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SAXICOLOUS COMMUNITIES IN THE SIERRA DEL MONCAYO (SPAIN): A CLASSIFICATORY STUDY

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Abstract. We used a set of multivariate methods to evaluate floristic relationships among saxicolous communities in the Sierra del Moncayo (Spain). In the first step, we established a community typology for homogeneous geomorphological units by means of ordination tecniques (CCA). Then we looked for the best clustering algorithm to explain the floristic variability in the original synthetic table and built a consensus tree based on the dendrograms that accounted for the initial variation. After that, we have isolated ten groups related to geomorphological units. Our approach is objective and logical to use in work with synthetic tables.

Introduction

Inherent difficulties in the study of saxicolous communities, especially in the mediterranean area, have been pointed out by many authors (Davies 1951, Heywood 1953, Snogerup 1971, Rivas-Martínez 1960 1963, 1977, Mota *et al.* 1991). These are mainly related to the low sociability of plants (Meier and Braun Blanquet 1934) and the problems associated with the identification of the ecological optimum of species. It is also difficult to identify community boundaries because microhabitat conditions and patch size can vary very extensively. Saxicolous vegetation often shows discontinuous variation, linked to the geomorphological patterns. This means that if the sampling unit size is larger than the community patches then the identification of the communities will be erroneous. A special phytosociological approach is needed to study this type of vegetation. As a special point of interest, we mention the high biogeographical value of these communities. Since they contain ancient chasmophytic and chomophytic species (Villar 1977, Montserrat 1980), they play a relevant role in the conservation of biodiversity.

Only from an ecological point of view and with the help of numerical methods it is possible to determine floristic fidelity in these communities. With this in mind (Escudero, 1992) we used canonical ordination techniques, CCA (ter Braak 1986, 1987, 1988), in a classificatory way (Gauch and Whittaker 1981, Økland 1990, Escudero *et al.* 1993) in order to identify the saxicolous communities on the Sierra del Moncayo (Escudero 1992) We note the plethora of other techniques that others used (Orlóci 1978, 1988, Kenkel & Orlóci 1986, Feoli & Orlóci 1991). The objectives of this study are then to examine the relationships among saxicolous communities of the Sierra del Moncayo and to evaluate the clustering techniques used to determine the relationships among communities.

Materials and methods

The study area

Sampling has been carried out in the Sierra del Moncayo. This range is located in the Sistema Ibérico, between Soria and Zaragoza, both provinces of the northern half of the Iberian Peninsula. This choice is in response to geomorphologic and lithologic diversity of conglomerates, limestones and sandstones; to high altitudinal gradient (650-2300 m); and to coincidence of three chorological provinces (Rivas Martínez 1987, Navarro 1990). Figure 1 shows the sampling sites in seven geomorphological units. Table 1 also shows the lithology and altitudinal ranges. These units have been selected to summarize the Moncayo variability and to define natural geomorphological islands.

Relevés

Fifty nine local tables covering all communities (Table 1) in the geomorphological units contributed to the original synthetic table. A total of 300 relevés are involved, taken according to phytosociological scheme (van der Maarel 1975). Local tables with less than four relevés were excluded in order to avoid random compositional effects (Hill *et al.* 1977, Flintrop 1984). The five-step constancy scale of Braun-Blanquet (1964) was used to summarize floristic composition and to study homotoneity in each table. The efficacy and importance of this scale of frequency in this type of studies have been pointed out by many others (Westhoff & van der Maarel 1978, Lausi & Feoli 1979). Mucina and van der Maarel (1989) enumerated the advantages over a cover scale.

Table 1. Characteristics of the geomorphological units.

Geomorphological units	N.of relevés	Lithology	Max. alt.	Min. alt.	N. of tables	Id. number
Plana de Beratón	35	Limestone	1580	1290	10	1-10
Siliceous stone fields	36	Sandstone	2300	1400	8	11-18
Siliceous cliffs	45	Sandstone	2250	1800	8	19-26
Los Fayos	48	Conglomerates	800	600	8	27-34
Plana de Purujosa	63	Limestone	1220	900	10	35-44
Calcareous stone fields	34	Limestone	1650	1100	6	45-50
Cerro del Morrón	36	Limestone	1731	1490	9	51-59

Cluster analysis

Different combinatorial clustering methods (SAHN tecniques) have been applied to this original synthetic table. These include: Weighted Average (WPGMA), β -Flexible (β-flex, β= -0.25), Minimum Increase of Sum of Squares (MISSQ), λ-Flexible (λ-flex , λ=-0.08), Minimum Variance of New Cluster (MNVAR), Minimum Average Distance within New Cluster (MNDIS), Complete Linkage (CL) and Unweighted Average (UPGMA). These algorithms have been pointed out by Podani (1989b) as those with the most interpretable results in vegetation terms. In every case the resemblance function used was a chord distance (Orlóci 1967). This measure considers the qualitative aspects of the data and it is more sensitive to this type of sudy than other similarity/dissimilarity indices. Chord distance is compatible with the algorithms.

Dendrogram comparison

The resulting dendrograms have been compared in every pair based on cladistic difference, subgraph membership divergence, and cluster membership divergence (Podani & Dickinson 1984, Podani 1990). The results, after standardization, were used to build a distance matrix of dendrograms (Podani 1990). This matrix was analyzed in a Principal Component Analysis (PCA) to reveal structural relationships among dendrograms and to find a consensus solution.

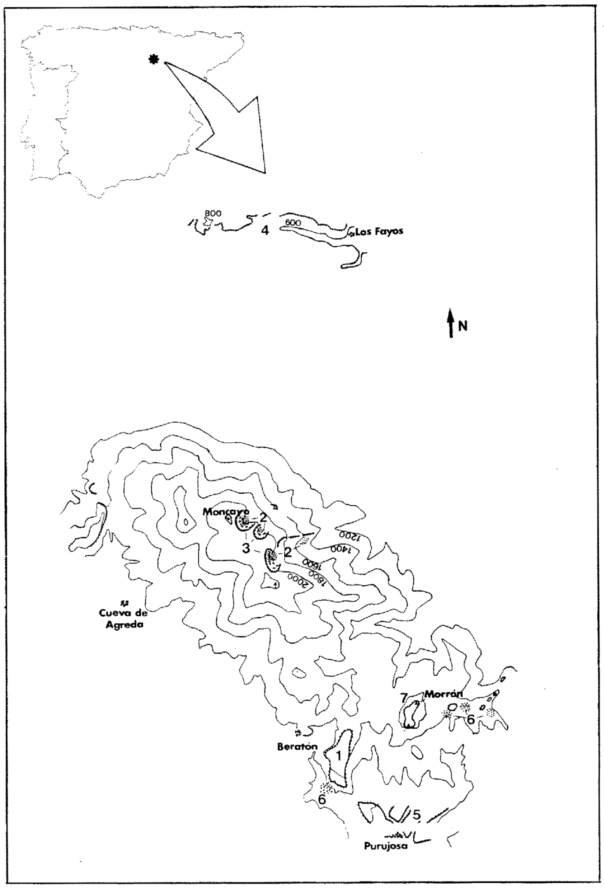

Figure 1. Map of Sierra del Moncayo showing the locations of the 7 geomorphological units of the study. 1- Plana of Beratón, 2- siliceous stone fields (dotted area), 3- siliceous cliffs, 4- Los Fayos, 5- Plana de Purujosa, 6- calcareous stone fields (dotted area), and 7- Cerro del Morrón.

Optimal partition

In order to obtain optimal groups of relevés, the best classifications revailed in PCA analysis were examined in CCA to identify natural partition levels and an optimal solution among them (Escudero and Pajarón 1993). The ratio between the inertia associated with a CA and that associated with CCA was used as described by ter Braak (1988) and Lebreton *et al.* (1988a, 1988b).

Consensus classification

By using optimal partitions the classifications were summarized in a consensus tree. Although the application of consensus methods has been a common practice in numerical taxonomy to synthesize several dendrograms (Rohlf 1982), there were few applications in vegetation research (Mucina & van der Maarel 1989). The present study used the method of Podani (1989a), involving a global fusion criterion (program MINGFC). This criterion relies on the ratio of the average within-cluster distances to the average of the distances between the clusters (Podani 1989a). It is clear that the minimum value of this index should approximate to the consensus solution (see Neumann and Norton 1986).

Species selection

In the Synthetic Table, species selection has been carried out by Jancey's method, looking for the most discriminating values (Jancey 1979). This method is based on the F-value, the relation of the between and within groups variance. We have selected species with values higher than 2.5. The advantages of this method have been pointed out by Jancey (1980), Wildi (1989), Jancey and Wells (1987).

The analyses were performed by the packages CANOCO (ter Braak 1988); MULVA IV (Wildi 1991) and SYNTAX IV (Podani 1991).

Results

The results of the PCA based on dendrogram comparisons are seen in Figure 2. The first two axes account for 49 % of the total initial variation. The scattergram in the plane of the first two axes provides an easy interpretable configuration. Most of the dendrograms are gathered around the centroid, whereas three of them, MNVAR, MISSQ and UPGMA, occur elsewhere. The rank order of percentage contributions to the error sum of squares (Table 2), coincides completely with the PCA results, because these three algorithms summed up more than 90 % of the total variation. The similarity of their contributions is noted.

The three dendrograms in Figure 3 have been examined at two levels, considering 10 clusters and 16 clusters. The results are summarized in Table 3. The partition at the 10-cluster level appears more efficient to explain the initial variation than partitions at the 16-cluster level. In fact, the I(CCA)/(n-1) index is higher in every case on the 10-cluster level. There is no significant difference among the three values (10 clusters), making it impossible to identify one of these dendrograms, as an optimal solution. Perhaps the best solution should have combined MNVAR, MISSQ and UPGMA in a new dendrogram.

Table 2. Percentage contributions to the error sum of squares of each dendrograms.

MNVAR	30.50
UPGMA	30.50
MISSQ	29.90
λ-flex (-.08)	2.28
MNDIS	2.17
β-flex (-.25)	2.17
CL	1.86
WPGMA	0.59

It is seen that consensus tree in Figure 4 represents a highly stable solution. Only few clusters related to the calcareous geomorphological units (1- Purujosa, 2- Beratón and 3- Cerro del Morrón), give problems with partition breaks in the dendrogram, owing to linkage on a higher level.

A PCA was run with all the local floristic tables, anticipating that the resulting diagram array make it possible to find natural clusters in floristic space, related to the limestone units (Feoli and Lagonegro 1991). This linear technique is used because it does not distort the sample space of the analysis (Feoli-Chiapella and Feoli 1977, Feoli and Orlóci 1991). The first two components accounted for 45% of the initial variation, so we can use the ordination diagram looking for the most coherent clusters. In the scattergram (Fig. 5) the more natural threshold limits of the unisolated clusters of the

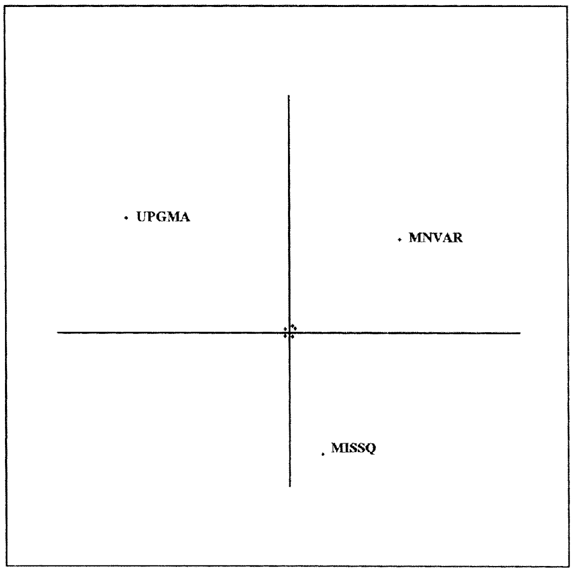

Figure 2. Distribution of dendrograms in relation to two main components of PCA.

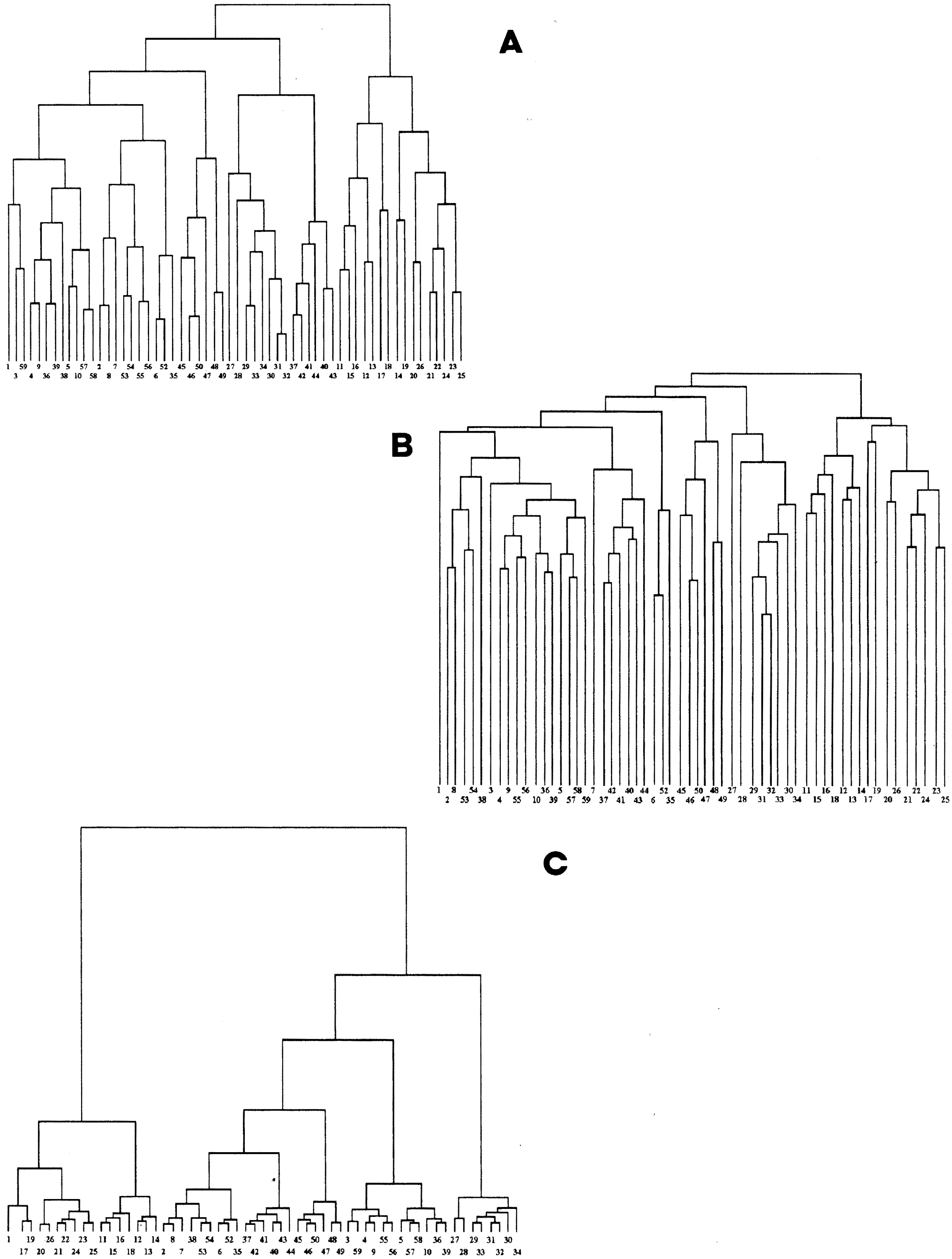

Figure 3. Results of MNVAR (a), UPGMA (b) and MNSSQ (c) in which Chord distance is applied.

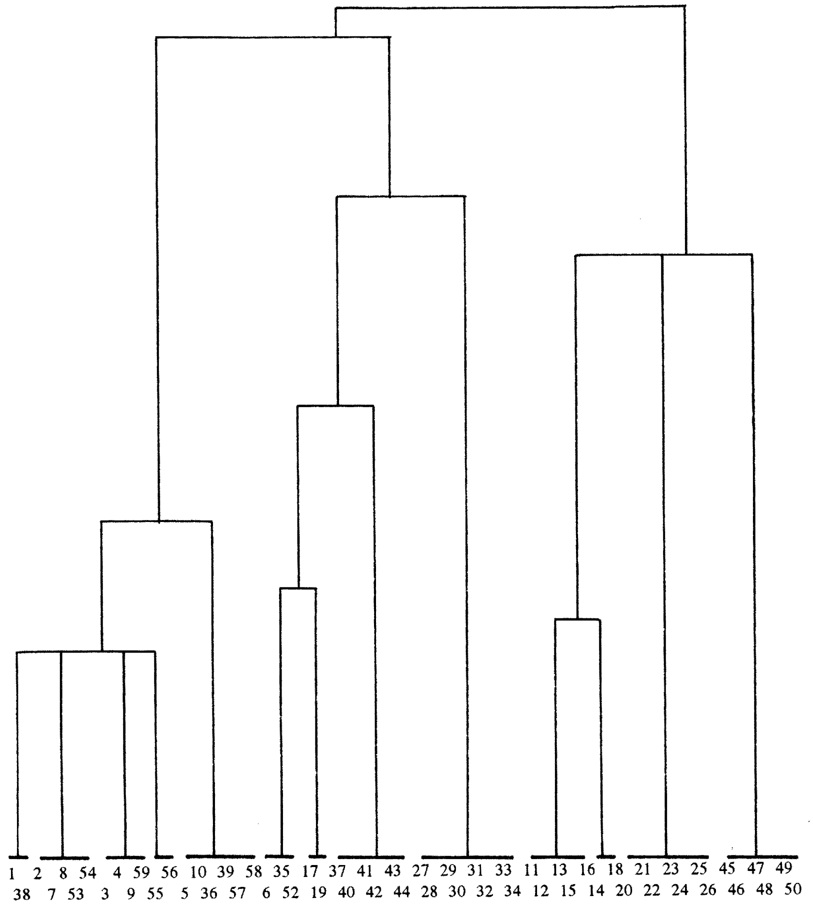

Figure 4. Consensus tree obtained by MINGFC based on MNVAR, UPGMA and MNSSQ dendrograms.

original consensus tree are drawn (Clusters 1, 2 and 3 in Fig. 5).

The final results are presented in Figure 5 and the final synthetic table in Table 4. The dendrogram was obtained with MINGFC. The taxa in this table have been sorted by ranking. The floristic groups in Table 4 are as follows:

Group 1: Tables of the calcareous units, from Cerro del Morrón and Plana de Beratón are fused with table 38 from Purujosa. Table 38 is in this group, probably because the relevés were taken from northern slopes. This group contains relevés from more or less clayey limestones, softer and prone to easy weathering than those from the localities in group 2. There are some places with these lithologic characteristics also in Plana de Purujosa, but they are more thermic than these in group 1, and for that reason they sustain communities of *Asplenietalia petrarchae.* These are considered in group 6.

Group 1 is obviously related to the communities of the *Lonicero-Rhamnetum alpini* and the *Saxifragetum segurae-moncayensis* (Navarro 1990). There are no exclusive floristic faithfuls, although among the shared species there are many with constancy values higher than those in the neighbouring groups. Typical rupicolous plants also occur, such as *Silene boryi* subsp. *barduliensis, Crepis albida and Hormathophyl-*

Table 3. Inertia at selected partitions. I_{CCA} is the inertia associated with the CCA and ICA with CA. I_{CCA}/I_{CA} is the total information acconated for each partition. $I_{CCA}/n\text{-}1$ is the information after reducing the dimensionality. It is clear that all partitions have the same ICA. Other symbols: n= the number of clusters, A= partition level of 10 clusters, B= 16 clusters.

	A			B,		
	I_{CCA}	I_{CCA}/I_{CA}	$I_{CCA}/n\text{-}1$	I_{CCA}	I_{CCA}/I_{CA}	$I_{CCA}/n\text{-}1$
UPGMA	3.73	0.37	0.46	5.17	0.51	0.37
MNVAR	3.51	0.34	0.44	5.14	0.50	0.34
MISSQ	3.59	0.35	0.45	5.10	0.49	0.34

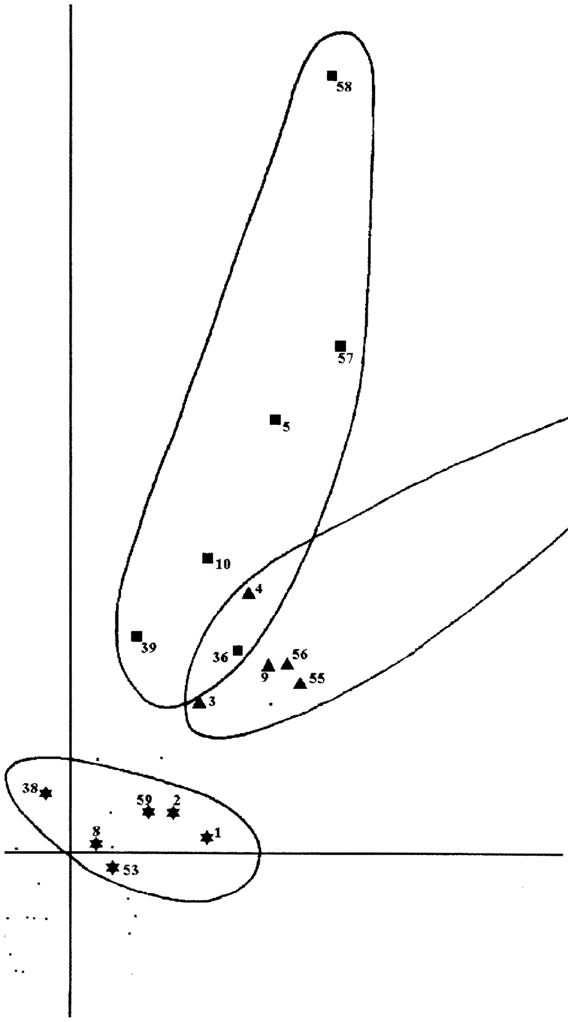

Figure 5. Principal Components Analysis of the Original Synthetic Table showing the distribution of the local tables of groups 1, 2 and 3 on the two first components.

la spinosa. Subrupicolous elements (Snogerup 1971) from the *Berberidion* such as *Rhamnus alpina* and *Lonicera pyrenaica,* appear.

Group 2: This group contains relevés from the Plana de Beratón and Cerro del Morrón. These generally represent rupicolous and chasmophytic communities, highly conditioned by substrate, always grey hard limestones, and exposure, on high altitude or extreme exposed sites. These charasteristics exclude the plant species of Purujosa, except for some of the plants from the deep gorges running accross the Plana de Purujosa. The relation of this group with the *Globulario-Saxifragetum longifoliae* is evident (see Navarro 1990).

There are no exclusive faithfuls in this group, although some of the plants shared with neighbouring groups give much information about their niches. Included among the species shared with group 3 are *Anthyllis montana* and *Poa ligulata,* although the latter has very low constancy. The group of calcareous stone fields shares *Festuca scoparia* and *Hieracium amplexicaule* with the siliceous cliffs group. Among the species shared with the first three groups and showing high constancy values there are *Globularia repens*, with high values also in the precacuminal community tables of group 3, *Hieracium elisaeanum* and *Iberis saxatilis*.

Group 3: Among the three calcareous groups recognized in PCA, this is the most homogeneous floristically and ecologically. They are communities having predominantly hemicryptophytic biotypes with a high percentage of psicroxerophyllous elements. Species of this group prefer the summits and other exposed environments with cryo-disturbed soils that are located only in northern exposures in the Muela de Purujosa.

Many of the discriminant species are from the discontinuous pastures, the *Androsaco villosae-Festucetum hystricis* (Navarro 1990, Rivas-Martínez *et al.* 1991), like *Teucrium expansum* and *Carex humilis,* while others are shared with the preceding groups but with highest constancy values in this group. These include *Festuca hystrix, Seseli montanum, Thymus praecox* subsp. *britannicus* and *Koeleria vallesiana.*

Group 4: This group includes tables with the most specialized taxa that form communities that overhang calcareous cliffs. One table represents each of the three calcareous units, Purujosa, Beratón and Cerro del Morrón. Sometimes the tables are outliers of intra-unit classification because of their unusual components. The three always appear together in the dendrograms.

The most important faithful species are the specialized rupicolous pteridophytes such as *Asplenium trichomanes* subsp. *pachyrachis and Asplenium celtibericum* together with the local endemic *Chaenorhinum segoviense* subsp. *semiglabrum,* and the ferns *Asplenium ruta-muraria* and *Asplenium trichomanes* subsp. *quadrivalens*. These are also scattered through others groups. The group is a phytosociological relative of the supramediterranean *Chaenorhino-Asplenietum* (Navarro 1990) and the mesomediterranean *Asplenio-Sarcocapnetum chaenorrhinetosum semiglabri* (Escudero 1992).

Group 5: This group is species poor. It only includes two tables, containing relevés from the most humid zones of the siliceous Moncayo. One of the tables is from the stone fields and the other from the cliffs. The communities are humicolous and pteridophytic with high cover values of ferns with large fronds. They occupy the ground either at the bottom of the morrenic blocks of rocks or crevices on the more shaded cliffs. The discriminant species include *Polystichum aculeatum, Dryopteris oreades* and some populations of the orophyllous forms of *Poa nemoralis.*

Group 6: The tables in this group contain relevés of the Plana de Purujosa. It is noted that tables 36, 38 and 39 occur in other groups as well, due to the northern exposure of the sites.

The unit of group 6 are located at altitudes 900-1200 m, thermophilous species are abundant and many of them are

Table 4. Synthetic table of the saxicolous communities in the Sierra del Moncayo. The classification is based on dendrograms in Figure 3. Species are sorted following Jancey's discriminating value (F ≥ 3).

	1	2	3	4	5	6	7	8	9	10
	3 55	555	13355	35	11	344444	22233333	1111111	2222222	444445
	1827834	349569	506978	652	79	701234	78901234	1234568	0123456	567890
Asplenium pachyrachis	....	1	......	443	..	......	....	....	....	......
Stipa offneri	....	......	......	...	..	253252	....	....	....	......
Stipa parviflora	....	......	......	...	..	...2..	55545534	....	....	......
Polystichum aculeatum	....	......	......	...	34	......	....	....	.11....	......
Rumex scutatus	....	......	......	...	1.	......	....	5555524	.21....	552545
Deschampsia iberica	....	......	......	...	..	......	....	1445443	43313.2	......
Silene cf. glareosa	....	......	......	...	..	......	....	....	....	414533
Anthyllis montana	....	243.13	443354	...	..	.2....	....	....	....	......
Sedum brevifolium	....	......	......	...	..	......	....	1..1.4.	4453555	......
Euphorbia characias	...2...	......	......	...	..	223354	...1....	....	....	......
Helianthemum incanum	....1..	121.12	543254	...	..	.1....	....	....	....	1
Arrhenatherum bulbosum	..1..21	......	......	...	12	......	....	3453422	12..1..	......
Lonicera pyrenaica	4543425	424.55	135112	435	..	......	....	....	....	.1....
Globularia repens	2.22211	535354	555422	...	..	.311..	....	....	....	......
Festuca hystrix	....	.1.314	532355	...	..	......	....	....	....	......
Silene ciliata	....	......	......	...	..	......	....	1	4214512	......
Chaenorrhinum semiglabrum	..453.1	......	..1...	555	..	1.....	....	....	....	......
Phagnalon sordidum	....	......	......	...	..	32222.	....	....	....	......
Galeopsis carpetana	....	......	......	...	..	......	....	543.423	....	......
Festuca cf. costei	....	......	......	...	..	......	....	....	1232.22	......
Hormatophylla spinosa	.533455	11131.	..33.1	312	..	435334	....	....	....	113223
Poa ligulata	....	111221	12	...	..	......	....	....	....	......
Melica minuta	...51..	.1....	......	...	..	525425	....	....	....	......
Amelanchier ovalis	2322211	115212	154222	.1.	..	331132	....	....	....	....1.
Arrhenatherum baeticum	....	......	......	...	..	......	....	....	....	43255.
Melica magnolii	....	......	......	...	..	2	..1.....	....	....	112131
Teucrium expansum	..1....	...3.2	432345	...	..	......	....	....	....	..3...
Festuca aragonensis	....	......	......	...	..	......	....	..1.211	51334.5	......
Galium fruticescens	....	..1...	......	...	..	21321.	.2542354	....	....	..323.
Sedum dasyphyllum	2312222	31342.	.2.2.2	2.1	..	315322	....	....	....	......
Dryopteris oreades	....	......	......	...	52	......	....	...1...	...3.1.	......
Hieracium elisaeanum	212.21.	312222	.33.2.	21.	..	......	....	....	....	......
Agrostis rupestris	....	......	......	...	..	......	....	....	121.21.	......
Asplenium ceterach	.1.2.11	.2121.	......	2.1	..	313223	....	....	....	...1..
Asplenium rutamuraria	..1....	.112.1	..1...	412	..	.2...2	......1.	....	....	......
Sedum sediforme	.5..232	.2352.	2.23..	...	..	32214.	42513434	....	....	..2...
Rosmarinus officinalis	....	......	......	...	..	......	..412351	....	....	......
Digitalis purpurea	....	......	......	...	12	......	....	231.2.2	.211...	......
Coronilla clusii	....	......	......	...	..	.2.122	....	....	....	......
Seseli montanum	..12..1	..122.	232421	...	..	.1....	....	....	....	1
Reseda lutea	...2...	..1...	.2....	.1.	..	1..11.	412134.4	....	....	......
Thymus vulgaris	.3.2312	13335.	33552.	...	..	433354	.1543254	....	....	.12.32
Alchemilla saxatile	....	......	......	...	1.	......	....	4	2113242	......
Asplenium celtibericum	....	......	......	3.5	..	......	....	....	....	......
Umbilicus rupestris	....	......	......	...	12	......	....	1......	.21....	......
Veronica fruticans	....	......	......	...	.2	......	....	11	41.2111	......
Saxifraga pentadactylis	....	......	......	...	.2	......	....	....	.3.1355.	......
Carex humilis	....	......	.21.24	...	..	......	....	....	....	......
Pistacia terebinthus	....	......	......	...	..	3131..	....	....	....	......
Cochlearia aragonensis	....	......	......	...	..	......	....	....	....	552..4
Santolina chamaecyparissus	...2322	11.2..	2311..	...	..	332142	....	....	....	....2.
Silene boryi	3.5.521	.11..1	......	2..	..	......	....	....	.1.....	2
Paronychia kapela	.1..2..	.23441	42.422	...	..	.1....	....	....	....	.33..3
Erinacea anthyllis	.21.122	233222	533425	...	..	.4113.	....	1.1.41.	2	.33..5
Rhamnus alpina	..3.215	3.3353	....1.	3.3	..	......	....	....	....	.1...3
Koeleria vallesiana	12	.34334	433555	...	..	11.2..	5.....14	....	....	.24.22
Hieracium amplexicaule	5.....1	122221	..1...	.1.	..	......	....	..11..1	1211532	......
Erysimum gx. grandiflorum	....	......	11	...	..	......	....	..1.3..	.1.....	242.22
Antirrhinum barrelieri	...3...	..1...	.2....	.1.	..	31111.	.343322.	....	....	..2...
Iberis saxatilis	2...1..	333.15	2...34	...	..	..1...	....	....	....	1
Anthyllis vulneraria	....	.11221	2..222	...	..	....1.	....	....	....	..3...
Coronilla minima	....	.1..11	4..121	...	..	......	....	....	....	......
Rubus idaeus	....	......	......	...	13	......	....	1.55.1.	1232...	......
Helychrysum stoechas	....	......	..1...	...	..	......	.21.1.21	....	....	......
Ranunculus ollisiponensis	....	......	......	...	1.	......	....	....	.2.212.	......
Sedum hirsutum	....	......	......	...	.2	......	....	....	.44.5.2	......
Conopodium pyrenaeum	....	......	......	...	1.	......	....	....	....	......
Lactuca tenerrima	...3...	......	......	...	..	......	....	....	....	......
Helianthemum cinereum	....	......	......	...	..	.1.1..	..4.1241	....	....	......
Piptatherum coerulescens	....	......	......	...	..	2..42.	.12412.1	....	....	......
Festuca gautieri	..1....	3..2.2	......	...	..	......	....	....	....	252..4
Rumex angiocarpus	....	......	......	...	..	......	....	4...342	111..14	......
Asplenium trichomanes	3..2...	1	......	311	12	..3..3	....	.2.3...	.3.....	......
Ruta angustifolia	....	......	......	...	..	1.124.	.12.1.1.	....	....	......
Jasonia glutinosa	...5...	......	......	2..	..	23232.	...1332.	....	....	......
Globularia vulgaris	...31..	.11...	...3..	...	..	.32222	......1.	....	....	......
Bupleurum fruticescens	....1..	1.1...	2.42..	...	..	212242	..1...4.	....	....	......
Hieracium glaucinum	....	......	......	...	1.	......	....	.2...11	.12113.	......
Biscutella pyrenaica	....	......	......	...	..	......	....	..31..2	321..11	......
Asplenium septentrionale	....	......	......	...	.2	......	....	....	.31..31	......
Scandix stellata	....	......	......	...	..	......	....	....	....	12...2
Polypodium vulgare	....	......	......	...	.5	......	....	...3...	.42211.	......
Armeria bigerrensis	....	......	......	...	.2	......	....	1	42.4.4.	......
Conopodium ramosum	2......	......	......	...	..	......	....	....	1......	23.1.2
Thymus britannicus	..1....	12..43	4.1.33	...	..	......	....	....	....	.1...3
Lavandula latifolia	1	.11...	2224..	...	..	23.143	....1.42	....	....	......
Ptychotis saxifraga	....	......	......	...	..	......	....	....	....	11...1
Linaria alpina	....	......	......	...	..	......	....	2.1.4.5	....	......
Crepis albida	..32425	.22241	..22.1	...	..	.2..2.	....	....	....	113...
Juniperus phoenicea	.31...1	.1....	3334..	.1.	..	351223	1514	....	....	......
Globularia alypum	....	......	......	...	..	......	..3123..	....	....	......
Poa nemoralis	5.1....	......	......	...	15	..1...	....	.2.5..1	1324.3.	......
Cerastium arvense	....11.	...2..	......	...	..	......	....	2.1.422	.225.31	14...5

shared with the Los Fayos unit. *Phagnalon sordidum* and *Melica minuta* stand out in this group as typical rupicolous plants, but there are also typical chamaephytes such as *Euphorbia characias, Stipa offneri* and *Coronilla minima* subsp. *clusii*. Among the characteristic elements, a nanophanerophyte with rupicolous niche, *Pistacia terebinthus* has high constancy values and a tree-like habit.

There are species shared by all the calcicolous groups. All of them are chamaephytes from the *Sideritido-Salvion* (Molina 1984). These with highest constancy values in group 6 include *Lavandula latifolia, Bupleurum fruticescens, Globularia vulgaris, Thymus vulgaris* and *Santolina chamaecyparissus*.

Group 7: This is a very compact and homogeneous group. All the tables from Los Fayos (conglomerate unit) are included. The rupicolous elements are very uncommon because of the nature of the conglomerate substrate which do not support chasmophytes. This is not the case with some xerothermophylous taxa that in fact use these cliffs as real refugia since the Tertiary period, and with some steppic taxa that extend up from the Ebro depression to this xeromorphic habitat (Montserrat 1975). Among the more or less exclusive descriptors are mentioned, *Stipa parviflora, Reseda lutea, Rosmarinus officinalis* and *Globularia alypum*.

As it would be expected, there is a large group of plants included in this group and related to the most thermic calcareous localities of Purujosa. Some of these may be considered as rupicolous *sensu amplo* such as *Anthirrhinum barrelieri, Jasonia glutinosa, Piptatherum coerulescens* and *Galium fruticescens*, occurring also in the calcareous stone fields. Some other species are woody chamaephytes such as *Helianthemum cinereum* and *Ruta angustifolia*.

Group 8: All the tables from the siliceous stone fields are included in this group, except number 17. Discriminant species are specialized, such as *Galeopsis carpetana, Linaria alpina* and *Arrhenatherum bulbosum*. Although there are species that also occur on the calcareous stone fields and on siliceous cliffs. *Rumex scutatus* is an example, considered calcophylous, but it very often occurs in sandstone rocky fields of the Sierra del Moncayo. This might be due to the less restrictive ecological character of the Moncayo sandstones (Carceler 1989). *Rumex angiocarpus, Rubus idaeus, Deschampsia iberica* and *Digitalis purpurea* are some of the species shared with the siliceous cliffs.

Group 9: This group includes all the tables from the siliceous cliffs except number 19 which is included in group 5. The homogeneity of the group is very high. The taxa contained in this group have typical biotypes of the oro- and crioromediterranean belts of the carpetanic siliceous mountains (hemicryptophytic and creeping chamaephytes, Rivas-Martínez 1963, Fernández Gonzalez 1992). All have wide ecological ranges, even though they are not rupicolous specialists. They come up easily in all kinds of vertical habitats. Good examples of the genuine rupicolous elements are *Festuca costei, Silene ciliata, Agrostis rupestris, Alchemilla saxatilis, Veronica fruticans, Ranunculus ollisiponensis, Biscutella pyrenaica, Armeria bigerrensis, Saxifraga pentadactylis, Sedum hirsutum, Sedum brevifolium* and *Hieracium glaucinum*.

Group 10: This is another homogeneous group recognized by the classification methods. It includes all the tables from calcareous stone fields, and species of decumbent biotypes, with long and flexuous stems, adapted to the stone movements, such as *Cochlearia aragonensis, Conopodium majus* subsp. *ramosum*, or a form of *Erysimum* gr. *grandiflorum* very close to *Erysimum gorbeanum*.

Some species with broader ecological requirements are able to accumulate a thin soil (turf building and stone field retention). Of these species we must mention: *Festuca scoparia*, (not exclusive of this habitat), *Arrhenatherum baeticum*, (with deep buried bulbs and aerial stems capable of reducing the gravitational gradient), or *Ptychotis saxifraga*. *Scandix stellata*, a steppic therophyte, is very common probably as a consequence of the intensive grazing.

Discussion

The seven geomorphological units under study are clearly distinguished by their floristic composition, except groups 1, 2 and 3, which have been difficult to delineate. The siliceous stone fields, siliceous cliffs, conglomerates from Los Fayos and calcareous stone areas have been separated with no difficulty. Groups 1, 2 and 3 come from calcareous units. The Plana de Purujosa unit, also calcareous, is almost isolated out as group 6. Groups 2 and 3 are closely related ecologically. They have plants which grow in cacuminal and precacuminal areas. Whereas group 2 prefer vertical localities, group 1 has a different lithological substratum and it is conditioned by exposure. The communities on the south slopes of the Cerro del Morrón belong to the oromediterranean belt, and they remain clustered together with the communities on northern cliffs of the Muela de Beratón which as a unit extends over the supramediterranean belt. This transitional character is due to the similarities of their geomorphological patterns. The Plana de Purujosa unit located in the mesomediterranean belt is the only one where the floristic composition changes, due to thermophytic conditions. The rest of the groups are independently clustered; only group 5, with a large pteridophytic component, allow establishment of the transition between both siliceous units, cliffs and stone fields. This is a consequence of high water-table and edaphic growth. The ecological requirements of both systems, cliffs and stone fields are basically different, for that the number of shared species is low.

Our results, from a phytosociological point of view, reinforce the results of Navarro (1989, 1990). They show the individualistic character of all the geomorphologic units sustaining exclusive plant communities with specialized floristic elements. Only over the three calcareous units can one recognize a clear gradient related to the altitude, along which the communities occur with gradual floristic changes.

Traditionally, manual sorting has been the means to constructing synthetic floristic tables. Numerical approaches (see Wildi 1989 and Mucina and van der Maarel 1989) help making up these tables with emphasis on duality of cluster cohesion and separation. However, the users of these techniques have to face the usual problems of choosing among algorithms, resemblance functions and data transformation (Kovar and Leps 1986). Authors often exaggerate the objectivity of these numerical methods. Only, if an obvious group structure is present in the data the use of an unique method could give an optimal interpretation (Lefkovitch 1985). Therefore, if one wants to avoid an overinterpretation of the results, one way is to look for a consensus solution (Podani 1989a). It seems clear that our scheme is a useful tool to manage synthetic tables, a quintessential objective of phytosociological studies (Westhoff and van der Maarel 1978, Mucina and van der Maarel 1989). This scheme finds and optimal solution among a number of partial results handed to the user by different clustering tecniques. It is important to point out that optimality does not always mean uniqueness (Podani 1989a).

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