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Patterns of community and species diversity in grassland vegetation of the southwestern Iberian System (Spain)

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Abstract: Rodríguez-Rojo, M.P., Sardinero, S. & Fernández-González, F. *Patterns of community and species diversity in grassland vegetation of the southwestern Iberian System (Spain). Lazaroa 34: 219-236 (2013).*

This paper reports a floristic and phytocenologic review of the mesic and dry grasslands of the southwestern Iberian Mountain System (Spain) based on numerical and indicator species analysis. The crispness of classification was checked resulting in four main groups that classify grasslands in mesic (*Molinio-Arrhenatheretea* and *Nardetea*), semi-dry calcareous (*Festuco-Brometea*), dry calcareous (*Sideritido fontquerianae-Arenarion microphyllae*), and dry siliceous grasslands (*Hieracio castellani-Plantaginion radicatae*). DCA and CCA were performed on topographic parameters as explanatory variables of the community diversity and differences in variability between communities were also tested with ANOVA. Rock cover and slope best explained the differences in the floristic composition between the main vegetation groups, and for the discrimination of the dry cryoturbated grasslands (*Sideritido-Arenarion*) from other types of grasslands, while altitude best discriminated some associations belonging to the same main vegetation group, such as the semi-dry grasslands (*Cirsio microcephalae-Onobrychidetum hispanicae* and *Festuco andresmolinae-Brachypodietum phoenicoidis*) and dry grasslands of upfrozen soils (*Festucetum hystricis* and *Paronychio capitatae-Artemisietum assoanae*). The exploration of the diagnostic species in combination with the topographic patterns of the community diversity brought out the phytosociological interpretation of transitional communities, like the case of *Festucetum hystricis* variant semi-dry with *Plantago maritima* subsp. *serpentina*.

Keywords: Classification, Canonical Correspondence Analysis (CCA), Detrended Correspondence Analysis (DCA), Pastures, Species richness, Topography.

Resumen: Rodríguez-Rojo, M.P., Sardinero, S. & Fernández-González, F. *Patrones de diversidad fitocenótica y florística en los pastizales del Sistema Ibérico suroccidental. Lazaroa 34: 219-236 (2013).*

Se ha realizado una revisión florística y fitocenológica de los pastizales mesófilos y xerófilos del Sistema Ibérico suroccidental, basada en análisis numéricos y de especies diagnósticas. La mayor nitidez de la clasificación se obtiene con cuatro grandes grupos que clasifican los pastizales en mésicos (*Molinio-Arrhenatheretea* y *Nardetea*), calcícolas semi-xerofíticos (*Festuco-Brometea*), calcícolas xerofíticos (*Sideritido fontquerianae-Arenarion microphyllae*) y silicícolas xerofíticos (*Hieracio castellani-Plantaginion radicatae*). Las variables topográficas se incluyeron en las ordenaciones (DCA y CCA) como posibles variables explicativas de la composición florística, y las diferencias topográficas entre grupos se analizaron mediante ANOVA. La cobertura de rocas y la pendiente han resultado ser las variables que mejor explican las diferencias en la composición florística entre los cuatro grandes grupos y para la discriminación de los pastizales xerofíticos crioturbados (*Sideritido-Arenarion*), mientras que la altitud se interpretó como un factor discriminante entre algunas asociaciones, como los prados meso-xerofíticos (*Cirsio microcephalae-Onobrychidetum hispanicae* y *Festuco andresmolinae-Brachypodietum phoenicoidis*) y los pastizales secos crioturbados (*Festucetum hystricis* y *Paronychio capitatae-Artemisietum assoanae*). El análisis de especies diagnósticas en combinación con los patrones topográficos de diversidad fitocenótica sirvieron para la interpretación fitosociológica de comunidades transicionales, como es el caso de la variante de ambiente semiseco de *Festucetum hystricis* con *Plantago maritima* subsp. *serpentina*.

Palabras clave: Clasificación, Análisis de Correspondencia Canónica (CCA), Análisis de Correspondencia sin tendencias (DCA), Pastos, Riqueza florística, Topografía.

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INTRODUCTION

Plant diversity patterns in grasslands have been for a long time a question of attention for management and conservation purposes. Several studies have dealt with the soil pH, altitude, topography (aspect and slope), and grazing intensity, as the main local abiotic factors influencing the variation of the plant species composition and species richness (CRICHTLEY & *al*., 2002; AMEZAGA & *al*., 2004; BENNIE & *al*., 2006; KLIMEK & *al*., 2007; MARINI & *al*., 2007; JIMÉNEZ-ALFARO & *al*., 2013). Topography has a strong effect on local hydrology and additionally affects patterns in local temperature and irradiation, as well as, local exposure to wind (MOESLUND & *al*., 2013); thus, it is considered an indirect factor for shaping local grassland vegetation patterns. Mechanisms controlling plant species richness in grasslands in Europe have been explained by the positive effect of slope angle (MAURER & *al*., 2006; KLIMEK & *al*., 2007; MARINI & *al*., 2007), and the negative effect of soil acidification and altitude (PIQUERAY & *al*., 2007; KOPÉC & *al*., 2010). Over the worldwide, the soil pH pattern may be different across floristic regions because the direction of the relationship between richness and pH depends on whether the species pool has its evolutionary origin on soils of high or low pH (PÄRTEL, 2002). In Europe, it may be also considered that the higher contemporary calciphile to acidiphile richness ratio corresponds to a disproportionate decline of acidic habitats and their flora during the ice age times (EWALD, 2003), which would also explain that the majority of the central European flora is restricted to base rich, calcareous soils.

The diversity of grasslands in the southwestern Iberian Mountain System s.l. has been reported in some traditional phytosociological studies (LÓPEZ GONZÁLEZ, 1978; BARRERA, 1985; RODRÍGUEZ-ROJO & *al*., 2010, 2011, 2012). They pointed out important levels of community diversity and originality in this territory, as a consequence of a varied lithology, including calcareous and siliceous substrates (limestone, dolomites, slates, quartzites, red sandstones, albian sands, etc), combined with a complex relief that also appear in near mountains (RIVAS GODAY & BORJA, 1961; GAVILÁN & *al*., 2012). Some mesic and dry grasslands are included in the Catalogue of Habitats of Special Protection in Castilla-La Mancha (Nature Conservation Law 9/1999) or in the Annex I of Habitats Directive (92/43/EC): semi-dry calcareous grasslands (*Festuco-Brometea*), *Nardus stricta* swards (species-rich *Nardus* grasslands), cryoturbated calcareous grasslands (alpine and subalpine calcareous grasslands). The cryoturbated calcareous grasslands colonize the ridges and slopes of the highlands, mesic grasslands fill the valley bottoms and basins, while semi-dry grasslands occupy a transitional range among both extremes but their topographic affinity has not been properly defined (RODRÍGUEZ-ROJO & *al*., 2010).

Because of the varied lithology combined with the complexity of relief given in this territory, and under the current moderate grazing intensity and no mowing practices, we hypothesize that the main floristic gradients in the mesic and dry grasslands should be related to lithological and topographic factors, and that these can serve as good predictors of species composition. According to this, our study develops an application of numerical and indicator species analyses on dry and mesic grasslands in the southwestern Iberian System in order to give responses to the following issues: (1) to determine the main vegetation types of these grasslands, (2) to compare the resulting classification with that used traditionally by previous authors, (3) to determine the diagnostic species of each vegetation type, and (4) to assess how far topographical (slope, aspect, rock cover and altitude) and lithological factors may discriminate the community diversity and the patterns of species richness in these grasslands.

MATERIAL AND METHODS

STUDY AREA

The main rangelands prospected were Sierra de Albarracín, Sierra de Valdemeca and Serranía de Cuenca, which according to the geomorphological sectorization of GUTIÉRREZ & PEÑA (1994) belong to the central sector and southwestern area of the Iberian System (Cordillera Ibérica) (Figure 1). The

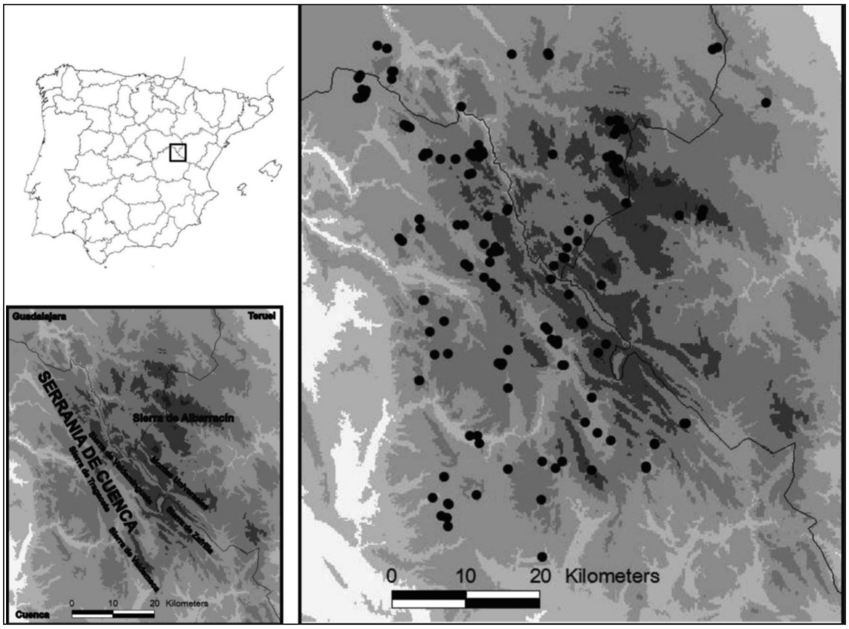

Figure 1. – Location of the study area and distribution of the sampled relevés.

highest altitude is registered in Caimodorro peak (1920 m asl). According to the bioclimatic typology of RIVAS-MARTÍNEZ (2007), the territory is in the transition between the macrobioclimates Mediterranean, in the lowlands, and Temperate (submediterranean variant) in the uplands (Figure 2). The bioclimatic belts of the study area correspond to the upper supramediterranean, upper suprasubmediterranean and lower orosubmediterranean, with ombrotypes ranging from upper subhumid to upper humid. Biogeographically, the territory is framed into the Maestracensean and Celtiberian-Alcarrean sectors, Mediterranean Central Iberian province (RIVAS-MARTÍNEZ, 2007).

DATA SAMPLING

Field sampling was carried out from 2009 to 2012 during summer (mid-June to late-July). We used orthoimages, forestry maps, topographic maps and geologic maps to locate a network of grassland areas of a certain extension that were also representative of the whole territory in terms of the geological and altitudinal variation. The

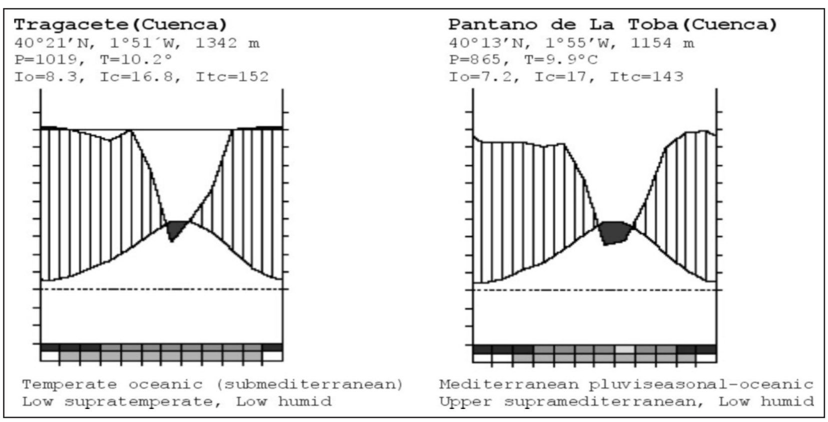

Figure 2. – Climatic diagrams in the southwestern Iberian System (RIVAS-MARTÍNEZ, 2007).

distribution of the sampled sites in the selected areas was designed to cover the lithological, topographical and altitudinal variation in every one of them. Most of the areas were located in the Serranía de Cuenca and Alto Tajo (Cuenca and Guadalajara provinces), while Sierra de Albarracín (Teruel) was prospected in order to complete the representation of siliceous grasslands (Figure 1). Plot size was fixed as a rule in 10x10 m2. Plant cover indices were visually estimated in percentage values (0.1, 1, 5, 10, 20, 30, 40, 50, 60, 70, 80, 90 and 100%). Altitude, slope, exposure, rock cover and bare soil cover percentages were recorded in each plot, as well as, other supplementary data (total plant cover, livestock type, grazing system, etc.). Taxonomic nomenclature follows the proposals of *Flora iberica* (CASTROVIEJO & *al*., 1986-2012) except for *Compositae* and *Poaceae* taxa that follow the Euro+Med PlantBase (Euro+Med, 2006-2013 ww2.bgbm.org/EuroPlusMed/ [accessed *4-4-2013*]).

NUMERICAL ANALYSES

Several types of agglomerative and divisive classification were applied to the final dataset of 160 relevés and 408 species, including the beta-flexible linkage method (beta= -0.25) with Sorensen distance, Ward´s method with relative Euclidean, and TWINSPAN modified according to ROLEČEK & *al*. (2009) with three pseudo-species cut-off levels (0%, 5% and 25%) and total inertia as a heterogeneity measure. Percentage cover values were log-transformed in order to reduce the importance of dominant species (VAN DER MAAREL, 1979), excepting for the application of TWINSPAN algorithm that uses pseudo-species cut-off levels. After examining several partitions of the data set, we selected the partition with beta-flexible clustering that produced the less-chained dendrogram and more homogeneous clusters with respect to the ordination (DCA) of the same dataset. The number of clusters accepted corresponds to the alliances traditionally recognized in the literature. Nevertheless, the crispness of classification was checked using the method suggested by BOTTA-DUKÁT & *al*. (2005) that revealed that crispness is higher at the level of four clusters and decreases gradually when the number of clusters increased. Centroids of each cluster were calculated using the Euclidean distance and 5 relevés were reassigned according to their relationship to the nearest cluster centroid. The cluster membership of these 5 relevés was also checked in the DCA scatter plot.

For the calculation of diagnostic species values, the size of the clusters was standardized to equal size of 15% of the data set (TICHÝ & CHYTRÝ, 2006). We only show the diagnostic species with values of the Φ-coefficient of association ≥ 0.25 for at least one cluster and with a statistically significant affinity at the probability level <0.001 according to Fisher´s exact test.

Using canonical correspondence analysis (CCA), the relationships between altitude, south exposure, west exposure, slope, rock cover and altitude with species composition of the vegetation data were tested. Previously, all these environmental variables were passively projected onto the DCA diagram. The power of each explanatory variable was also tested with a Monte Carlo permutation test (reduced model, 999 permutations) and a forward manual selection procedure was used to select the most important variables. Differences in altitude among particular vegetation types were tested with the Tukey post-hoc test following one-way ANOVA, while differences in slope and rock cover were tested with Kruskal-Wallis ANOVA by Ranks applied for variables with a non-gaussian distribution. An attribute plot showing changes in species richness along the first two DCA axes was constructed applying a Generalized Additive Model (GAM), using Poisson distribution and testing for nonlinearity.

Numerical analyses were performed with JUICE 7.0 software (TICHÝ, 2002) combined with PC-ORD v.5 (MCCUNE & MEFFORD, 1999) for Cluster Analysis, and CANOCO 4.5 package (TER BRAAK & ŠMILAUER, 2002) for DCA and CCA.

RESULTS

VEGETATION CLASSIFICATION AND PATTERNS

Ten clusters were considered in the dendrogram that best fit with the classification of the re-

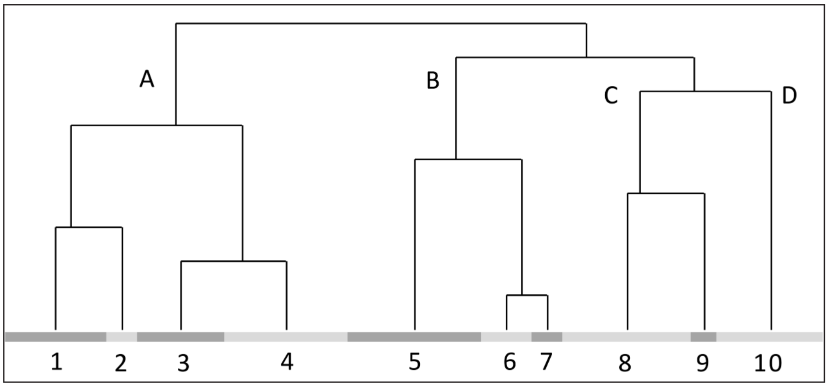

Figure 3. – Dendrogram of the flexible beta clustering (ß= -0.25). The numbers of clusters correspond to the synoptic table.

levés at the association level (Figure 3). However, maximum crispness occurred at the cutting level of the following four groups: A) mesic grasslands (clusters 1-4), B) semi-dry calcareous grasslands (clusters 5-7), C) dry calcareous grasslands (clusters 8-9), and D) dry siliceous grasslands (cluster 10). Frequencies of the diagnostic species in the ten clusters are summarized in Table 1.

The DCA diagram of Figure 4 shows the floristic relationships between these clusters. As gradient length of the first DCA axis was 6.24 standard deviation units, the use of an unimodal ordination is quite appropriate. The first DCA axis was positively correlated with slope and rock cover, and negatively with plant cover. Dry calcareous grasslands were positioned in the positive part of this axis, while mesic grasslands were in the negative part. The second DCA axis showed a positive correlation with altitude and dry siliceous grasslands were positioned in its positive part. South and west components of aspect had a very low correlation with first and second DCA axes. According to the Monte Carlo permutation test, only rock cover, altitude and slope were significant in CCA as explanatory variables of the variation of species composition, corresponding to the former the stronger relationship.

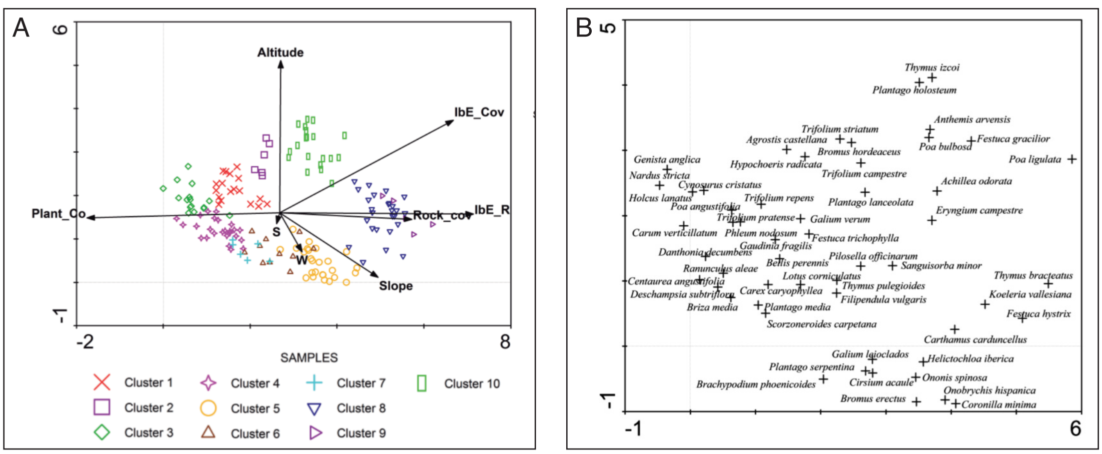

Figure 4. – DCA ordination plots obtained from the vegetation data. Axis 1 and 2 explains the 5.9% and the 4% of the total species variability, respectively. Sample-environment biplot (A) shows the distribution of sites according to the dendrogram clusters (cluster numbers are the same as in Table 1). Environmental variables are: altitude, slope, south component of exposure (S), west component of exposure (W), rock cover, plant cover, total cover of Iberian endemics (IbE_Cov), and species richness of Iberian endemics (IbE_R). Species plot (B) only includes the species with higher weights (>15) along the gradients.

Table 1

Synoptic table of the grasslands studied in the southwestern Iberian System. Columns correspond to the ten clusters obtained in the beta-flexible classification, ordered according to the four main groups. Frequency values of species in every group are shown. Dark grey shaded values indicate Φ values ≥50% and light grey shading values 50% > Φ ≥ 25%.

Higher level group	A	A	A	A	B	B	B	C	C	D
Cluster No.	1	2	3	4	5	6	7	8	9	10
N. of relevés	19	6	16	25	26	11	6	26	5	20
N. order	1	2	3	4	5	6	7	8	9	10
Lolium perenne	63	.	.	16	4	.	.	.	.	.
Trifolium dubium	58	.	31	12	.	9	.	.	.	.
Bromus hordeaceus	74	33	6	4	4	27	.	8	.	40
Cares muricata subsp. *pairae*	37	17	.	4	.	.	.	.	.	.
Phleum nodosum	95	33	56	68	38	27	83	.	.	10
Convolvulus arvensis	47	17	.	4	12	.	33	4	.	.
Trifolium striatum	63	67	.	8	8	.	17	4	.	45
Poa angustifolia	53	.	25	20	8	27	50	.	.	.
Trisetum flavescens	37	.	19	4	.	9	33	.	.	.
Trifolium pratense	63	17	62	52	8	55	33	.	.	.
Festuca trichophylla	89	83	75	84	50	45	83	.	.	20
Trifolium campestre	84	100	19	52	46	55	83	4	.	80
Jasione montana	.	67	.	.	.	.	.	.	.	10
Agrostis castellana	32	100	38	12	.	45	.	4	.	.
Jasione crispa subsp. *sessiliflora*	.	50	.	.	.	.	.	.	.	10
Conopodium pyrenaeum	.	50	12	4	.	.	.	.	.	.
Nardus stricta	11	.	94	.	.	9	.	.	.	.
Genista anglica	5	17	75	.	.	.	.	.	.	5
Anthoxanthum odoratum	.	.	62	12	.	.	.	.	.	.
Juncus squarrosus	.	.	44	4	.	.	.	.	.	.
Carex leporina	5	.	38	.	.	.	.	.	.	.
Carex panicea	5	.	38	.	.	.	.	.	.	.
Cerastium fontanum subsp. *vulgare*	.	.	38	8	.	.	.	.	.	.
Potentilla erecta	.	.	31	.	.	.	.	.	.	.
Stachys officinalis	.	.	44	4	.	18	.	.	.	.
Geum hispidum	11	.	38	.	.	.	.	.	.	.
Luzula campestris	16	17	56	4	4	9	.	.	.	10
Euphrasia hirtella	11	17	56	28	.	18	.	.	.	.
Danthonia decumbens	5	33	62	40	.	27	.	.	.	.
Helictochloa marginata	.	.	38	.	4	.	.	.	.	25
Orchis coriophora	5	17	44	4	.	.	17	.	.	5
Rhinanthus minor	.	.	31	12	4	.	.	.	.	.
Saxifraga granulata	5	.	38	4	.	9	.	.	.	20
Holcus lanatus	32	17	56	16	.	9	33	.	.	.
Scorzoneroides carpetana	11	.	25	52	31	9	.	.	.	.
Centaurea jacea subsp. *angustifolia*	16	.	44	56	4	27	.	.	.	.
Carex caryophyllea	.	33	25	60	4	9	33	.	.	10
Leontodon hispidus	11	33	19	44	.	.	.	.	.	.
Lotus corniculatus	74	33	75	100	73	100	100	4	.	20
Prunella hyssopifolia	5	17	12	44	15	27	33	.	.	.
Coronilla minima	.	.	.	.	81	27	17	27	20	10
Jasonia tuberosa	.	.	.	.	35	.	.	.	.	.
Polygala monspeliaca	5	.	.	.	38	.	17	.	.	.
Carthamus carduncellus	.	17	6	12	77	73	.	42	.	25
Hippocrepis comosa	.	.	.	.	31	9	.	4	.	.
Onobrychis argentea subsp. *hispanica*	11	.	.	.	50	36	17	12	.	5

N. order	1	2	3	4	5	6	7	8	9	10
Helianthemum oelandicum subsp. *incanum*	.	.	.	.	58	27	17	38	20	15
Ononis cristata	5	.	.	4	46	36	.	12	20	.
Leucanthemum pallens	5	.	.	4	31	27	.	.	.	.
Potentilla neumanniana	.	.	.	.	50	55	.	35	20	30
Medicago sativa	21	17	.	.	38	27	17	.	20	.
Bromopsis erecta	5	.	.	.	42	91	17	15	20	5
Thymus pulegioides	16	17	25	20	4	73	17	.	.	15
Trifolium ochroleucon	11	33	19	12	12	64	.	.	.	5
Salvia pratensis	.	.	.	.	4	36	.	12	.	.
Geum sylvaticum	.	.	6	.	23	55	17	8	.	25
Filipendula vulgaris	5	50	56	56	23	82	33	4	.	20
Brachypodium phoenicoides	5	.	.	8	4	45	100	4	.	.
Polygala calcarea	.	.	.	8	.	18	50	.	.	.
Thymus bracteatus	.	.	.	.	50	18	.	96	.	15
Anthyllis vulneraria subsp. *vulnerarioides*	es.	.	.	.	.	.	.	54	.	5
Xeranthemum inapertum	5	.	.	.	8	.	.	81	60	20
Androsace maxima	.	.	.	.	.	.	.	62	40	.
Poa ligulata	.	.	.	.	.	.	.	58	20	15
Arenaria obtusiflora subsp. *ciliaris*	11	.	.	.	4	9	.	46	.	10
Bromus squarrosus	11	.	.	12	4	.	.	58	40	5
Alyssum simplex	.	.	.	.	.	9	.	46	20	10
Carduus assoi	.	.	.	.	4	.	.	46	40	.
Teucrium chamaedrys	.	.	.	.	.	.	.	31	20	.
Marrubium supinum	.	.	.	.	4	.	.	35	20	10
Dianthus pungens subsp. *brachyanthus*	.	.	.	.	4	9	.	46	40	20
Bombycilaena erecta	11	.	.	.	12	9	.	54	80	5
Helianthemum apenninum	.	.	.	.	27	18	17	54	40	15
Armeria alliacea subsp. *matritensis*	.	.	6	16	4	27	.	42	20	5
Arenaria erinacea	.	.	.	.	.	.	.	31	40	.
Crupina vulgaris	.	.	.	.	4	.	.	31	40	.
Convolvulus lineatus	.	.	.	.	12	.	17	35	20	15
Asphodelus cerasiferus	.	.	.	.	4	.	.	31	60	5
Artemisia pedemontana	.	.	.	.	.	.	.	19	100	.
Sideritis hirsuta	.	.	.	.	8	.	.	15	100	.
Phlomis lychnitis	.	.	.	.	4	.	.	4	80	5
Taeniatherum caput-medusae	.	.	.	.	.	.	.	4	60	.
Thymus vulgaris	.	.	.	.	35	.	17	8	80	5
Thymus zygis subsp. *sylvestris*	.	.	.	.	.	.	.	.	40	.
Trigonella gladiata	.	.	.	.	.	.	.	.	40	.
Centaurea paniculata subsp. *castellana*	.	.	.	.	.	.	.	.	40	.
Thymus leptophyllus subsp. *izcoi*	.	.	.	.	.	.	.	.	.	85
Plantago holosteum	5	67	6	.	4	.	.	4	.	100
Scleranthus polycarpos	5	33	.	.	.	9	.	4	.	80
Sedum amplexicaule	16	67	.	.	.	9	.	12	.	95
Potentilla cinerea	5	17	.	.	.	.	.	.	.	65
Evax carpetana	.	50	.	.	.	.	.	.	.	65
Festuca rivas-martinezii	.	.	6	.	.	.	.	.	.	40
Cerastium pumilum	21	.	6	4	8	9	.	31	20	70
Festuca glacilior	.	.	.	.	12	.	.	12	40	55
Petrorhagia prolifera	5	50	.	.	4	9	.	38	20	70
Koeleria crassipes	.	17	.	.	.	.	.	.	.	35

N. order	1	2	3	4	5	6	7	8	9	10
Herniaria cinerea	.	17	.	.	.	.	.	.	.	35
Crucianella angustifolia	.	17	.	.	4	.	.	23	20	50
Trifolium strictum	16	17	6	.	.	.	.	.	.	40
Poa bulbosa	47	17	6	12	12	9	17	38	.	70
Pilosella castellana	.	50	.	.	.	.	.	.	.	40
Carduus carpetanus	11	17	.	.	.	.	.	4	.	30
Achillea odorata	21	33	.	16	62	82	33	50	20	85
Anthyllis vulneraria subsp. *gandogeri*	.	.	.	.	8	.	.	8	40	35
Trifolium arvense	5	33	.	.	.	.	.	.	.	30
Aira caryophyllea	21	67	38	4	.	18	.	.	.	55
Ranunculus paludosus	16	33	12	4	4	9	.	.	.	40
Anthemis arvensis	26	33	6	4	.	9	.	31	20	50
Trifolium repens	95	33	12	72	12	36	17	.	.	35
Cynosurus cristatus	68	.	56	28	.	9	.	.	.	.
Bellis perennis	79	.	44	68	23	9	33	.	.	5
Gaudinia fragilis	42	.	6	36	.	.	.	.	.	.
Hypochaeris radicata	74	100	50	44	12	18	17	.	.	35
Achillea tomentosa	.	83	.	.	.	.	.	8	.	45
Rumex acetosella subsp. *angiocarpus*	11	83	6	.	.	.	.	.	.	75
Logfia minima	5	67	.	.	.	.	.	.	.	40
Carum verticillatum	32	.	94	60	.	.	17	.	.	.
Ranunculus bulbosus subsp. *aleae*	42	.	88	92	27	18	67	.	.	.
Deschampsia caespitosa subsp. *subtriflora*	32	.	75	100	15	27	33	.	.	.
Plantago media	37	.	69	96	23	91	67	.	.	.
Plantago maritima subsp. *serpentina*	5	.	.	60	69	18	.	.	.	.
Briza media	5	.	56	72	4	73	17	.	.	.
Festuca hystrix	.	.	.	.	81	27	.	96	60	5
Koeleria vallesiana	11	.	.	4	100	64	50	100	100	45
Galium estebanii var. *leioclados*	16	.	50	20	77	82	83	4	.	10
Helictochloa pratensis subsp. *iberica*	.	.	.	8	58	73	50	15	40	15
Cirsium acaule	16	.	25	36	62	100	50	8	.	5

Next, a brief description of the vegetation types inferred from the classification, their diagnostic species and the related syntaxa is given (see also the syntaxonomical scheme included after the section of Discussion).

Group A is very heterogeneous and comprises wet meadows and mesic grasslands growing on well-developed soils, usually, at the bottom of valleys and with a 100% plant cover. Cluster 1 includes the southern Oroiberian intensively grazed grasslands of *Phleo nodosi-Cynosuretum cristati* (Rodríguez-Rojo & Fernández González, 2014) characterized by *Lolium perenne, Trifolium dubium, Bromus hordeaceus, Phleum nodosum, Trisetum flavescens, Trifolium striatum, T. campestre*, etc. Cluster 2 includes grasslands growing on siliceous soils moderately wet in spring and characterized by *Agrostis castellana, Jasione montana* and *J. crispa* subsp. *sessiliflora*. Cluster 3 corresponds to *Nardus stricta* swards with *Genista anglica* (*Genisto anglicae-Nardetum strictae*) that grow in deep, siliceous and hydromorphic soils, characterized by a high number of diagnostic species such as *Genista anglica, Nardus stricta, Anthoxanthum odoratum, Juncus squarrosus, Potentilla erecta, Luzula campestris, Carex leporina*, etc. Finally, cluster 4 includes pastures growing on temporarily wet, base-rich and clayey soils, characterized by *Deschampsia cespitosa* subsp. *subtriflora, Leontodon hispidus, Scorzoneroides carpetana, Carex caryophyllea, Centaurea jacea, Prunella hyssopifolia*, etc, and framed into the *Sanguisorbo lateriflorae-Deschampsietum refractae*. Although the presence of *Trifolium repens* and *Bellis perennis* indicates floristic similarities with *Cynosurus cristatus* grasslands, as well as, intensive grazing, *Sanguisorbo-Deschampsietum* is also characterized by *Plantago media* and *P. maritima* subsp. *serpentina*, indicators of the calcareous nature of soils.

Group B represents the typical semi-dry calcareous grasslands of the region (*Festuco-Brometea*). Cluster 6 includes the Oroiberian calcareous grasslands adscribed to *Cirsio microcephalae-Onobrychidetum hispanicae* characterized by *Bromopsis erecta, Thymus pulegioides, Trifolium ochroleucon, Salvia pratensis*, etc; while cluster 7 is related to the *Brachypodium phoenicoides* communities growing in valley bottoms at lower altitudes, which should be framed into the Maestracensean *Festuco andresmolinae-Brachypodietum phoenicoidis*. Cluster 5 represents a transition between the semi-dry grasslands (*Cirsio-Onobrychidetum hispanicae*) and the dry pastures from cryoturbated soils (*Festucetum hystricis*) (Figure 4). Diagnostic species of this cluster are *Coronilla minima, Jasonia tuberosa, Carthamus carduncellus, Polygala monspeliaca, Onobrychis argentea* subsp. *hispanica, Ononis cristata*, etc.; among the diagnostic species shared with *Cirsio-Onobrychidetum* are *Cirsium acaule, Helictochloa pratensis* subsp. *iberica* and *Galium estebanii* var. *leioclados*. *Festuca hystrix* and *Thymus bracteatus* denote the xerophytic character of this type of grasslands and its relationship with cluster 8. *Plantago maritima* subsp. *serpentina* is characteristic of clayey or loamy soils, lightly humid and basic to saline (PEDROL, 2009), and it denotes the typical substrates associated to these grasslands. The slope arrow in the DCA diagram points towards this cluster, and the ANOVA test showed significant differences in slope with respect to cluster 6 (semi-dry grasslands) but not to cluster 8 (dry grasslands) (Figure 5).

Group C contains the most typical Oroiberian short and sparse grasslands proper to upfrozen soils and framed into the *Sideritido fontquerianae-Arenarion microphyllae*. Cluster 8 corresponds to the *Festucetum hystricis*, characterized by *Thymus bracteatus, Anthyllis vulneraria* subsp. *vulnerarioides, Poa ligulata, Carduus assoi, Dianthus pungens* subsp. *brachyanthus, Armeria alliacea* subsp. *matritensis*, etc. Cluster 9 corresponds to the *Paronychio capitatae-Artemisietum lanatae*, mainly characterized by *Artemisia pedemontana*. The arrow corresponding to rock cover points towards these two clusters in the DCA diagram (Figure 4). According to the ANOVA test, rock cover is significantly higher in

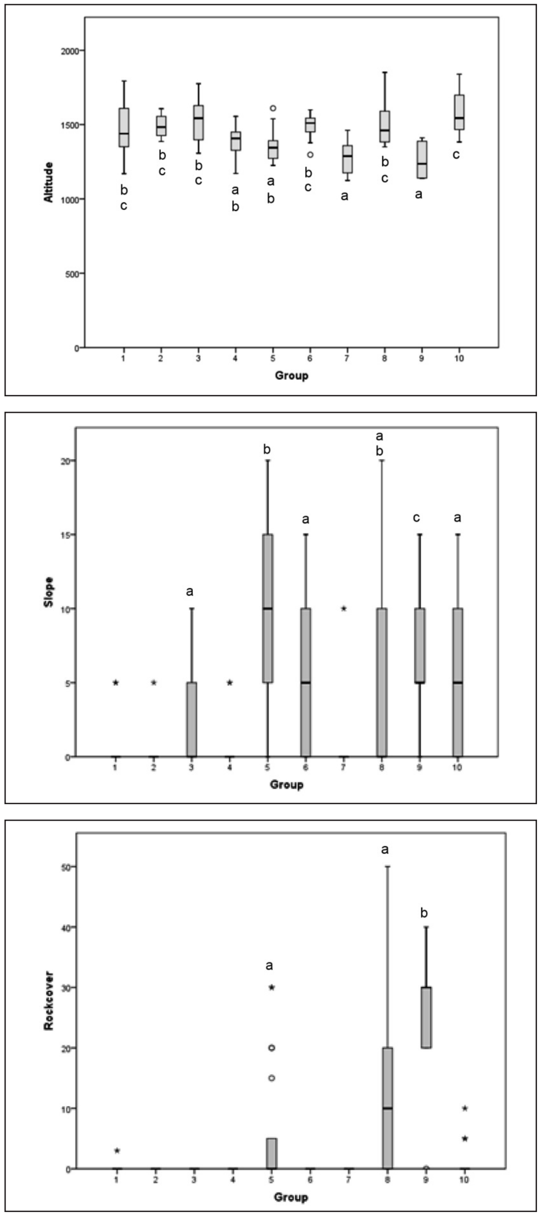

Figure 5. – Box-and-whisker plot of altitude, slope and rock cover in the ten clusters obtained in the beta-flexible classification (cluster numbers are the same as in Table 1 and text). Post hoc comparisons were tested with ANOVA (Tukey for altitude and Kruskal-Wallis by ranks for rock cover and slope; p values considered for significance are <0.05).

these two clusters, excepting for cluster 5 (transitional to semi-dry grasslands) (Figure 5). The xerophytic character of this group is reflected by the high number of annuals among its diagnostic species (*Xeranthemum inapertum, Androsace maxima, Alyssum simplex, Bombycilaena erecta*, etc). Richness in Iberian endemics is also correlated with rock cover (Figure 4). The endemic diagnostic species for group C are *Arenaria erinacea, Arenaria obtusiflora* subsp. *ciliaris, Armeria alliacea* subsp. *matritensis, Carduus assoi, Centaurea paniculata* subsp. *castellana* and *Thymus bracteatus*. Altitude is significantly higher in *Festucetum hystricis* than in *Paronychio-Artemisietum lanatae* (Figure 5).

Group D only includes the xerophile thyme-grasslands from siliceous bedrock soils (slates, sandstones and quartzites). Their floristic combination is characterized by the diagnostic species *Thymus leptophyllus* subsp. *izcoi, Festuca rivas-martinezii, Plantago holosteum, Pilosella castellana* and *Koeleria crassipes*, besides *Rumex acetosella* subsp. *angiocarpus* and several silicicolous therophytes (*Aira caryophyllea, Evax carpetana, Scleranthus polycarpos, Logfia minima*, etc). The high cover of Iberian endemics is due to the abundance of the Oroiberian *Thymus leptophyllus* subsp. *izcoi* and the Iberian *Festuca rivas-martinezii*. This vegetation type has been recently described (*Fumano procumbentis-Thymetum izcoi* G. Navarro; Rodríguez-Rojo & *al*., 2012).

Species richness

Trends in species richness along the major floristic gradients are not linear. The GAM model shows skewed unimodal trends along the two DCA axes, the decrease in species richness being more evident along the first axis (Fig. 6). Species density ranges from a minimum value of 15 species per 100 m^2, that corresponds to the clusters 5 and 9, and a maximum of 51, that corresponds also to the cluster 9. The average of the species density ranges from 25 to 35 species, and the values around 30 (28-32) are the most frequent. The higher values appear around the center of the DCA diagram and are not associated to any particular cluster. Lower species richness values are associated to both extremes of the first DCA axis, corresponding to the *Nardus stricta* swards in the negative extreme, and the most xerophytic grasslands in the positive extreme. On the contrary, the number of Iberian endemics increases towards the positive part of the first DCA axis where calcareous dry grasslands are positioned (cluster 8). The cumulative number of Iberian endemics for this vegetation type is equal to 19 in total (see list of Iberian endemics in Appendix 1).

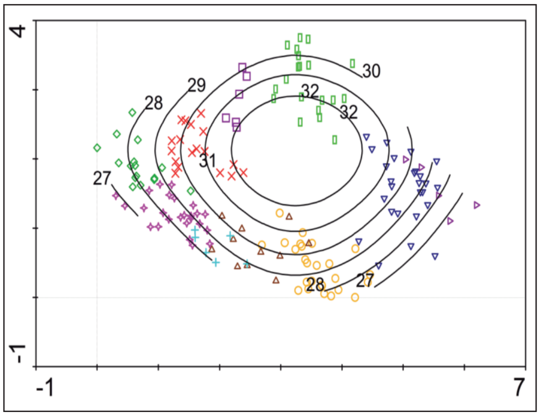

Figure 6. – Change in species richness along the first two DCA axes expressed as an attribute plot based on the GAM model (Poisson distribution, see legend in Figure 4).

DISCUSSION

Topography and lithology are the main factors influencing the vegetation diversity of grasslands in the study area. Rock cover and slope are associated to a gradient of water availability that determine the major floristic differences: the wet and mesic meadows (*Molinio-Arrhenatheretea* and *Nardetea*) are positioned in flat terrains at the valley bottoms with null rock cover, while the dry grasslands (*Festuco-Ononidetea* and *Festucetea indigestae*) show the higher values for both variables. Floristic differences linked to lithological variability (calcareous vs. siliceous substrates) were larger in dry grasslands than in mesic grasslands. Siliceous thyme-grasslands of the *Fumano-Thymetum izcoi* appear well differentiated against calcareous dry grasslands by a large pool of diagnostic species from *Festucetea indigestae* and *Tuberarie-*

talia. The lithological gradient is narrower in the mesic grasslands, opposing the associations *Phleo-Cynosuretum cristati* (cluster 1), from more or less decalcified soils, to *Sanguisorbo-Deschampsietum hispanicae* (cluster 4) from base-rich soils. However, more analysis would be needed involving other environmental variables, such as soil properties or grazing intensity, for the interpretation of the community diversity of mesic meadows.

Differences in altitude appeared among communities belonging to the same major vegetation types. For instance, although the two types of semi-dry grasslands (*Festuco-Brometea*) were characterized by few diagnostic species and their clusters were linked at the lowest dissimilarity level in the dendrogram, they showed altitudinal differences: *Cirsio-Onobrychidetum hispanicae* occurs at higher altitudes, in the upper suprasubmediterranean belt (altitudes: 1300-1600 m) whereas *Festuco-Brachypodietum phoenicoidis* at lower altitudes (altitudes: 1100-1500 m). However, only a community analysis of the *Festuco-Brometea* grasslands in all the southern Iberian System with more phytosociological data would bring out a right ecological interpretation of the environmental patterns in this grassland type. It is also interesting the relation between siliceous thyme-grasslands and altitude in the DCA diagram, although altitude is not significantly higher compared with the rest of the grassland groups. These thyme-grasslands have a wide altitudinal range, reaching the highest belts of the mountains crowned by Paleozoic quartzites (Sierra de Albarracín, Sierra Menara and Sierra de Valdemeca), above 1800 m.

The classification results were explained according to the flexible beta method selected, but the performance of the three applied clustering methods allowed us to compare differences in the linkage of some intermediate vegetation types, as it is the case of the semi-dry grasslands (group B) with moisture requirements intermediate between mesic and dry grasslands. Moreover, in combination with the ordination analysis, it is possible to reinterpret the similarity level between clusters separated in the dendrogram. For instance, cluster 5 was linked in the Ward dendrogram to the cluster node of the typical dry calcareous grasslands (*Sideritido-Arenarion*). But in the divisive TWINSPAN method, cluster 5 showed more affinity with the typical semi-dry grasslands (*Cirsio-Onobrychidetum*), and even their respective centroids were much closer in the DCA scatter plot where the two groups do not appear well separated. Cluster 5 has been treated here as a transitional community between *Cirsio-Onobrychidetum* and *Festucetum hystricis* and its syntaxonomical position cannot be clarified only upon the cluster dendrogram, but also upon the diagnostic species analysis and the information of the topographic variables. *Onobrychis argentea* subsp. *hispanica, Ononis cristata, Leucanthemum pallens, Medicago sativa* and *Cirsium acaule* may lead to interpret this type of vegetation as belonging to the *Cirsio-Onobrychidetum hispanicae*, but *Festuca hystrix* and *Thymus bracteatus* are also diagnostic and are even more abundant (cover values from 20 to 40%). On the other hand, the ANOVA test for the rock cover and slope variables showed that cluster 5 does not differ from cluster 8 (*Festucetum hystricis*) while it does from cluster 6 (*Cirsio-Onobrychidetum*). Rivas-Goday & Borja (1961) described in Sierra de Gúdar (eastern Iberian System), a submediterranean subassociation for *Cirsio-Onobrychidetum* characterized by *Koeleria vallesiana, Carthamus carduncellus* and *Linum salsoloides*, that would be the most frequent subassociation in our study territory. *Cirsio-Onobrychidetum* is limited to shady places in closed valleys, at the bottoms or hillsides, usually under the canopy of *Pinus sylvestris* forests (López González, 1978), where the warm temperatures of summer are attenuated. In open exposed situations, in deforested valleys and steep sites, the grasslands become more xerophytic, and if the grazing intensity is high, as it usually occurs in the surroundings of rural villages, xericity is more stressed as a consequence of the effect of the erosion of the superficial soil with the bedrock coming to the surface. Only dry grasslands may colonize these exposed and topographic sites that are related to the *Festucetum hystricis*. However, in clay and loamy soils, a variant in transition to semidry grasslands may occur with the presence of *Jasonia tuberosa, Plantago maritima* subsp. *serpentina, Cirsium acaule, Helictochloa pratensis* subsp. *iberica* and *Galium estebanii* var. *leioclados*, and cluster 5 represents this vegetation type (Table 2). The presence of *Jasonia tuberosa*

Table 2
Festucetum hystricis
semi-dry var. with *Plantago maritima* subsp. *serpentine*
(*Sideritido fontquerianae-Arenarion microphyllae, Festuco hystricis-Poetalia ligulatae, Festuco hystricis-Ononidetea striatae*)

Altitude (m asl)	1300	1288	1272	1360	1610	1478	1358	1392	1537	1539	1277	1225	1330	1267	1265	1326	1270	1342
Exposure	W	W	N	W	.	S	N	.	.	.	W	.	W	SW	NE	N	E	SW
Slope (°)	5	20	10	15	.	15	15	.	.	.	15	.	20	10	20	20	15	20
Cover (%)	100	80	100	90	95	80	90	90	60	95	70	60	80	70	70	70	100	70
Releve N.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Characteristics:																		
Koeleria vallesiana	5	10	20	10	5	5	1	20	20	20	10	10	5	10	30	10	20	20
Festuca hystrix	.	1	.	.	30	30	20	30	20	40	10	10	10	5	10	10	5	20
Coronilla minima	1	10	10	20	5	5	10	5	1	.	5	5	10	5	.	.	10	5
Carthamus carduncellus	1	.	5	1	10	10	5	1	5	5	.	0.1	1	1	0.1	0.1	5	5
Helianthemum oelandicum subsp. *incanum*	1	.	.	1	5	1	5	5	1	1	1	.	1	.	.	.	1	.
Achillea odorata	5	1	0.1	1	.	.	.	.	.	1	.	1	1	.	.	.	1	.
Thymus bracteatus	.	.	.	20	10	10	10	20	.	.	.	1	1	.	.	.	5	5
Linum salsoloides	.	0.1	.	1	.	.	10	1	1	.	.	.	.	.	.	.	.	.
Plantago monosperma subsp. *discolor*	.	.	.	.	5	.	.	.	10	.	.	.	.	.	.	.	.	.
Carex humilis	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.
Differentials of the variant:																		
Plantago maritima subsp. *serpentina*	20	5	1	10	1	1	10	5	1	5	10	10	5	20	0.1	10	1	1
Jasonia tuberosa	10	5	.	5	5	1	.	1	1	.	.	1	.	.	.	.	.	.
Cirsium acaule	.	5	.	1	5	10	5	.	.	5	1	.	10	.	10	5	5	.
Galium estebanii var. *leioclados*	5	5	5	1	1	1	1	.	.	1	5	.	5	5	5	5	5	.
Helictochloa pratensis subsp. *iberica*	.	.	1	1	0.1	1	.	.	.	.	20	5	1	5	.	1	.	.
Deschampsia caespitosa subsp. *subtriflora*	.	.	.	1	1	.	.	.	.	1	.	.	.	.	.	.	.	.
Companions:																		
Eryngium campestre	1	1	5	0.1	.	0.1	0.1	1	.	0.1	1	1	1	1	1	1	1	10
Pilosella officinarum	10	5	.	5	.	1	.	.	.	5	1	5	10	5	5	1	1	5
Lotus corniculatus	1	1	1	.	.	0.1	.	.	0.1	1	1	.	.	1	1	0.1	5	1
Plantago lanceolata	5	1	1	.	.	0.1	.	.	.	.	1	1	.	.	.	0.1	0.1	1
Sanguisorba minor	.	.	.	.	.	1	.	.	0.1	.	0.1	1	.	1	0.1	1	1	.
Onobrychis argentea subsp. *hispanica*	.	5	5	1	.	.	.	.	.	.	.	10	5	1	.	0.1	10	1
Potentilla neumanniana	1	.	.	.	.	1	1	.	.	.	0.1	.	.	.	1	1	1	.
Teucrium expassum	.	1	.	1	.	1	.	1	.	.	1	1	0.1	1	1	.	0.1	.

Releve N.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Festuca trichophylla	10	5	5	5	.	.	0.1	.	.	.	.	.	.	1	.	.	.	.
Ononis cristata	.	1	.	1	5	.	1	1	.	.	.	.	5	.	.	.	5	.
Ononis spinosa	.	1	.	.	.	.	.	.	.	.	5	.	1	1	.	5	5	5
Trifolium campestre	1	.	0.1	.	.	.	.	.	.	.	0.1	.	.	.	1	1	.	1
Bromopsis erecta	10	5	20	5	.	5	1	.	.	.	.	.	10	.	.	.	.	10
Medicago sativa	.	.	10	.	.	.	.	.	.	.	1	1	1	.	1	.	.	0.1
Polygala monspeliaca	.	0.1	1	0.1	.	.	.	.	.	.	0.1	.	.	0.1	.	.	.	0.1
Phleum nodosum	5	.	1	.	.	.	.	.	.	1	.	.	.	.	0.1	.	.	.
Prunella laciniata	10	5	.	.	.	1	.	.	.	.	.	.	.	0.1	1	5	0.1	.
Galium verum	5	1	.	1	.	1	.	1	.	5	.	.	.	.	.	.	.	.
Thymus vulgaris	.	1	0.1	.	.	.	.	.	.	.	1	1	1	1	0.1	1	.	.
Taraxacum sect. *Ruderalia*	.	.	.	.	.	.	.	.	.	.	0.1	.	.	0.1	0.1	.	.	1
Hippocrepis comosa	.	.	.	.	.	.	.	.	.	.	1	.	.	1	1	5	5	.
Scorzoneroides carpetana	1	.	.	1	.	.	.	.	.	0.1	.	.	.	.	1	1	.	1
Leucanthemum pallens	.	0.1	.	.	.	.	.	.	.	.	.	1	.	.	1	1	0.1	.
Aegilops geniculata	1	.	1	1	.	.	.	.	.	.	.	1	.	.	.	.	.	.
Brachypodium distachyon	.	.	1	.	.	.	.	.	.	.	1	1	1	1	.	.	.	.
Ranunculus bulbosus subsp. *aleae*	1	.	.	0.1	.	.	0.1	.	.	.	.	.	.	0.1	.	0.1	.	.
Helianthemum apenninum	.	.	1	.	.	.	.	.	.	.	.	.	1	.	.	.	.	0.1
Cirsium echinatum	.	.	.	.	.	.	.	.	.	.	0.1	.	.	.	1	.	.	.
Plantago media	.	1	.	5	.	.	5	.	.	.	.	.	.	.	.	.	1	.
Bellis perennis	5	1	.	1	.	.	.	.	.	.	.	.	.	1	.	.	.	.
Geum sylvaticum	.	.	.	.	.	.	.	.	.	0.1	.	.	.	.	.	.	0.1	.
Filipendula vulgaris	.	.	.	.	.	0.1	5	.	.	1	.	.	0.1	.	.	.	.	.
Crepis vesicaria subsp. *haenseleri*	0.1	.	.	0.1	.	.	.	.	.	.	.	.	1	.	.	.	0.1	.
Astragalus incanus	.	.	.	1	.	.	.	.	.	.	.	0.1	.	.	.	.	.	1
Prunella hyssopifolia	.	1	.	.	.	.	.	.	.	1	.	.	1	.	.	.	.	.
Arabis hirsuta	.	.	1	.	.	.	.	.	.	.	.	.	0.1	.	.	.	.	.
Euphorbia nicaeensis	.	.	.	.	.	0.1	.	.	.	.	.	.	.	.	.	0.1	.	.
Klasea nudicaulis	.	.	.	.	.	.	.	.	0.1	1	.	.	.	.	.	.	.	.
Carex flacca	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	0.1	.
Bombycilaena erecta	.	.	0.1	.	.	.	.	.	.	.	.	.	.	.	0.1	.	.	.
Convolvulus arvensis	.	.	.	.	.	.	.	.	0.1	.	0.1	.	.	.	.	.	.	.
Helictochloa bromoides	.	5	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Carex halleriana	.	.	.	.	.	.	5	.	.	.	.	.	.	.	.	.	1	.
Plantago afra	.	.	.	.	.	.	.	.	.	.	1	0.1	.	.	.	.	.	.

Releve N.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Lavandula latifolia	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	0.1	.	.
Taraxacum obovatum	.	.	1	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.
Globularia vulgaris	.	.	.	.	.	.	5	1	.	.	.	.	.	.	.	.	.	.
Cerastium pumilum	.	.	1	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.
Herniaria glabra	.	.	.	.	.	.	.	.	0.1	0.1	.	.	.	.	.	.	.	.
Sideritis hirsuta	.	.	.	.	.	.	.	.	.	.	0.1	0.1	.	.	.	.	.	.

Other species: *Carex caryophyllea* 5 in1; *Bromus squarrosus, Centaurea jacea* 1 in 1; *Scabiosa columbaria* subsp. *affinis* 1 in 2; *Festuca gracilior* 10 in 3; *Bupleurum baldense, Convolvulus lineatus, Medicago rigidula, Melilotus sulcatus, Poa bulbosa, Myosotis ramosissima, Rhinanthus minor* 1 in 3; *Alyssum alyssoides, Crucianella angustifolia, Daucus carota, Leontodon longirostris, Veronica arvensis* 0.1 in 3; *Fritillaria lusitanica* 0.1 in 5; *Brachypodium phoenicoides* 5 in 6; *Aphyllanthes monspeliensis, Cuscuta epithymum* subsp. *kotschyi* 1; *Knautia subscaposa* in 6; *Asphodelos cerasiferus, Festuca fenas, Marrubium supinum, Salvia pratensis, Thesium humifusum* 0.1 in 6; *Briza media* 0.1 in 7; *Arenaria obtusiflora* subsp. *ciliaris, Brassica repanda* subsp. *blancoana* 0.1 in 8; *Klasea nudicaulis, Ornithogalum narbonense* 0.1 in 9; *Ranunculus paludosis* 1 in 10; *Armeria alliacea* subsp. *matritensis* 0.1 in 10; *Poa angustifolia* 1 in 11; *Arenaria modesta, Phlomis lychnitis* 0.1 in 11; *Dorycnium pentaphyllum* 0.1 in 12; *Logfia gallica, Xeranthemum inapertum* 0.1 in 13; *Helictochloa marginata* 1 in 15; *Hypochaeris radicata* 0.1 in 15; *Cichorium intybus* 0.1 in 15.

Localities: 1, 2: Cuenca, Sierra de Zafrilla, Loma de la Herradura, 30TXK0557, 20.06.2010; 3: Guadalajara, Pinilla de Molina, La Hoya del Perdigón, 30TWL9403, 17.06.2010; 4: Cuenca, Sierra de Valdemeca, Cerro del Bu, 30TXK0453, 20.06.2010; 5: Guadalajara, Checa, P.N. Alto Tajo, Los Asperones, 30TXK0275, 2.07.2010; 6: Cuenca, Sierra de Zafrilla, Cerro del Zarzal, 30TXK1853, 2.07.2009; 7: Guadalajara, Cueva del Hierro, 30TWK8093, 9.06.2009;8: Cuenca, Sierra de Valdemeca, El Bujedal, 30TXK0652, 20.06.2010; 9.10: Cuenca, Serranía de Cuenca, Quinto de los Prados, 30TWK8989, 7.07.2009; 11: Cuenca, Serranía de Cuenca, Loma del Ocejón, 30TWK9966, 10.06.2009; 12: Cuenca, Serranía de Cuenca, El Montón de Tierra, 30TXK0161, 11.06.2009; 13: Cuenca, Serranía de Cuenca, Puntal de la Salceda, 30TXK0851, 20.06.2010; 14: Cuenca, Serranía de Cuenca, Riscos de la Carrascosa, 30TWK8879, 10.06.2009; 15: Cuenca, Serranía de Cuenca, Monte Sierra de las Canales, 30TXK0064, 11.06.2009; 16: Cuenca, Serranía de Cuenca, Prados de la Cierva, 30TWK9843, 11.06.2009; 17: Cuenca, Sierra de Tragacete, Cerro de San Miguel, 30TXK0064, 11.06.2009; 18: Cuenca, Sierra de Valdemiguete, Herrería de los Chorros, 30TXK0164, 11.06.2009.

and *Plantago maritima* subsp. *serpentina* in this community also denotes a similarity with the most xerophilous grasslands of the *Deschampsion mediae* (*Plantagini serpentinae-Jasonietum tuberosae* O. Bolós & Masalles in O. Bolós 1983; *Prunello hyssopifoliae-Plantaginetum serpentinae* Biurrun 1999; *Eryngio dilatati-Jasonietum tuberosae* Torres & Cano 2000) (Torres & *al*., 2000). On the other hand, although *Jasonia tuberosa* is not present in our samples from the *Sanguisorbo-Deschampsietum* grasslands, López-González (1978) did include it in his table of the association. The ecological factor that is associated to this floristical similarity is explained by some edaphic and lithological affinities: compact and base-rich, clayed soils.

The number of species recorded in the mountain grasslands of the southwestern Iberian System is analogous to that referred in previous studies in the Western European mountains (Kopeć & *al*., 2010). The DCA diagram showed that an increase in species richness is not skewed towards any of the vegetation types. According to our results, the grassland communities recorded do not differ significantly in species richness at the spatial grain of 100 m^2. At first, it was expected that it was higher in the temperate semi-dry calcareous grasslands (*Cirsio-Onobrychidetum hispanicae*), reported as one of the plant communities with the world record for plant species richness (Wilson & *al*., 2012), but the submediterranean context of the Iberian System is far from the optimum of these temperate grasslands in central Europe. If species richness in grasslands from more hydromorphic soils is reduced by competitive exclusion of the high abundances of few species, and is also reduced in more xerophytic grasslands by hydric stress, then mesic or semi-dry grasslands would contain more species richness. This tendency may be interpreted in the species richness plot based on the fitted additive model (Fig. 6). On the other hand, the negative effect of soil acidification on plant species richness observed by previous authors (Pärtel, 2002; Piqueray & *al*., 2007; Kopeć & *al*., 2010) is not evident in the southern Oroiberian grasslands, maybe as a consequence of the Mediterranean character of the siliceous thyme-grasslands that are locally rich in annual species.

As a conclusion, the evaluation of the floristic value of the semi-natural grasslands in the southwestern Iberian System should take into account other criteria such as the endangered status, the level of rarity and the endemicity of the species composition. According to the latter, the *Sideritido fontquerianae-Arenarion microphyllae* grasslands, included in the Annex I of Habitats Directive, represent one of the most valuable vegetation types of this area.

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SYNTAXONOMICAL SCHEME OF THE GRASSLANDS IN THE SOUTHWESTERN IBERIAN SYSTEM (SYNTAXONOMY NOMENCLATURE FOLLOWS RIVAS-MARTÍNEZ, 2011)

Molinio-Arrhenatheretea Tüxen 1937
  Arrhenatheretalia elatioris Tüxen *1931*
    Cynosurion cristati Tüxen 1947
Phleo nodosi-Cynosuretum cristati Rodríguez-Rojo & Fernández-González 2014 in press
  Holoschoenetalia vulgaris Br.-Bl. ex Tchou 1948
    Deschampsion mediae Br.-Bl. in Br.-Bl., Roussine & Nègre 1952
      Sanguisorbo lateriflorae-Deschampsietum hispanicae Rivas-Martínez & G. López in G. López 1978 corr. Rivas-Martínez, Fernández-González, Sánchez-Mata & Pizarro 1990

FESTUCO-BROMETEA Br.-Bl. & Tüxen ex Klika & Hadăc 1944
Brometalia erecti Br.-Bl. 1936
Teucrio pyrenaici-Bromion erecti Rivas-Martínez, Fernández-González & Loidi 1999
Cirsio microcephalae-Onobrychidetum hispanicae Rivas Goday & Borja 1961 corr. Rivas-Martínez, Fernández-González & Loidi 1999
Brachypodietalia phoenicoidis Br.-Bl. ex Molinier 1934
Brachypodion phoenicoidis Br.-Bl. ex Molinier 1934
Festuco andresmolinae-Brachypodietum phoenicoidis Rivas Goday & Borja 1961 corr. Rivas-Martínez, T.E. Díaz, Fernández-González, Izco, Loidi, Lousã & Penas 2002
FESTUCO HYSTRICIS-ONONIDETEA STRIATAE Rivas-Martínez, T.E. Díaz, F. Prieto, Loidi & Penas 2002
Festuco hystricis-Poetalia ligulatae Rivas Goday & Rivas-Martínez 1963
Sideritido fontquerianae-Arenarion microphyllae Rivas-Goday & Borja 1961 corr. Rivas-Martínez, T.E. Díaz, Fernández-González, Izco, Loidi, Lousã & Penas 2002
Festucetum hystricis Font Quer 1954
typicum
variant semi-dry with *Plantago maritima* subsp. *serpentina*
Paronychio capitatae-Artemisietum assoanae Rivas Goday & Borja 1961 corr. Rivas-Martínez 2011
FESTUCETEA INDIGESTAE Rivas Goday & Rivas-Martínez 1971
Jasiono sessiliflorae-Koelerietalia crassipedis Rivas-Martínez & Cantó 1987
Hieracio castellani-Plantaginion radicatae Rivas-Martínez & Cantó 1987
Fumano procumbentis-Thymetum izcoi G. Navarro ex Rodríguez-Rojo & al. 2012

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APPENDIX 1

Iberian endemics present in the ten vegetation clusters (numbers correspond to the synoptic table).

Cluster number	1	2	3	4	5	6	7	8	9	10
Arenaria erinacea								*	*	
Arenaria obtusiflora subsp. *ciliaris*	*				*	*		*		*
Armeria alliacea subsp. *matritensis*			*	*	*	*		*	*	*
Biscutella atropurpurea										*
Brassica repanda subsp. *blancoana*					*					
Carduus assoi					*			*	*	
Centaurea cavanillesiana								*		
Centaurea paniculata subsp. *castellana*									*	
Centaurea pinae								*		*
Dianthus legionensis		*								
Euphorbia minuta				*			*	*		
Festuca marginata subsp. *andres-molinae*						*				
Festuca paniculata subsp. *paui*								*		
Festuca rivas-martinezii			*							*
Galium lucidum subsp. *fruticescens*							*	*		
Jasione crispa subsp. *sessiliflora*		*								*
Knautia subscaposa		*			*	*	*	*		
Leucanthemopsis pallida var. *virescens*								*		*
Linum salsoloides					*	*		*		*
Minuartia campestris								*		
Plantago monosperma subsp. *discolor*					*			*		*
Sanguisorba lateriflora	*	*		*	*		*			
Satureja intricata subsp. *gracilis*									*	
Scorzoneroides carpetana	*		*	*	*	*				
Sedum nevadense	*									
Senecio minutus								*		
Seseli cantabricum			*							
Silene legionensis						*		*	*	*
Silene mellifera						*				
Tanacetum vahlii										*
Teucrium expassum					*	*		*	*	*
Thymelaea pubescens								*		
Thymus bracteatus					*	*		*		*
Thymus leptophyllus subsp. *izcoi*										*