

Measures of rank distances followed by repeated clustering and tests
of rank correlations in the study of biological and chemical data from
tropical forest soils (Ivory Coast).

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Investigations on soil microbial activity or microbial populations in
the field are usually based on large numbers of microbiological, che-
mical and physical data. The aim of this paper is to present two me-
thods which may speed up and facilitate their interpretation.

I - METHODS

Four programs written in Fortran have been used on the 1108 and 370
computers (AUBRY, 1972):

Capacity.- The program package allows for a maximum number of 37 sam-
ples, 100 variables and no more than 17 samples per cluster.

Data sheet.- The raw data matrix consists of m rows and y columns.
The row entries are the sample numbers, the column entries are the
biological or chemical variables. Data are punched in the F5.0 format
(with 9999 as greatest value instead of 99999) or in a smaller Fn.0
format. Missing data are punched -1 right justified. As a single card
can only accomodate a limited number of variables, several cards may
have to be used in sequence for each sample.

The programs manipulate simultaneously ordinal and interval variables.
Only interval variables appear in the example given in Table 2, which
has been punched into 2 x 32 cards.

The distance program.- A distribution-free measure of distance between
samples using ranks has been adopted (KENDALL & STUART, 1966; VAN DEN
BRIESSCHE & GARCIA GOMEZ, 1972). The data matrix of the x_{hi} is repla-
ced by a rank matrix of r_{hi} , where ordering has taken place a column
at a time, in other words independently for each variable. No replace-

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ment occurs : the coded form -1 is used for missing data. A weighing coefficient I_i which takes into account the eventual number of missing data, the number e_i of sets of tied ranks and their size t_{qi} is used :

$$I_i = \left[m_i^3 - m_i - \sum_{q=1}^{e_i} (t_{qi}^3 - t_{qi}) \right] / 12$$

where m_i is the actual number of samples for variable i ($m_i = m -$ missing data of i). I_i equals zero and variable i is then deleted when all the data of variable i are equal.

The distance index between samples h and k varies between zero and ~~one~~ two and is computed as follows :

$$D_{hk} = \frac{1}{v} \sum_{i=1}^v \frac{(r_{hi} - r_{ki})^2}{I_i}$$

If for a given i one or both ranks r_{hi} r_{ki} are missing, due to missing data, no difference occurs and the variable i vanishes for the interested distance.

The $\binom{m}{2}$ distances are computed. Both punched and printed output is provided : punched cards with all the distances in the F9.4 format and a printed matrix in the A1 format, where class symbols 0, 1, 2, ..., 9, A, B, ..., N, P, Z take the place of the distances less than .34, the higher distances being deleted.

The clustering program. - Input is the lower half of the distance matrix in the F9.4 format. Output from the distance program. A clustering procedure is followed using two criteria :

- (1) mean distance between two clusters \succ mean distance within both clusters ;
- (2) distances between unclustered samples and the clusters \succ mean distance within each cluster.

Mean distances between and within clusters are printed with two decimals in matrix form. Content of each cluster appears as row and column entries.

The program for averaging the data within the clusters. - Data are averaged among the samples of each cluster. Punched output as well as printed output is provided in the F9.4 format.

Repeated clustering. - The distance program is then used a second time with this punched output and repeated clustering follows. The whole procedure is repeated once again and the final clusters appear in the matrix form of Table 4.

The correlation program. - A rank measure of correlation between variables has been used (SPEARMAN, 1904). The same ranking procedure is followed as for the distance approach.

Two weighing coefficients I_i and I_j are needed for the variables i and j :

$$I_i = \frac{m_{ij}^3 - m_{ij}}{12} - \sum_{q=1}^{e_i} \frac{t_{qi}^3 - t_{qi}}{12}$$

$$I_j = \frac{m_{ij}^3 - m_{ij}}{12} - \sum_{q=1}^{e_j} \frac{t_{qj}^3 - t_{qj}}{12}$$

m_{ij} stands for the sample size expressed in number of samples where both variables i and j occur. Symbols e_j and t_{qj} are homologous to e_i and t_{qi} already encountered.

The correlation coefficient :

$$R_{ij} = \left[I_i + I_j - \sum_{h=1}^m (r_{hi} - r_{hj})^2 \right] / 2 \sqrt{I_i I_j}$$

varies between -1 and 1.

Tabular values (BEYER, 1966) are available for the correlation test at the .01 and .05 probability levels, for sample sizes comprised between 6 and 37, and are part of the program.

The same printed output appears on the left and right half of each page. Output is divided into non-significant, positive and negative correlations. The actual sample size appears underneath the two variables and the probability level is indicated. Variables appear in plain language. (Fig. 2).

II - EXAMPLIFICATION

The above methods are exemplified by the results of an investigation on forest soils from the Ivory Coast.

This work was based on the analysis of 32 soil samples (0-10 cm horizon) collected in November 1969 and March 1970 from 16 stations (Table 1 & 2). For each soil sample 20 variables were used :

(1) Chemical variables sensu stricto (plus clay content)

C/N

PH (pH H₂O 1:2.5)

S/ (total exchangeable cations, meq/100 g soil)

T (cation exchange capacity, meq/100 g soil)

TCC (total cation content, meq/100 g soil)

TFE (total Fe, expressed as Fe₂O₃ percentage)

TP (total P, mg P/g soil)

CLA (clay content, percentage)

(2) Humic variables

FA (fulvic acids expressed as mg carbon/g soil)

HA (humic acids expressed as mg carbon/g soil)

GHA (gray humic acids, percentage of HA)

HU (humine expressed as mg carbon/g soil)

(3) Biological variables

CO₂ (potential CO₂ evolution, expressed as mg CO₂ evolved/g soil.7 days)

DES (dehydrogenase activity expressed as μ l H transferred/g soil.24 hr)

SAC (saccharase, expressed as μ mole reducing sugars/g soil.24 hr)

AMY (amylase, expressed as μ mole reducing sugars/g soil.96 hr)

GLU (beta-glucosidase, same expression as amylase)

URE (urease, expressed as mg NH₃-N/g soil.3 hr)

ASP (asparaginase, expressed as mg $\text{NH}_3\text{-N/g soil}$.21 hr)

PHO (phosphatase, expressed as mg phenol/g soil.3 hr).

1. Interpretation through the clustering method

Table 3 and Fig. 1 show the clustering of the 32 samples. On step 3, six clusters appear, which have been called A, B, C, D, E, F. A contains 14 samples of northern and central forests. D contains 8 samples from southern forests. The remaining 10 samples are grouped into the 4 clusters B, C, E, F. Moreover, the distance between clusters A and D is the highest observed : .43 (Table 4 and Fig. 1) and it may be observed that A and D constitute the two main clusters. Clusters C and F are near to cluster D as distances DC and DF are small (.09 and .13). Clusters B and E are at the same distance from A and D (.16, .20, .20, .19) : they cover intermediate sites.

In addition, clustering suggests (1) that the time of sampling (November or May) has no influence, (2) that the geographic location is of importance but that the assumed partition in three zones (northern, central, southern) is not satisfactory, (3) that, within the two main clusters A and D, the rock factor is determining.

2. Interpretation through the rank correlation method

Despite several shortcomings, correlation is of considerable use in ecology. The existence of a positive or negative interdependency between two variables does not prove an eventual causality ; it can however support stimulating hypotheses for further studies, especially for experiments on models.

In most soils, it may be postulated that biological and humic characteristics are governed by two groups of causal factors : (1) chemical (sensu stricto) and physical soil-factors, (2) vegetation-factors. If that is so, the existence or the absence of interdependency between the different variables may prompt hypotheses on the role of the assumed factors.

Thus Table 5 induces the hypothesis that biological activity (saccharase excepted) is predominantly governed by the exchangeable cation status (S/ and T), total cation content (TCC), total Fe content (TFE), clay content (CIA). Humine (HU) and gray humic acids (GHA) seem

also to be governed by one of these assumed factors, presumably clay ; this hypothesis agrees with the known fact that gray humic acids are adsorbed on clay minerals and protected by these colloids from bacterial and enzymatic degradation. On the other hand it can be hypothesized that saccharase (SAC), fulvic (FA) and humic acids (HA) are essentially vegetation-dependent variables.

Another conclusion drawn from Table 5 is that the comparison of the 0-10 cm horizons of the different Ivory Coast forest soils can be easily performed through but a few determinations such as dehydrogenase (DES), saccharase (SAC), humic acids (HA), humine (HU), cation-exchange capacity (T), clay content (CIA).

S U M M A R Y

Both methods, distances and correlations, start from a data matrix with a few missing data ; rows correspond to m soil samples and columns correspond to v variables. A distance matrix is constructed between the samples, using ranks instead of the original data. A clustering procedure follows, using these non-parametric distances with two criteria : (1) mean distance between two clusters > mean distance within both clusters, (2) distances between unclustered samples and the clusters > mean distance within each cluster. The data matrix is then manipulated in the opposite direction by testing the rank correlation coefficients between the variables, in order to locate eventual interdependency between biological and chemical variables. The four programs are written in Fortran.

In order to illustrate the proposed methods, results of a study on forest soils from the Ivory Coast have been given.

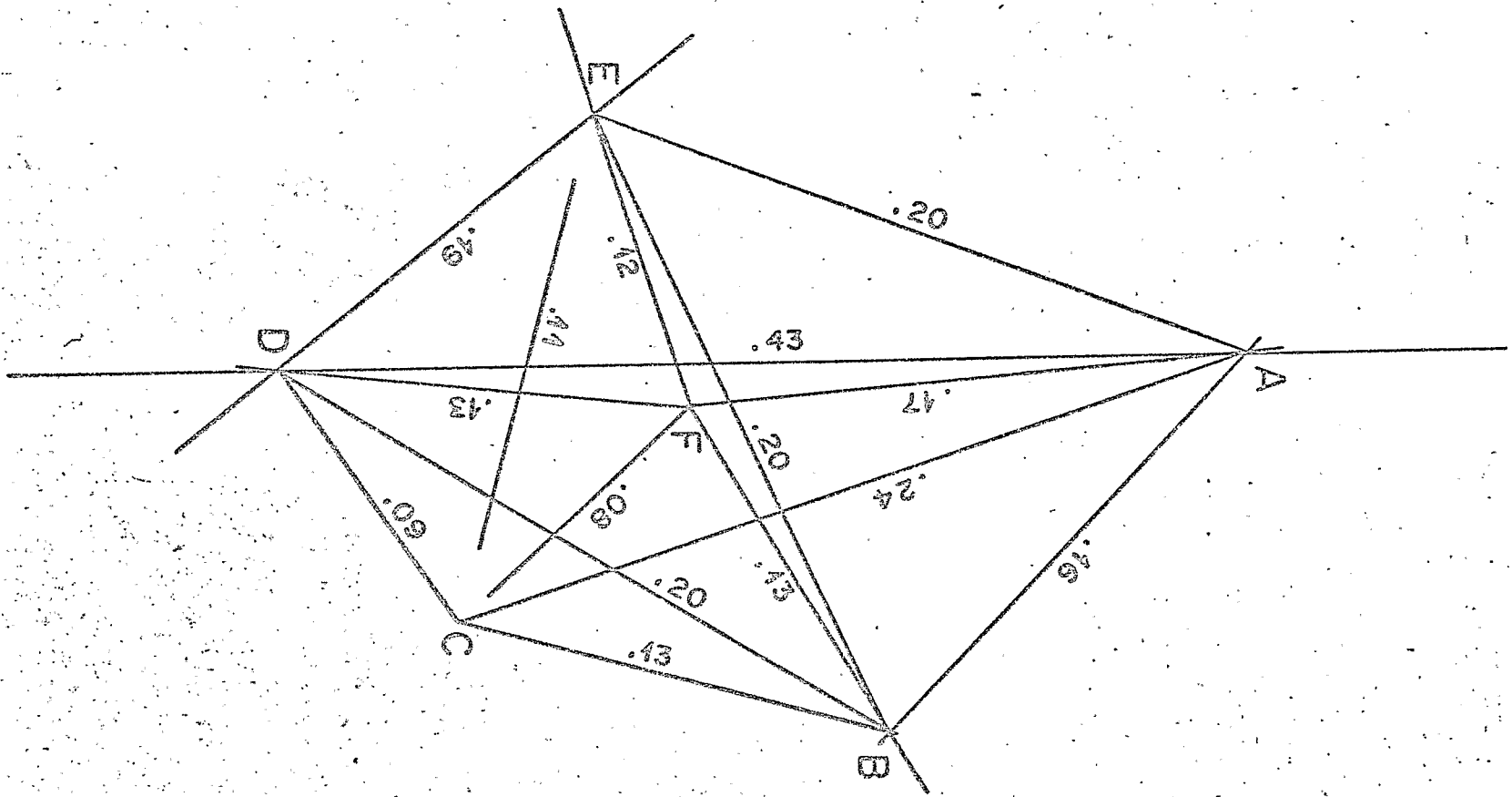
REFERENCES

- AUBRY A.M. 1972. Programmes pour l'obtention des distances et des corrélations non-paramétriques en pédologie. O.R.S.T.O.M., Bondy, multigr., 54 pp.
- BEYER W.H. (edit.) 1966. Handbook of tables for probability and statistics, Chemical Rubber, Cleveland, 517 pp.
- KENDALL M.G. & STUART A. 1966. The advanced theory of statistics, vol. 3. Design and analysis, and time series, Griffin, London, 552 pp.
- PERRAUD A. 1971. La matière organique des sols forestiers de la Côte d'Ivoire (relations : sol-végétation-climat). Thèse doct. ès-sc. Univer. Nancy I, 87 pp.
- SPEARMAN C. 1904. The proof and measurement of association between two things. Am. J. Psych., 15:72-101.
- VAN DEN DRIESSCHE R. & GARCIA GOMEZ A. 1972. Distances non-paramétriques entre profils. Rev. Ecol. Biol. Sol, 9: (in press).

CAPTIONS FOR THE ILLUSTRATIONS

Fig. 1 - Mean distances between arbitrary locations of clusters, step 3.

Fig. 2 - A page of computer output with the rank correlation program (sample size underneath the two variables).



AUBREY & SONS. FIG. 1

CORRELATION DE SPEARMAN POSITIVE ENTRE LES VARIABLES:

UREASE
SOMME DES BASES TOTALES
EFFECTIF 32 RISQUE 1 POUR CENT

UREASE
FER TOTAL
EFFECTIF 32 RISQUE 1 POUR CENT

UREASE
PHOSPHORE TOTAL
EFFECTIF 22 RISQUE 1 POUR CENT

UREASE
ACIDES FULVIQUES
EFFECTIF 32 RISQUE 5 POUR CENT

UREASE
POURCENTAGE D ACIDES HUMIQUES GRIS
EFFECTIF 32 RISQUE 1 POUR CENT

UREASE
HUMINE
EFFECTIF 32 RISQUE 1 POUR CENT

UREASE
ARGILE
EFFECTIF 32 RISQUE 1 POUR CENT

ASPARAGINASE
PHOSPHATASE
EFFECTIF 32 RISQUE 1 POUR CENT

ASPARAGINASE
SOMME DES BASES ECHANGEABLES
EFFECTIF 32 RISQUE 1 POUR CENT

ASPARAGINASE
CAPACITE D ECHANGE
EFFECTIF 32 RISQUE 1 POUR CENT

CORRELATION DE SPEARMAN POSITIVE ENTRE LES VARIABL

UREASE
SOMME DES BASES TOTALES
EFFECTIF 32 RISQUE 1 POUR CENT

UREASE
FER TOTAL
EFFECTIF 32 RISQUE 1 POUR CENT

UREASE
PHOSPHORE TOTAL
EFFECTIF 22 RISQUE 1 POUR CENT

UREASE
ACIDES FULVIQUES
EFFECTIF 32 RISQUE 5 POUR CENT

UREASE
POURCENTAGE D ACIDES HUMIQUES GRIS
EFFECTIF 32 RISQUE 1 POUR CENT

UREASE
HUMINE
EFFECTIF 32 RISQUE 1 POUR CENT

UREASE
ARGILE
EFFECTIF 32 RISQUE 1 POUR CENT

ASPARAGINASE
PHOSPHATASE
EFFECTIF 32 RISQUE 1 POUR CENT

ASPARAGINASE
SOMME DES BASES ECHANGEABLES
EFFECTIF 32 RISQUE 1 POUR CENT

ASPARAGINASE
CAPACITE D ECHANGE
EFFECTIF 32 RISQUE 1 POUR CENT

Table 1 - Sample numbers and sites (Ivory Coast forest soils)

Sample n ^o	Sites	Rocks	Sample réf.	Month
1	Southern forest	Schists	A11	Nov.
2	Southern forest	Schists	A21	Nov.
3	Southern forest	Granites	B11	Nov.
4	Southern forest	Granites	B21	Nov.
5	Southern forest	Tertiary sands	C11	Nov.
6	Southern forest	Tertiary sands	C21	Nov.
7	Central forest	Schists	E11	Nov.
8	Central forest	Schists	D71	Nov.
9	Central forest	Granites	D31	Nov.
10	Central forest	Granites	F11	Nov.
11	Central forest	Amphibolites	G11	Nov.
12	Central forest	Amphibolites	G21	Nov.
13	Northern forest	Schists	N41	Nov.
14	Northern forest	Schists	N21	Nov.
15	Northern forest	Granites	K21	Nov.
16	Northern forest	Granites	M11	Nov.
17	Southern forest	Schists	A11	March
18	Southern forest	Schists	A21	March
19	Southern forest	Granites	B11	March
20	Southern forest	Granites	B21	March
21	Southern forest	Tertiary sands	C11	March
22	Southern forest	Tertiary sands	C21	March
23	Central forest	Schists	E11	March
24	Central forest	Schists	D71	March
25	Central forest	Granites	D31	March
26	Central forest	Granites	F11	March
27	Central forest	Amphibolites	G11	March
28	Central forest	Amphibolites	G21	March
29	Northern forest	Schists	N41	March
30	Northern forest	Schists	N21	March
31	Northern forest	Granites	K21	March
32	Northern forest	Granites	M11	March

Table 2 - Ivory Coast forest Soils : chemical and biological d

Sample N°	VARIABLES												
	C/N	PH	CO ₂	DES	SAC	AMY	GLU	URE	ASP	PHO	S/	T	TCC
1	12.8	4.9	2.45	10.8	80.7	34.1	24.6	.16	.59	.94	2.84	8.62	9.69
2	13.3	4.5	1.78	3.27	56.6	24.5	15.2	.14	.35	.63	1.24	6.93	2.08
3	15.0	4.5	1.30	6.13	29.7	29.7	17.6	.16	.27	.81	3.47	7.41	5.74
4	13.1	4.9	1.79	6.90	26.2	24.5	21.5	.28	.33	.72	2.97	7.44	7.77
5	16.3	3.9	1.08	5.71	15.2	20.7	11.9	.06	.22	.72	1.01	11.1	3.17
6	12.2	4.4	1.11	4.30	15.1	15.1	10.9	.11	.23	.37	1.19	5.04	2.73
7	12.2	4.6	2.38	14.9	30.3	26.7	29.8	.29	.58	.92	5.57	12.6	11.0
8	9.3	6.1	3.08	34.8	52.3	46.5	44.6	.52	.73	1.21	10.4	10.9	19.8
9	10.0	5.4	2.06	17.9	24.7	29.7	30.0	.24	.49	1.05	6.04	8.36	12.3
10	11.1	6.2	3.90	31.0	47.8	48.3	89.3	.49	.72	1.19	15.6	14.4	19.7
11	9.2	7.4	5.22	21.9	56.5	62.7	31.7	3.44	1.30	1.65	66.4	45.0	159
12	9.4	7.5	5.16	15.9	58.0	60.3	24.3	3.07	1.13	1.64	73.6	49.6	145
13	9.9	5.8	2.96	28.9	47.8	48.3	72.1	.27	.61	1.12	11.3	13.2	28.9
14	10.7	5.8	5.34	16.5	41.0	35.5	36.3	.20	.70	1.03	7.90	10.3	25.1
15	14.1	6.3	1.11	40.1	74.2	37.0	43.1	.12	.37	.41	7.19	9.09	14.0
16	9.3	7.6	2.93	70.9	57.8	63.9	90.1	2.22	.77	1.13	28.4	20.0	40.3
17	14.8	4.9	1.59	11.2	64.6	28.0	28.3	.17	.33	.92	3.02	8.67	9.69
18	13.7	4.5	.76	5.06	36.7	15.2	15.0	.07	.24	.48	1.28	6.92	2.08
19	13.4	4.7	.64	5.18	22.5	11.5	10.5	.09	.20	.60	2.84	6.95	5.74
20	13.2	4.8	1.12	5.61	37.0	20.8	30.5	.08	.34	.79	4.32	9.00	7.77
21	15.8	3.9	.90	1.02	17.2	26.2	29.3	.02	.25	.67	.94	10.2	3.17
22	12.2	4.7	.68	1.52	17.6	17.0	14.3	.06	.20	.43	1.39	4.91	2.73
23	13.4	4.6	.89	9.19	27.8	43.0	37.1	.15	.30	.89	5.88	14.4	11.0
24	10.5	5.9	2.00	21.2	59.4	33.4	41.1	.29	.75	1.03	10.1	11.5	19.8
25	10.0	5.3	1.40	6.38	28.0	22.7	19.4	.26	.51	.84	5.86	9.10	12.3
26	10.6	6.0	1.87	28.7	40.4	40.3	67.3	.34	.60	.99	13.7	13.9	19.7
27	10.2	7.2	2.99	10.9	61.1	55.3	35.9	1.99	1.00	1.56	65.5	44.8	159
28	10.1	7.2	3.43	8.34	56.2	50.2	18.5	2.56	.85	1.59	68.8	47.9	145
29	12.3	5.9	1.75	22.7	52.0	50.2	51.1	.29	.62	1.11	10.5	13.7	28.9
30	11.1	5.6	2.72	16.5	44.8	44.9	48.2	.20	.69	.97	9.48	12.2	25.1
31	12.4	6.4	1.00	33.4	60.9	33.2	36.1	.09	.72	.59	6.37	7.81	14.0
32	10.4	7.6	2.21	69.8	56.5	34.0	81.9	1.36	.83	1.09	30.6	23.0	40.3

Ivory Coast forest Soils : chemical and biological data

VARIABLES

AMY	GLJ	URE	ASP	PHO	S/	T	TCC	TFE	TP	FA	HA	GHA	HU	CLA
34.1	24.6	.16	.59	.94	2.84	8.62	9.69	2.00	.30	2.93	1.46	48	8.04	11.8
24.5	15.2	.14	.35	.63	1.24	6.93	2.08	1.45	.23	2.32	1.22	47	5.01	8.8
29.7	17.6	.16	.27	.81	3.47	7.41	5.74	.78	.21	1.65	.70	42	6.24	8.8
24.5	21.5	.28	.33	.72	2.97	7.44	7.77	2.75	.52	2.63	1.21	45	8.81	19.5
20.7	11.9	.06	.22	.72	1.01	11.1	3.17	1.80	.41	3.01	3.16	50	7.90	9.1
15.1	10.9	.11	.23	.37	1.19	5.04	2.73	1.50		1.48	1.25	50	6.47	8.8
26.7	29.8	.29	.58	.92	5.57	12.6	11.0	4.75	.65	4.77	5.40	49	18.4	21.9
46.5	44.6	.52	.73	1.21	10.4	10.9	19.8	4.45	.78	3.01	1.78	57	16.2	21.3
29.7	30.0	.24	.49	1.05	6.04	8.36	12.3	1.00	.41	2.85	2.18	55	9.12	16.6
48.3	89.3	.49	.72	1.19	15.6	14.4	19.7	3.00	.54	3.01	1.85	58	17.3	23.2
62.7	31.7	3.44	1.30	1.65	66.4	45.0	159	9.25		2.71	1.06	58	43.7	41.9
60.3	24.3	3.07	1.13	1.64	73.6	49.6	145	10.5		3.37	1.29	52	46.6	41.4
48.3	72.1	.27	.61	1.12	11.3	13.2	28.9	5.25		3.12	3.02	65	20.2	26.4
35.5	36.3	.20	.70	1.03	7.90	10.3	25.1	3.50		3.48	3.30	61	15.7	23.8
37.0	43.1	.12	.37	.41	7.19	9.09	14.0	2.75	.40	.92	1.92	61	8.84	15.8
63.9	90.1	2.22	.77	1.13	28.4	20.0	40.3	4.25	.75	3.12	2.91	68	24.0	28.3
28.0	28.3	.17	.33	.92	3.02	8.67	9.69	2.00	.30	3.03	1.93	43	9.26	11.8
15.2	15.0	.07	.24	.48	1.28	6.92	2.08	1.45	.23	2.16	1.61	47	5.76	8.8
11.5	10.5	.09	.20	.60	2.84	6.95	5.74	.78	.21	1.56	.92	46	6.03	8.8
20.8	30.5	.08	.34	.79	4.32	9.00	7.77	2.75	.52	2.66	1.88	45	9.19	19.5
26.2	29.3	.02	.25	.67	.94	10.2	3.17	1.80	.41	3.24	2.56	52	7.64	9.1
17.0	14.3	.06	.20	.43	1.39	4.91	2.73	1.50		1.62	1.26	50	6.74	8.8
43.0	37.1	.15	.30	.89	5.88	14.4	11.0	4.75	.65	6.28	5.39	52	20.3	21.9
33.4	41.1	.29	.75	1.03	10.1	11.5	19.8	4.45	.78	2.78	1.81	55	15.6	21.3
22.7	19.4	.26	.51	.84	5.86	9.10	12.3	1.00	.41	2.32	2.37	55	8.06	16.6
40.3	67.3	.34	.60	.99	13.7	13.9	19.7	3.00	.54	2.43	2.30	58	15.6	23.2
55.3	35.9	1.99	1.00	1.56	65.5	44.8	159	9.25		3.12	.91	61	44.0	41.9
50.2	18.5	2.56	.85	1.59	68.8	47.9	145	10.5		2.32	.70	56	42.0	41.4
50.2	51.1	.29	.62	1.11	10.5	13.7	28.9	5.25		3.29	3.04	64	21.2	26.4
44.9	48.2	.20	.69	.97	9.48	12.2	25.1	3.50		3.50	3.37	59	13.8	23.8
33.2	36.1	.09	.72	.59	6.37	7.81	14.0	2.75	.40	1.52	1.25	63	7.74	15.8
34.0	81.9	1.36	.83	1.09	30.6	23.0	40.3	4.25	.75	3.59	2.75	66	27.9	28.3

Table 3 - Sample names and results of repeated clustering.
 Mean distances after step 3 appear in Table 4

Sites	Rocks	Sample ref.	Month	Sample n ²	Clusters		
					Step 1	Step 2	Step 3
Central forest	Granites	D31	Nov.	10]]	A
Central forest	Granites	F11	March	26			
Central forest	Schists	D71	Nov.	8]]	
Central forest	Schists.	D71	March	24			
Northern forest	Schists	N21	Nov.	14]]	
Northern forest	Schists	N21	March	30			
Northern forest	Schists	N41	Nov.	13]]	
Northern forest	Schists	N41	March	29			
Northern forest	Granites	M11	Nov.	16]]	
Northern forest	Granites	M11	March	32			
Central forest	Amphibolites	G11	Nov.	11]]	
Central forest	Amphibolites	G11	March	27			
Central forest	Amphibolites	G21	Nov.	12]]	
Central forest	Amphibolites	G21	March	28			
Central forest	Schists	E11	Nov.	7]]	B
Central forest	Schists	E11	March	23			
Southern forest	Schists	A11	Nov.	1]]	C
Southern forest	Schists	A11	March	17			
Southern forest	Granites	B21	Nov.	4]]	
Southern forest	Granites	B21	March	20			
Southern forest	Tertiary sands	C21	Nov.	6]]	D
Southern forest	Tertiary sands	C21	March	22			
Southern forest	Schists	A21	March	18]]	
Southern forest	Granites	B11	March	19			
Southern forest	Schists	A21	Nov.	2]]	
Southern forest	Granites	B21	Nov.	3			
Southern forest	Tertiary sands	C11	Nov.	5]]	E
Southern forest	Tertiary sands	C11	March	21			
Northern forest	Granites	K21	Nov.	15]]	F
Northern forest	Granites	K21	March	31			
Central forest	Granites	D31	Nov.	9]]	
Central forest	Granites	D31	March	25			

Table 4 - Mean distances within clusters on the diagonal (underlined), and mean distances between clusters, step 3. Content of clusters in Table 3.

Clusters	A	B	C	D	E	F
A	<u>.06</u>	.16	.24	.43	.20	.17
B	.16	<u>.05</u>	.13	.20	.20	.13
C	.24	.13	<u>.06</u>	.09	.11	.08
D	.43	.20	.09	<u>.07</u>	.19	.13
E	.20	.20	.11	.19	<u>.01</u>	.12
F	.17	.13	.08	.13	.12	<u>.01</u>

Table 5 - Results of rank correlation test : N stands for a negative, P for a positive correlation ; hatching for absence of correlation at the .01 probability level

	C/N	PH	CO ₂	DES	SAC	AMY	GLU	URE	ASP	PHO	S/	T	TCC	TFE	TP	FA	HA	GHA	HU	CLA
C/N	o	N	N	N	/	N	/	N	N	N	N	N	N	N	N	/	/	N	N	N
PH	N	o	P	P	P	P	P	P	P	P	P	P	P	P	/	/	/	P	P	P
CO ₂	N	P	o	P	P	P	P	P	P	P	P	P	P	P	/	/	/	/	P	P
DES	N	P	P	o	P	P	P	P	P	P	P	P	P	P	P	/	/	P	P	P
SAC	/	P	P	P	o	P	/	/	P	/	P	/	P	P	/	/	/	/	/	/
AMY	N	P	P	P	P	o	P	P	P	P	P	P	P	P	/	P	/	P	P	P
GLU	/	P	P	P	/	P	o	P	P	P	P	P	P	P	P	P	P	P	P	P
URE	N	P	P	P	/	P	P	o	P	P	P	P	P	P	P	/	/	P	P	P
ASP	N	P	P	P	P	P	P	P	o	P	P	P	P	P	P	/	/	P	P	P
PHO	N	P	P	P	/	P	P	P	P	o	P	P	P	P	P	P	/	P	P	P
S/	N	P	P	P	P	P	P	P	P	P	o	P	P	P	P	/	/	P	P	P
T	N	P	P	P	/	P	P	P	P	P	P	o	P	P	P	P	/	P	P	P
TCC	N	P	P	P	P	P	P	P	P	P	P	P	o	P	P	/	/	P	P	P
TFE	N	P	P	P	P	P	P	P	P	P	P	P	P	o	P	P	/	P	P	P
TP	N	/	/	P	/	/	P	P	P	P	P	P	P	P	o	P	/	/	P	P
FA	/	/	/	/	/	P	P	/	/	P	/	P	/	P	P	o	P	/	P	P
HA	/	/	/	/	/	/	P	/	/	/	/	/	/	/	/	P	o	/	/	/
GHA	N	P	/	P	/	P	P	P	P	P	P	P	P	P	/	/	/	o	P	P
HU	N	P	P	P	/	P	P	P	P	P	P	P	P	P	P	P	/	P	o	P
CLA	N	P	P	P	/	P	P	P	P	P	P	P	P	P	P	P	/	P	P	o