONUM AVICULARE L.	1-5	0	25	1	0	2	0	**49**	72	64
CONVOLVULUS ARVENSIS L.	1-6	0	35	5	0	14	3	**32**	47	81
PAPAVER RHOEAS L.	1-4	0	10	0	0	6	0	**31**	83	47
CIRSIUM ARVENSE (L.) SC	1-5	0	43	6	0	3	0	**30**	33	58
POLYGONUM CONVOLVULUS L	1-4	0	0	0	0	6	0	**30**	93	50
ANAGALLIS ARVENSIS L.	1-4	0	19	1	0	7	0	**28**	65	50
CHENOPODIUM ALBUM L.	1-5	0	23	1	0	0	0	**24**	73	41
STELLARIA MEDIA (L.) VI	1-6	0	17	0	0	2	0	**22**	62	41
SONCHUS ASPER (L.) HILL	1-5	0	31	1	0	8	0	**19**	54	35

NOM DES PLANTES		GPMENT **1554**			GPMENT **1687**		
		DIS	FID	CST	DIS	FID	CST
PLANTES DISCRIMINANTES DU GROUPEMENT NUMERO 1554							
CORYLUS AVELLANA L.	1-6	**38**	72	51	26	16	41
FAGUS SILVATICA L.	1-6	**32**	79	44	17	12	26
CARPINUS BETULUS L.	1-6	**29**	93	43	4	3	6
QUERCUS PEDUNCULATA EHR	1-6	**29**	80	46	1	2	5
FRAXINUS EXCELSIOR L.	1-6	**26**	89	42	4	6	11
LAMIUM GALEOBDOLON (L.)	1-6	**17**	98	31	0	0	0
ANEMONE NEMOROSA L.	1-6	**17**	88	29	1	3	4
ACER PSEUDOPLATANUS L.	1-6	**16**	92	27	0	3	3
VIOLA SILVESTRIS (LAM.)	1-5	**14**	70	34	13	13	23
CAREX SILVATICA HUDS.	1-5	**14**	97	27	0	0	0
LONICERA PERICLYMENUM L	1-6	**12**	82	32	2	9	14
BRACHYPODIUM SILVATICUM	1-6	**12**	73	32	11	19	30
PLANTES DISCRIMINANTES DU GROUPEMENT NUMERO 1687							
HEDERA HELIX L.	1-6	31	69	57	**50**	17	52
CRATAEGUS MONOGYNA JACQ	1-6	11	55	39	**44**	21	55
QUERCUS LANUGINOSA LAM.	1-6	0	12	5	**35**	42	64
VIBURNUM LANTANA L.	1-5	1	43	15	**24**	35	45
SORBUS ARIA (L.) CRANTZ	1-6	0	31	10	**24**	38	44
CORNUS SANGUINEA L.	1-6	13	67	36	**23**	20	39
LIGUSTRUM VULGARE L.	1-6	5	63	26	**20**	22	34
HIERACIUM MURORUM L.	1-6	0	22	8	**18**	24	32
RUBIA PEREGRINA L.	1-6	0	9	3	**16**	32	41

NOM DES PLANTES		GPMENT **1750**			GPMENT **1805**		
		DIS	FID	CST	DIS	FID	CST
PLANTES DISCRIMINANTES DU GROUPEMENT NUMERO 1750							
RUBIA PEREGRINA L.	1-6	**50**	16	45	31	18	57
BRACHYPODIUM RAMOSUM (L	1-6	**40**	28	45	28	33	58
QUERCUS ILEX L.	1-6	**40**	20	43	21	18	42
ASPARAGUS ACUTIFOLIUS L	1-6	**38**	48	61	12	22	32
SMILAX ASPERA L.	1-6	**32**	44	51	10	19	25
PHILLYREA ANGUSTIFOLIA	1-6	**29**	48	58	10	20	26
PISTACIA LENTISCUS L.	1-6	**28**	41	35	9	18	17
PLANTES DISCRIMINANTES DU GROUPEMENT NUMERO 1805							
THYMUS VULGARIS L.	1-5	19	5	11	**49**	35	76
APHYLLANTHES MONSPELIEN	1-6	2	1	1	**26**	49	55
TEUCRIUM CHAMAEDRYS L.	1-5	5	4	16	**24**	6	30
FUMANA CORIDIFOLIA (VIL	1-4	2	0	0	**19**	55	46

CAREX HALLERIANA ASSO	1-4	6	9	14	**18**	23	41
PINUS HALEPENSIS MILL.	1-6	18	26	25	**18**	41	44
JUNIPERUS OXYCEDRUS L.	1-5	11	26	20	**17**	42	37
ROSMARINUS OFFICINALIS	1-6	13	23	20	**17**	48	48
DORYCNIUM SUFFRUTICOSUM	1-6	7	18	12	**17**	41	32
AVENA BROMOIDES GOUAN	1-4	5	5	4	**16**	36	39
SUBSP. PHOENICOIDES	1-6	6	11	12	**13**	25	30
ONONIS MINUTISSIMA L.	1-4	5	2	1	**12**	40	28
BRACHYPODIUM PINNATUM	1-6	1	3	19	**12**	5	33

Fig. 6 - Discriminant plants of the 7 French main vegetation types
The lists are limited to 25% of the peculiarity of the type. This table shows the main plants which discriminate the main types.
DIS = Discriminant power, per 1.000. FID = Fidelity, in %, of the plant to the type.
CST = Constancy, in %, of the plant in the type.



Classif. P Num.	Eff.	Classif. M Num.	Eff.	Dist.	socio.
624	625	548	549	0.02	Northern meadows
980	357	829	282	0.03	Southern meadows
1055	53	1833	57	0.02	Weeds
1554	485	1424	366	0.07	Northern forests
1687	134	1766	91	0.09	Submediterranean forests
1750	62	975	118	0.06	Mediterranean forests
1805	56	1041	67	0.07	Mediterranean garrigues

Fig. 7 - Hierarchy of the 7 French main vegetation types. Same legend than fig. 5.

1.2. Repetition of the types in the two classifications

Each of the main types, in the classification P, is repeated in the classification M. For the Southern meadows (types P-980 and M-829) as for the weeds (types P-1055 and M-1833), the discriminant plants are nearly the same, except the last plants in the lists, with low discriminant powers. The last plants contribute very little to the peculiarity of the type. For the Northern meadows, the 8 first discriminant plants are identical, but there are some noticeable discrepancies among the 16 following plants of the list, in particular *Calluna vulgaris* and *Molinia caerulea*, which are among the discriminant plants for P-624 but not for M-548. In fact, M-548 is the best repeated type for P-624, but it has a smaller effective (549 instead of 624 relevés). The two plants which are missing, on this level of synthesis, will appear, in parallel, on the next level, among the discriminant plants, for both subtypes P-503 (from P-624) and M-423 (from M-548). Repeatability is often very high, according to the distances between the two repeated types. When it is not completely shown by the discriminant plants on one level of synthesis, it appears to become complete again on the next level.

The comparison between the different types of the same hierarchy explains the nature of the types, as in Fig. 6. The comparison between the repeated types, in the two classifications, explains the repetition, as in Fig. 8.

PLANTES LES PLUS DISCRIMINANTES DU GROUPE 624 PLANTES LES PLUS DISCRIMINANTES DU GROUPE 548
DIS FID CST A-D DIS FID CST

A-D									
8	75	19	FESTUCA RUBRA L.	1-6	10	70	19	FESTUCA RUBRA L.	1-6
8	61	20	ANTHOXANTHUM ODORATUM L	1-6	9	66	28	PLANTAGO LANCEOLATA L.	1-5
6	69	17	HOLCUS LANATUS L.	1-6	9	70	19	HOLCUS LANATUS L.	1-6
6	71	17	POTENTILLA TORMENTILLA	1-6	8	67	18	TRIFOLIUM PRATENSE L.	1-6
6	56	22	PLANTAGO LANCEOLATA L.	1-5	8	57	25	ANTHOXANTHUM ODORATUM L	1-6
4	74	13	TRIFOLIUM REPENS L.	1-6	7	76	16	TRIFOLIUM REPENS L.	1-6
4	62	20	AGROSTIS VULGARIS WITH.	1-6	5	73	12	RUMEX ACETOSA L.	1-5
4	56	13	TRIFOLIUM PRATENSE L.	1-6	**4**	**82**	**11**	**RANUNCULUS ACER L.**	**1-5**
4	**62**	**26**	**CALLUNA VULGARIS (L.) H**	**1-6**	4	60	19	POTENTILLA TORMENTILLA	1-6
3	**66**	**12**	**LUZULA CAMPESTRIS L.**	**1-5**	4	77	14	PLANTAGO LANCEOLATA L.	2-5

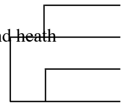
PLANTES LES PLUS DISCRIMINANTES DU GROUPE 980					PLANTES LES PLUS DISCRIMINANTES DU GROUPE 829				
DIS	FID	CST		A-D	DIS	FID	CST		A-D
39	72	48	BROMUS ERECTUS HUDS.	1-6	40	63	58	BROMUS ERECTUS HUDS.	1-6
35	73	53	THYMUS SERPYLLUM L.	1-6	37	63	57	THYMUS SERPYLLUM L.	1-6
31	49	49	BRACHYPODIUM PINNATUM (	1-6	32	62	56	TEUCRIUM CHAMAEDRYS L.	1-5
31	64	43	TEUCRIUM CHAMAEDRYS L.	1-5	32	43	54	BRACHYPODIUM PINNATUM (	1-6
26	80	40	HIPPOCREPIS COMOSA L.	1-5	28	77	45	HIPPOCREPIS COMOSA L.	1-5
25	70	38	SANGUISORBA MINOR SCOP.	1-6	27	77	48	ASPERULA CYNANCHICA (BA	1-4
24	82	33	ASPERULA CYNANCHICA (BA	1-4	26	60	48	SANGUISORBA MINOR SCOP.	1-6
24	49	40	LOTUS CORNICULATUS L.	1-6	22	52	45	HIERACIUM PILOSELLA L.	1-6
20	53	36	HIERACIUM PILOSELLA L.	1-6	22	38	37	LOTUS CORNICULATUS L.	1-6

PLANTES LES PLUS DISCRIMINANTES DU GROUPE 1055					PLANTES LES PLUS DISCRIMINANTES DU GROUPE 1833				
DIS	FID	CST		A-D	DIS	FID			CST
A-D									
49	72	64	POLYGONUM AVICULARE L.	1-5	49	79	66	POLYGONUM AVICULARE L.	1-5
32	47	81	CONVOLVULUS ARVENSIS L.	1-6	31	50	63	CIRSIUM ARVENSE (L.) SC	1-5
31	83	47	PAPAVER RHOEAS L.	1-4	31	100	57	POLYGONUM CONVOLVULUS L	1-4
30	33	58	CIRSIUM ARVENSE (L.) SC	1-5	30	62	47	ANAGALLIS ARVENSIS L.	1-4
30	93	50	POLYGONUM CONVOLVULUS L	1-4	28	87	50	PAPAVER RHOEAS L.	1-4
28	65	50	ANAGALLIS ARVENSIS L.	1-4	26	57	75	CONVOLVULUS ARVENSIS L.	1-6
24	73	41	CHENOPODIUM ALBUM L.	1-5	23	60	43	STELLARIA MEDIA (L.) VI	1-6
22	62	41	STELLARIA MEDIA (L.) VI	1-6	23	93	47	CHENOPODIUM ALBUM L.	1-5
19	54	35	SONCHUS ASPER (L.) HILL	1-5	20	56	45	SONCHUS ASPER (L.) HILL	1-5

Fig. 8 - Repeatability of the main vegetation types : Example of the meadows
Same legend than Fig. 4.
P-624 with M-548: Northern meadows and heath
P-980 with M-829: Southern meadows with Bromus erectus
P-1055 with M-1833: Weeds and ruderal vegetation

2. Repetition of the 4 types of meadows on level 3

Repeatability occurs on all levels of synthesis. For instance, the 4 types of meadows, on level 3, are repeated in the two classifications (fig. 9). The two types of Southern meadows still have together, among their discriminant plants, *Bromus erectus*, *Teucrium chamaedrys*, *Thymus serpyllum*, etc, though with various importances. The submediterranean type P-784 has on its own *Eryngium campestre*, *Coronilla minima*, *Carex halleriana*, etc. The extra-mediterranean type P-922 is characterized by the importance of mesophilous common species, as *Lotus corniculatus*, *Briza media*, *Linum catharticum*, *Carex glauca*, etc. The repetition of the types is illustrated by nearly identical lists of discriminant plants, except the last plants of the list (fig. 10).



	Classif. P		Classif. M		Dist.	
	Num.	Eff.	Num.	Eff.	socio.	
	503	504	423	424	0.03	Mountain and hygrophilous meadows and heath
	623	121	544	122	0.03	Meso-hygrophilous meadows in plains
	784	161	699	152	0.04	Xerophilous and Submediterranean meadows
	922	139	813	115	0.04	Extra-Mediterranean mesophilous meadows

Fig. 9 - Scheme of 4 types of meadows and heath, on level 3

PLANTES LES PLUS DISCRIMINANTES DU GROUPE 784

DIS		FID		CST
CST	A-D			
33	31	47	TEUCRIUM CHAMAEDRYS L.	1-5
32	31	46	BROMUS ERECTUS HUDS.	1-6
30	33	53	THYMUS SERPYLLUM L.	1-6
26	52	52	POTENTILLA VERNA L.	1-5
22	36	32	ASPERULA CYNANCHICA (BA	1-4
20	33	37	HIPPOCREPIS COMOSA L.	1-5
20	**42**	**39**	**FESTUCA DURIUSCULA L.**	**1-6**
19	51	32	TEUCRIUM MONTANUM L.	1-5
18	23	34	HIERACIUM PILOSELLA L.	1-6
16	**41**	**37**	**ERYNGIUM CAMPESTRE L.**	**1-6**
15	**56**	**29**	**CORONILLA MINIMA L.**	**1-5**

PLANTES LES PLUS DISCRIMINANTES DU GROUPE 699

A-D	DIS			FID
43	39	66	TEUCRIUM CHAMAEDRYS L.	1-5
38	33	57	BROMUS ERECTUS HUDS.	1-6
31	30	51	THYMUS SERPYLLUM L.	1-6
26	33	38	ASPERULA CYNANCHICA (BA	1-4
26	47	44	POTENTILLA VERNA L.	1-5
24	37	40	HIPPOCREPIS COMOSA L.	1-5
22	**18**	**43**	**BRACHYPODIUM PINNATUM (**	**1-6**
22	57	40	TEUCRIUM MONTANUM L.	1-5
20	23	37	HIERACIUM PILOSELLA L.	1-6

PLANTES LES PLUS DISCRIMINANTES DU GROUPE 922

DIS		FID		CST
CST	A-D			
40	28	60	LOTUS CORNICULATUS L.	1-6
38	26	67	BRACHYPODIUM PINNATUM (	1-6
37	37	64	BROMUS ERECTUS HUDS.	1-6
34	39	56	SANGUISORBA MINOR SCOP.	1-6
31	32	60	THYMUS SERPYLLUM L.	1-6
26	45	48	BRIZA MEDIA L.	1-5
24	38	49	HIPPOCREPIS COMOSA L.	1-5
22	36	51	CAREX GLAUCA MURR.	1-5

PLANTES LES PLUS DISCRIMINANTES DU GROUPE 813

A-D	DIS			FID
40	28	68	LOTUS CORNICULATUS L.	1-6
40	24	76	BRACHYPODIUM PINNATUM (	1-6
36	38	75	SANGUISORBA MINOR SCOP.	1-6
36	29	66	BROMUS ERECTUS HUDS.	1-6
35	32	72	THYMUS SERPYLLUM L.	1-6
29	41	60	BRIZA MEDIA L.	1-5
26	40	57	HIPPOCREPIS COMOSA L.	1-5
25	33	63	CAREX GLAUCA MURR.	1-5

Fig. 10 - The discriminant plants of the repeated types P-784 with M-699 and P-922 with M-813. Same legend than Fig. 4.

CONCLUSIONS

1. A NUMERICAL CLASSIFICATION OF FLORISTICAL RELEVÉS MAY DETERMINE ECOLOGICAL VEGETATION TYPES

A completely automatic classification is able to give intelligent results and to show coherent vegetation types, from the highest levels of synthesis, above the phytosociological classes, till the detailed sub-types. These types remind the familiar types, and their corresponding environments, but they are objective and accurate.

2. Repeatability is a test for objectivity

The test is possible because the repeated types, based on different relevés, are located in the same statistical space where they are the nearest reciprocal neighbours. The vegetation types are repeated at all levels of synthesis. The repeated types are illustrated by similar lists of discriminant plants, with similar values of fidelities and constancies, though they characterize relevés having different floras and different effectives.

3. The method translates the hypothesis of plant sociology

The content and the hierarchy of the types depend only on a few initial hypothesis, which translate for the computers the traditional hypothesis of plant sociology. Two hypothesis are enough, perhaps, to explicit the nature of the computation and the meaning of the results. 1) All the taxa together, in a plant community, give evidence of the environment. About this first hypothesis, all botanists agree, except those who reduce the number of taxa in factor analysis (Mucina & van der Maarel, 1989). 2) The capability of a taxon to give an information about a type of environment may be measured by the fidelity of the taxon to the type. This point was expressly stated by Braun-Blanquet (1932).

If you accept these two points, for a computation, you are led to consider the plants as quantitative indices of the environment (hypothesis 1), then to calibrate the behaviour of a plant by the set of its fidelities to the other plants (hypothesis 2). The whole computation is derived from this beginning (Appendix 1).

4. Calibrated floristical data reflect ecological and geographical differences

The sociological calibration of plants falls in with the care of vegetation scientists to take in account ecology and geography (Pignatti *et al.*, 1995). Calibration avoids the use of ill-matched data, the empirical delimitation of territories or plant formations, the splitting of a taxon in several behaviours according to its geographical or sociological background. Calibration may be suspected of vicious circle, if it seems to define first the environment according to the flora (hypothesis 1), then the flora according to the environment, when it determines the probable flora of a relevé (§ 1.2 page 202).

In fact, the computation just determines an ecological difference according to a floristical difference. The ecological difference is the consistent part of the floristical difference, coming from the plants which usually show concordant variations. The aleatory part of the floristical difference comes from 1) the plants having low indicator capacities, in the socio-ecological space; 2) the plants which are different in two relevés but which have similar behaviours; 3) the plants which show together inconsistent ecological differences.

5. Evolution towards numerical taxonomy in vegetation science

The two classifications P and M of vegetation types are not supposed to last longer than the demonstration of repeatability, because : 1) Each is based on only 2.000 relevés, when the bank 'Sophy' is going to reach 100.000 relevés and to produce a socio-ecological classification of French plant communities; 2) Each covers the gradients throughout France only, not Europe. The unavoidable evolution towards a numerical taxonomy in vegetation science implies exchanges between national data banks and a consensus for numerical processing of floristical data, especially for the few initial hypothesis which command the computation and the result.

RÉSUMÉ

Les groupements végétaux supérieurs sont généralement établis par approximations successives, sur des critères de géographie floristique. En revanche, des critères de sociologie écologique déterminent des groupements qui sont statistiquement reproductibles à l'identique, ou presque. Ces critères sont purement floristiques, mais ils sont dotés d'une signification écologique grâce à un étalonnage préalable des relations entre les plantes, traitées comme des indices du milieu. Ces critères sont appliqués à deux lots homologues de 2.000 relevés échantillonnés dans une banque de 60.000 relevés situés en France. Chacun des deux lots couvre les principaux gradients écologiques de la banque, il définit une hiérarchie de groupements végétaux et il explique, pour moitié, l'originalité d'un groupement par 10 à 30 plantes discriminantes parmi les 5.000 plantes recensées dans les relevés.

Résultats : 1) Des plantes discriminantes, en nombre limité, caractérisent la flore et le milieu d'un groupement, même supérieur. 2) Dans les deux classifications de relevés, établies indépendamment l'une de l'autre, et hiérarchisées différemment, les mêmes groupements supérieurs se retrouvent. Ce sont les groupements qui sont réciproquement voisins l'un de l'autre, dans l'espace socio-écologique et qui, quoique composés de relevés différents, ont les mêmes plantes discriminantes. 3) Les deux principaux groupements montrent la différence majeure entre l'ombre et la lumière. Les mêmes plantes discriminantes se retrouvent dans les deux classifications. Ces plantes sont toutes herbacées pour un groupement, et toutes ligneuses ou sciaphiles, pour l'autre, et elles ont des fidélités à leur groupement supérieures à 90%. 4) La même concordance se retrouve dans les groupements subordonnés, qui sont reproductibles. Ils rappellent les groupements classiques définis par consensus mais non-reproductibles.

REFERENCES

BRAUN, J., 1932. Plant sociology. The study of plant communities. Authorized English translation of Pflanzen-soziologie (1928), edited by FULLER, G.D. & CONARD, H.S., University of Chicago, Ill. (U.S.A.), 438 p.

BRISSE, H. RUFFRAY, P. DE, G. GRANDJOUAN & HOFF, M., 1995. The Phytosociological Database «Sophy». I. Calibration of indicator plants. II. Socio-ecological classification of the relevés. Ann. Bot. (Roma), **53**: 177-223.

BRISSE, H. & M. GRUBER, 1996. *Jumelage de la prospection régionale d'un auteur avec une banque de données nationale en phytosociologie*. Bull. Soc. Hist. Nat. Toulouse, **132**: 29-39.

MUCINA, L. & VAN DER MAAREL, E., 1989. *Twenty years of numerical taxonomy*. Vegetatio, **81**: 1-15.

PIGNATTI, S., OBERDORFER, E., SCHAMINEE, J.H.J. & WESTHOFF, V., 1995. *On the concept of vegetation class in phytosociology*. J. Veg. Sc., **6**: 143 - 152.

RUFFRAY, P. DE, H. BRISSE, G. GRANDJOUAN & M. HOFF, 1989. Sophy, une banque de données phytosociologiques; son intérêt pour la conservation de la nature. Actes du colloque «Plantes sauvages et menacées de France: bilan et protection». Brest, 1987. Bureau des ressources génétiques, Paris, 129-150.

SOKAL, R.R. & P.H.A. SNEATH, 1963. Principles of Numerical Taxonomy. W.H. Freeman and Co., 359 p.

APPENDIX 1

COMPUTATION OF AN SOCIO-ECOLOGICAL DISTANCE BETWEEN TWO VEGETATION TYPES

1. Notations

A, B	Numbers of plants
DER(R1,R2)	Square distance between the relevés or the types R1 and R2, in a socio-ecological space
E	The whole data in the bank
FCO(A,B)	Frequency of the relevés having the plants A and B together
FID(A,B)	Fidelity of plant A to plant B
FIM(R,B)	Average fidelity of the relevé or the type R to plant B
FRQ(A)	Frequency of plant A in the bank
NPB	Effective of plants in the bank
NPR(R)	Number of plants in the relevé R or cumulation of NPR in the type R
PDR(A,R)	Discriminant power of plant A for the relevé or the type R
R, R1, R2	Numbers of relevés or vegetation types

2. Formulas

DER(R1,R2)	$= \sum (FIM(R1,B) - FIM(R2,B))^2$ for B = 1 to NPB
FID(A,B)	= FCO(A,B) / FRQ(A)
FIM(R,B)	$= (1/NPR(R)) \times \sum FID(A,B)$ for A present in relevé R or in any relevé of the type R
PDR(A,R)	$= (FIM(E,A) - FIM(R,A))^2 / DER(E,R)$