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A new method for linking plant groups and environmental variables in northern Greece's mountain pastures

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ABSTRACT: The Northern Greece's mountain pastures correspond at least to three phytosociological orders, the Daphno-Festucetalia which is proper to the Greek mountain, and two others that spread in Europe, the Festuco-Brometalia and the Nardetalia strictae, both found in lower altitude than in Greece. We used the relevés from Thrace, Macedonia and Thessaly from the previous 6 years' national Conservation Status Assessment of the Natura 2000 network database, that last in 2015, to find the correspondence between the habitat types as they are codified in the Natura 2000 network, the phytosociological order and environmental variables quoted in the relevés. We have selected the relevés with less than 10% trees (417 relevés) and applied frequential analysis to establish clusters of Vegetation Groups (VG) and Relevés Groups (RG), using the same matrice Species x Relevés. We presented then the links betweeen each VG and each RG in a general table with the VG in column and the RG in lines where the RG are defined by their class values (altitude, geology, soil granulometry, rock cover and shrub cover). This could lead us to associate each VG to a phytosociological order and a Natura 2000 habitat type. The results showed for our sample an altitude around 1500m as a limit between, downwards, the Festuco-Brometalia and, upwards, the Daphno-Festucetalia and the Nardetalia. The results showed also the link between the Daphno-Festucetalia and limestone. For the Festuco-Brometalia the substrate is mainly basic, but it is frequently of tertiary deposits and alluvions.

KEYWORDS: Mountain Pastures, Northern Greece, Phytosociological orders, Frequential analysis.

1 INTRODUCTION

In Greece, a considerable extent is devoted to pastures. They include cultivated lands after harvest, abandoned cultures, wetlands and loose forests. In the frame of the ongoing Thessalian Protected Zones Manage Plan, we focused on this paper our interest on long term pastures and especially grassland's ecology. These pastures are mainly in mountain because land use repartition let cultivation in plains where access and soil management are less difficult. Pastoralism is an antique economy and way of live in Greece that is threatened by modern economic changes. These changes can influence the dynamics between forest and pasture and then threat the mountain grasslands to be invaded by ligneous as studied in Greece and abroad [1], [2], [3]. The new E.U. Common Agricultural Policy try to remediate to this trend [4] and the Natura 2000 habitat types are considered as suitable units to range management [5]. For better comprehension of pasture ecology in Northern Greece, we considered the rough results of the past Natura 2000 habitat types of Community Interest Monitoring and Conservation Status Assessment campaign (conducted at European level) that lasted in Greece in 2015 under the responsibility of the Ministry of Environment, Energy and Climate Change [6]. Working on Thessaly, we chose to use the data volume of Thrace, Macedonia and Thessaly. In these regions, the Mediterranean bioclimatic divisions can range from eu-Mediterranean to mountain-Mediterranean and the bioclimatic storages from semi-arid to axeric in high mountain. According to Dafis et al. [7], the pastures concerned by the present studies correspond at least to three phytosociological orders, the Daphno-festucetalia which is proper to the Greek mountains (named Daphneeto-festucetalia by Quezel [8]), and two others that spread in Europe, the Festuco-Brometalia and the Nardetalia strictae, both found in lower altitude than in Greece. In this study, our objective is to give correspondence between Northern Greece pastoral Natura 2000 habitat types, phytosociological orders and environmental variable's classes using the 2014-2015 Conservation Status Assessment campaign and it's phytosociological relevés with information on 16 environmental variables concerning altitude, topography, geology, soil and vegetation variables.

The above data have been processed by Tsiripidis et al. [9] using cluster analysis methods to define vegetation groups and relate these groups with habit types, using also a special algorithm [10] to find their typical species by an "intuitive fidelity threshold". We present here a new calculation method in cluster analysis to find vegetation groups with direct links with habitat's variable values, that facilitate their identification with Natura 2000 habitat types, give further ecological value to these habitats and facilitate the finding of typical species. One important advantage of this analysis method is to be founded on Fisher's exact probabilities tests which is completely independent of any theoretic distribution of the species, as linearly dependance used in the TWIN SPAN method (Hill, 1979) and subsequently independent of the sampling

method. It gives a picture of the sample, like in extended reality. Another advantage is to be applied at site scale (with around 100 relevés) because it provides information with few relevés, as shown in Bendali & Nellas [11].

2 MATERIAL AND METHOD

3202 relevés have been done during the previous Conservation Status Assessment campaign in Northern Greece (2014-2015) concerning 38 Natura 2000 sites in Thrace, Macedonia and Thessaly. We used here the rough results of the campaign that concerns the presence of each Species (with its abundance, vitality and its vegetation strata) and the status of 16 environmental variables noted on the plots. To focus the search for pasture flora Specie's groups, we used 417 vegetation and environmental variables field samples (= relevés). The selection has been done with tree cover: The 417 relevés concerns only the ones that have a tree cover inferior or equal to 10%. Only process of Species' presence and 6 variables is presented here: habitat type, altitude, geology, soil granulometry, rock cover and shrub cover.

2.1 PHYTOSOCIOLOGICAL PROCESSING METHOD AND FREQUENCY ANALYSIS

2.1.1 FINDING VEGETATION GROUPS (VG)

Phytosociology is based on the probability to find in the same relevé two or more given plant Species. Characteristic Species of a vegetation unit (an association or a vegetation taxon of higher rank) has tight link with at least one another species. The difficulty is to know the reason of this link. M. Godron [12], [13], calculated the probability for a Species to be found with another Species. If that probability is high, these species are member of the same vegetation unit. The probability is calculated with Fisher's exact probability, which has the advantage to be not inferential. The probability calculation is explained downwards.

Table 1. Combination number of presence and absence of two Species in the relevés

Frequencies		2d Species		
		Presence	**Absence**	**Total**
1st Species	**Presence**	a	b	a+b
	Absence	c	d	c+d
	Total	a+c	b+d	n

Where: n = a+b+c+d

The probability (P) of the table is:

$$P=\frac{(a+b)!(c+d)!(a+c)!(b+d)!}{n!a!b!c!d!}$$

The information obtained when computing "p" is then given by Brillouin's formula:

$$I=\log_2\frac{1}{P}$$

The unit of Information I is named binon and since this information is given by a species on another species it is named Mutual Information (MI). This information is the most suitable value of the spatial links between the species, and it gives a dendrogram named "archipel" showing the groups (or clusters) of Species linked to one another and constituting a cluster analysis.

The algorithm starts with the two Species that have the highest MI. The two first Species form a first vegetation unit that will be enlarged with a third Species that has the highest information with one of the Species of the group and so on till a threshold MI. The algorithm is reinitiated with the rest of the Species that are not in the first group to form a second group and so on, in order to obtain the vegetal groups VG, which may correspond to groups of characteristic species of phytosociological units of any rank. The set of methods using Fisher's exact formula is named Frequency analysis. It does not define an a priori fidelity threshold for a species to be differential taxon between species groups but it let the frequency analysis determine few species to be hierarchically representative of vegetation groups.

2.1.2 FINDING RELEVÉS GROUPS (RG)

The same cluster analysis as for the VG search, gives RG clusters. The same process applied to find vegetal groups is applied to find relevés groups, transposing the species/relevés matrix. While searching for VG is computing the frequencies of species' co-occurrences in all the relevés, searching for RG is computing the frequencies of similarities of relevés for all species.

The method described upwards is a generalization of the traditional table's lines and columns interpretation made by hand by the first phytosociologists in order to find the VG groups. It permits to give relation between vegetation groups and relevés groups.

2.2 CONSTRUCTING THE CONSTELLATION

From the matrix of data where lines are the species and columns the relevés, the function "Constel" extract all the the sub-matrices whose lines are the species of a VG or species cluster and whose columns are the relevés of a RG or relevés cluster. Each of these sub-matrixes is a "Star" in the constellation constituted by the set of all Stars. For each Star, the density is the percentage of presences of the species in the sub-matrix.

For example, the VG n° 20 contains 5 species (whose total number of presences in the whole sample is in parentheses): *Astragalus angustifolius (25), Festuca varia (61), Cerastium banaticum (13), Trinia frigida (4), Jurinea consanguinea (1).* It gives a star with the relevés of RG n° 29, whose characters are:

Relevé rank	Altitude (m)	Geology	Soil granulometry	Rock cover % class	Shrub cover %
2636	1800	Limestone	Argilous	25-50	40
2638	1800	Limestone	Argilous	25-50	40
2640	1800	Limestone	Argilous	25-50	35
2639	1900	Limestone	Argilous	25-50	40
3323	1400	Silicious	Argilous	50-75	0

The sub-matrix or Star is

Relevés					Species
2636	2638	2640	2639	3323	
1	1	1	1	0	*Astragalus angustifolius*
0	1	1	1	0	*Festuca varia*
1	1	1	1	1	*Cerastium banaticum*
1	1	1	1	0	*Trinia frigida*
0	1	0	0	0	*Jurinea consanguinea*

The density d of the Star is 37, defined as follow:

$$d=100n/(m*N) = 68$$

With:

- n as the number of presences of the VG's species,
- m as the number of the RG'relevés,
- N as the number of the species'VG
- Density ranges from 0 to 100 and measures the strength of the link between the VG and the RG.

Almost all the relevés are from the Ossa mount but the last one is from the Kato Olympos mount, at 23,5 km. This is interesting because it means that the RG does not exist only by geographic proximity of the relevés, but also because of environmental proximity. They are in quite the same altitude range and soil type, but different in geology, rock and bush cover. That is normal because the strength of the link between the relevés and also between the species weakens along the relevé or specie's rank in the cluster. Let's remark also that the two last species in the VG are only present in the RG n° 29, that weakens the link between them and the first VG's species (a low frequency enhances the hazard in the links). In the VG presentation we give the mutual information (the link) between the species.

To present the "Stars" in one result table we have selected the 21 first VG (Clusters) of the cluster analysis and these VG are represented by their rank in the cluster analysis as table's columns where the RG are in lines with their rank in their cluster analysis.

We did not present the Stars where only one species is present because these species are often ubiquist and not especially attached with a particular habitat type.

The calculations have been processed through ECHO database' software of the Montpellier's Institut de Botanique which uses Dyalog progiciel and can be provided mailing to migodron@wanadoo.fr.

3 RESULTS AND DISCUSSION

3.1 RESULTS TABLE OF RELEVÉS GROUPS (RG) VERSUS VEGETATION GROUPS (VG)

We present downwards a table where the lines represent the RG and the columns the VG.

The RG and the VG are defined by the 4th line, with, from left to right:

The rank number of the RG. This rank is the one of the cluster analysis.

The number of the relevés in the RG

The mean of the shrub cover % in the RG (Shrub %)

The mean of the classes' lower rock cover % in the RG (Rock %)

The principal granulometry type and (after the comma) the secondary granulometry type (Gran)

(Arg = Argilous)

The principal geological substrate and (after the comma) the secondary geological substrate (Geol): All = Alluvions, Cos = Silicious Colluvions, Det = Tertiary deposits, Fly = Flysches, G&G = Gneiss and Granits, Lim = Limestones, Mar = Marbles, Sch = Schists, Ser = Serpentine, Sil = Other silicious.

The altitude range in meters (Alt)

The rank number of the VG. This rank is the one of the cluster analysis.

At the intersections of the RG line and the and the VG column lines is indicated the density of the Star, as defined upwards. Density ranges from 0 (minimal) to 100 (maximal).

The 2th line of the table indicates the phytosociological order and the habitat code associated with the VG, as discussed forward.

The table has been arranged to show the altitudinal succession of the VG.

RELEVÉS GROUPS		Environmental variables					VEGETATION ORDERS AND HABITAT CODE																				
							Festuco-Brometalia 62A0	Erico-Pinetalia 5210	Festuco-Brometalia 62A0						Phragmitetalia 7140	Daphno-Festucetalia 6170	Daphno-Festucetalia 4090		Daphno-Festucetalia 6170			Erico-Pinetalia 4060	Phragmitetalia 7230	Nardetalia 6230			
							Vegetation groups																				
No	Relevés Number	Shrub %	Rock %	Gran	Geol	Alt	1	12	2	19	13	8	14	15	10	16	21	17	9	18	20	4	5	11	7	3	6
40	3	0	0	Arg	All	500	16	57																			
68	2	0	0	Arg	All	500	10	29																			
48	2	0	0	Arg	Mar	600	30																				
27	3	55	12,5	Arg	Mar	600	20		60																		
32	2	0	0	Arg	Mar	600	13	43																			
23	4	0	12,5	Arg	Mar	600	43																				
39	5	0	10	Arg	Mar	600-700	21																				
15	10	0	7,5	Arg	Mar	600-700	47																				
6	2	0	0	Silt	Det	600-700	17						33														
22	4	0	12,5	Arg	Mar	600-700	45																				
26	13	0	27,3	Arg	Mar	600-700	34				27																
10	2	55	12,5	Arg	Mar	600-700	20		80																		
2	4	7,5	50	Silt	G&G	600-900				97	100																
20	5	0	1	Arg, Silt	Mar, All	600-1000	19	31				11	20														
19	8	0	0	Silt, Sand	Lim, Det	600-1100	18				75	63	19	17													
11	9	0	3	Silt, Arg	Lim-Det	500-1500					83	30	41	63	22												
8	19	53	7	Arg, Silt	Mar, G&G	600-1500	15		65																		

16	8	1,8	1,2	Sand, Silt	Lim	600-1800							42														
73	3	28,3	10	Arg	Lim, All	800-1300			20																		
3	11	0	0	Sand	Ser, Si, Lim	800-1500						18	18		77												
18	8	6,4	3,5	Arg	Lim	800-1600		11				16		71													
28	5	0	0	Silt	All	700-1800										100										30	
25	7	0	0	Silt, Sand	G&G, Lim	1000-1100					64	45	14	14	29												
17	4	0	13,75	Sand	Lim	1100-1200							33					15									
33	5	0	1	Sand, Silt	Lim	1100-1500							17				28										
12	2	2,6	10	Arg	Lim	1100-1600								67					50								
72	6	0	0	Arg, Silt	Lim, G&G	1100-1800									58												
9	12	5,2	13	Arg	Lim	1100-2000					21	13	26	39	67				24								
37	11	3,1	11,4	Arg	Lim	1100-2000							11						36								
24	4	0	31,2	Silt	Lim	1300-1500							21				60				25						
35	3	40	0	Silt	G&G, Sil	1400-1500			60													10					
75	3	0	0	Silt	G&G, Cos	1400-1800																					21
76	7	0	7,1	Silt	G&G	1400-1800																					25
29	5	31	30	Arg	Lim	1400-1900														33	68						
80	3	30	0	Silt	G&G, Cos	1400-1900																				30	
42	3	0,3	66,6	Sand	G&G, Sch	1500													13								
58	2	0	0	Silt	G&G	1500																				35	
30	5	0	1,6	Silt	Lim	1500-1700												37	16		16						
59	2	0	0	Silt	G&G	1500-1700																					25
74	6	0	0	Silt	G&G, Sil	1500-1700																					23
31	6	48,3	15	Arg	Lim	1500-1800														48	40						
41	6	0	0,8	Silt	G&G	1500-1800																					33
60	3	0	0	Silt	G&G	1500-1800																					38
69	3	0,7	66,6	Sand	G&G, Sch	1500-2000																	10				
55	3	0	33,3	Silt	Lim	1600											47	11			40						
54	2	60	2,5	Arg	Lim	1600-1700													30								
34	8	0	0	Silt	Sch	1600-2100																			50		
64	6	51	3,3	Silt	G&G	1600-2100																			36		
5	2	0	0	Silt	Lim	1700-1800																			33		
4	5	0	2,5	Sand, Silt	Lim	1700-1900												10				37	29	35			
79	6	0	0,8	Silt	G&G	1700-1900																					25
7	7	0	23	Sand	Mar	1700-2100																63	57				
36	7	0	0	Silt	G&G, All	1700-2100																				44	
56	5	0	22	Sand, Silt	Sch, G&G	1700-2200																	26				
1	3	0	0	Sil, Sand	Lim, Sch	1800-1900											20				53	33		56			
13	3	0	0	Silt	Lim, Sch	1800-1900															47	43		33			
38	3	0	1,6	Silt	Lim	1800-1900												31	17		27	19					
78	3	0	0	Silt	Fly	1800-1900																					25
67	2	52	0	Arg	Lim	1800-2000													20								
47	2	70	0	Arg	Lim	1800-2000													20								
61	4	0	0	Silt	G&G	1800-2000																					38
66	5	0	0	Silt	Fly	1800-2000																					38
21	6	0	0	Silt	Sch, G&G	1800-2100																					40
53	3	0	3,3	Silt	G&G	1800-2200																				43	
62	4	0	0	Silt	G&G	1800-2200																					34
63	3	0	3,3	Silt	G&G	1800-2300																				27	
14	3	0	0	Arg	Sch	1900																				40	
43	2	30	2,5	Silt	G&G	1900-2000																			50		
70	4	0	75	Silt	Sil, Lim	1900-2000																	18				
71	4	0	0	Silt	Fly	2000-2100																					34
51	2	0	0	Silt	G&G	2100																				45	
52	3	0	0	Silt	G&G	2100-2400																					54
44	3	**0**	**0**	Silt	G&G	2300																					50
45	2	0	**0**	Silt	G&G	2300																					50

3.2 DISCUSSION

The analysis of the Stars's table showed quite clear relations between vegetation groups and environmental variable classes. The vegetation groups are sorted as follow (with mutual information between species in parentheses) by cluster analysis between the species.

3.2.1 WET GRASSLANDS OF HIGH MOUNTAIN (1700-2100M) ON ACID SUBSTRATE

VG 3: *Geum coccineum* (73), *Veratrum album* (63), *Eriophorum latifolium* (54), *Myosotis nemorosa* (45), *Deschampsia cespitosa* (45) *Galium palustre*

VG 16: *Carex echinata* (36), *Carex flava* (36), *Sphagnum subsecundum*.

The VG 3 has been found in 7 relevés (RG 36) characterized as "Alkaline fens" (habitat type 7230) in the Voras mounts (on the North Macedonian border), although they are on gneiss substrate for 5 of 7 relevés, and on alluvions for the two others. It has been found also on schists (3 relevés, RG 14) with the same habitat code. Perhaps it should be better to give another name and habitat code for the stands with this VG because the indicated typical species in the interpretation manual of European Union Habitats ("eur28", 2013) [14] description for the Alkaline fens habitat 7230 are not these of the VG 3 with exception of *Eriophorum latifolium*. The altitude ranges from 1700 to 2100m. The greek Natura 2000 network (Dafis, 2001) orders this VG into the Magnocaricion *(Phragmitetalia).* This VG (3) has been found also in four VG (51, 53, 58, 63) on Gneiss or granite with habitat code 6430 ("Species-rich Nardus Grasslands, on silicious substrates in mountain areas") referred downwards.

The EUR28 notice that these wet grasslands may form part of the fen system, with communities related to transition mires that is the habitat type of the VG 16 "Transition mires and quaking bogs" (7140), found in 5 relevés (RG 28) with 3 species of the VG 3 (*Geum coccineum, Eriophorum latifolium, Myosotis nemorosa*), also on the Vorras mount at an altitude from 700 to 1800 m (only one relevé at 700m, on pit). This habitat is extinct in several regions and gravely endangered in most regions.

3.2.2 DRY GRASSLANDS OF HIGH MOUNTAIN (1800-2400M) MAINLY ON ACID SUBSTRATE

VG 6: *Deschampsia flexuosa* (58) *Nardus stricta* (46) *Luzula spicata* (34) *Trifolium parnassi* (31) *Bellardiochloa variegata* (25) *Phleum alpinum* (24) *Agrostis castellana* found in 5 relevés on schist on the Tzena mount (on the North Macedonian border), one on Granito-gneiss on the Vernon mount (western Macedonia, RG U) and in 3 relevés on gneiss on the Vorras mount (RG AY). They range from 1800 to 2400m

The relevés in which the VG. 6 is living have been characterized as "Species-rich Nardus Grasslands, on silicious substrates in mountain areas" (habitat type 6230). It is ordered in Trifolion parnassi (Trifolietalia) In the Greek Natura 2000 network (Dafis, 2001). Following Quezel (1967) this VG can also be identified as the association with *Nardus stricta* and *Luzula spicata.* In the general Natura 2000 network (EUNIS Factsheet) it is mentioned as "Closed, dry or mesophile, perennial Nardus Grasslands occupying siliceous soils in Atlantic or sub-Atlantic or boreal lowland, hill and montane regions of middle and northern Europe and western Iberia". Quezel (1964) [15] noticed that in the south Greece mountains some little surfaces of this association can be encountered on limestone substrate, but with entirely decalcified soil.

3.2.3 DRY GRASSLANDS OF HIGH MOUNTAIN MAINLY ON BASIC SUBSTRATE

VG 4: *Carex kitaibeliana* (65) *Festuca koritnicensis* (28) *Leontodon crispus* (27) *Asperula aristata* (22) *Minuartia attica* found in 6 relevés on marbles and one on dolomite on the Tzena mount (RG G), characterized as "Calcareous rocky slopes with chasmophytic vegetation" (habitat type 8210), and in 5 relevés on limestone (RG D, only for *Carex kitaibeliana, Festuca koritnicensis* and *Asperula aristata*), all on the Tzena mount, characterized as "Alpine and subalpine calcareous Grasslands" (habitat type 6170), together with the following VG. 11 (for *Gentiana verna, Sesleria robusta, Anthyllis vulneraria* and *Thymus longicaulis*).

VG 5: *Saxifraga scardica* (59) *Thymus boissieri* (41) *Sesleria tenerrima* (31) *Carum appuanum* (22) 5 *Saxifraga paniculata* (20) *Sedum album* found in the same 5 upwards relevés on limestone characterized with the code 6170 and the same 6 relevés on marble, characterized as 8210, both on the Tzena mount.

VG 11: *Gentiana verna* (40) *Sesleria robusta* (29) *Anthyllis vulneraria* (29) *Thymus longicaulis* (28) *Helictotrichon aetolicum* (18) *Hypericum barbatum* found in 2 relevés on limestone and one on schist characterized 6170 on the Tzena mount together with the VG 4 (only for *Gentiana verna, Sesleria robusta* and *Thymus longicaulis*).

These three VG have been found at altitudes of 1700 to 1900m, although the species of the VG 4 can be found till 2100 m and those of the VG 5 can be found till 2200. This is explained by the absence of relevés on limestone higher than 2000 m and on marbles higher than 2100 m. They are encountered on land that can be covered by 50% rocks, especially the VG 4 and 5. They have been characterized as habitat type 6170 "Alpine and subalpine calcareous grasslands" and ordered by Dafis et al. (2001) in the Daphno-Festucetalia and also, for the VG4 and 5, as habitat type 8210 "Calcareous rocky slopes with chasmophytic vegetation" in some relevés (RG 63).

The Natura 2000 network characterize the 6170 habitat as alpine and subalpine vegetation of Alps, the Carpathians, the Pyrenees, the mountains of the Balkan peninsula and the Mediterranean mountains. We can assume that the VG 5 should be the most representative of the

Daphno-festucetalia order on rocky basic surfaces (limestones, marbles and dolomite, confirmed by the characterization as 8210 (Calcareous rocky slopes with chasmophytic vegetation). The VG 5 corresponds to the association with *Sesleria coerulens* (*Sesleria tenerrima* = *Sesleria coerulans var. tenerrima* Fritsch) and *Thymus boissieri* of the Astragalo-seslerion alliance (Quezel, 1967). Let's notice that the relevés noted 8210 where the VG 4 and 5 have been found has slopes that do not excess 27° (<50% slope). That means that cattle can browse the vegetation. This can explain why none of the present VGs include typical species of the 8210 habitat type according to the Eur 28 definitions. The VG 5 is most represented on marbles and dolomites but can be found also on acid substrate. The VG 11 has also a larger possibility to be found on silicious and serpentine substrate, but with less rocky surfaces than the two others.

3.2.4 SHRUBLANDS OF HIGH MOUNTAIN MAINLY ON ACIDIC SUBSTRATE

VG 7: *Juniperus communis ssp. nana* 56 *Vaccinium myrtillus* 43 *Bruckenthalia spiculifolia* 9 *Bupleurum gerardi* 5 *Dianthus deltoides* 5 *Festuca hirtovaginata*

The VG.7 is codified in the relevés from the Tzena and Vorras mounts with the code 4060 which means "Alpine and boreal heaths". They are found on schists and gneiss and range from 1600 to 2100m. Dafis and al. (2001) ordered this habitat type in the Erico-Pinetalia.

They are mentionned in the Eur28 interpretation manual as small, dwarf or prostrate shrub formations of the alpine and sub-alpine zones of the mountains of Eurasia dominated by ericaceous species, Dryas octopetala, dwarf junipers, brooms or greenweeds. In the Carpathians, the Balkan Range, the Pontic Range, the Caucasus and the Himalayan system, they are often with Vaccinium spp., sometimes with dwarf pines.

3.2.5 LOW SHRUBLANDS OF HIGH MOUNTAIN MAINLY ON BASIC SUBSTRATE

VG 20: *Astragalus angustifolius* 30 *Festuca varia* 23 *Cerastium banaticum* 20 *Trinia frigida* 7 *Jurinea consanguinea*. This VG has been found in an RG of the Ossa mount, one relevé from The Kato Olympus mount (Thessaly) and from the Tzena mount in the same relevés with the VG 4 and VG 11.

VG 18: *Erysimum microstylum* 30 *Marrubium thessalum* 18 *Daphne oleoides* 16 *Asyneuma limonifolium* 16 *Poa thessala* 7 *Thymus teucrioides* 5 *Festuca jeanpertii* 5 *Linaria peloponnesiaca*. This VG has been found in two RG from the Ossa mount together with the VG 20.

These VG range from 1300 to 1900m. They grow on around 25% rocky ground. The given habitat code number is 4090 "Endemic oro-Mediterranean heaths with gorse". This habitat type is ordered in the Daphno-Festucetea by the Eur28 classification. *Astragalus angustifolius, Daphne oleoides, Poa thessala, and Festuca jeanpertii* are cited in this order by this classification. Dafis et al. (2001) order also them in the Daphno-Festucetalia. *Astragalus angustifolius* and *Sesleria tenerrima* characterize together the association Marrubio thessali - Astragaletum angustifolii cited by Quezel (1967) as member of the Eryngio-bromion alliance on the Mount Olympus, that has been found also on the Oiti mount [16]. But in the sample that we have processed, the two last species are separated in two VG. In fact, these VG are in the same dynamic sequence with the ones of the habitat 6170. It is the same large group with differences in the cover of spiny shrubs like *Astragalus angustifolius*. The difference between the two VG is that the VG 20 has been found not only on argilous soil, but also on silty, even sandy, with bush and rocky surface cover under 10%. Let's remark that *Festuca varia* characterizes another association of the same alliance, the one with *Festuca varia* and *Marrubium velutinum* (Quezel, 1967). Also, the VG 20 has been found at higher altitude than the 18.

3.2.6 INTERMEDIATE ALTITUDE GRASSLANDS ON BASIC SUBSTRATE

VG 17: *Dianthus petraeus* 32 *Hieracium pannosum* 21 *Vincetoxicum hirundinaria* 18 *Stipa pennata* 16 *Helianthemum nummularium* 16 *Sedum urvillei* 16 *Onobrychis montana* 14 *Linum elegans* 8 *Anthyllis aurea* 7 *Bromus riparius* 7 *Haplophyllum balcanicum* 6 *Sanguisorba minor*

VG 9: *Sesleria rigida* 45 *Thymus praecox* 34 *Thymus thracicus* 26 *Draba lasiocarpa* 25 *Bromus cappadocicus* 22 *Teucrium montanum* 9 *Thlaspi praecox* 8 *Genista carinalis* 7 *Centaurea salonitana* 7 *Plantago arenaria*

VG 10: *Achillea millefolium* 40 *Festuca valesiaca*

VG 21: *Achillea holosericea* 29 *Alyssum montanum* 17 *Thalictrum minus* 9 *Erysimum drenowskyi* 8 *Eryngium creticum*

They range from 1100 to 1700m (one relevé at 800m for the VG10). The VG 17 has been found in codified stands as 6170 (see definition upwards) and should be then ordered in the Daphno-Festucetalia, but this is not so clear for the others. The VG10 have been found in relevés characterized with the habitat code 62A0 that means "Eastern sub-mediteranean dry grasslands (Scorzoneratalia villosae"). It has been found on serpentine in 4 of 11 relevés on the Vourinos mount where the remaining substrate of the relevé group is mainly silicious. On other mountains (Falakro, Vermio), the substrate is mainly limestone. The VG 9 has been found in relevés characterized with code 62A0, that means "Eastern sub-mediteranean dry grasslands (Scorzoneratalia villosae) " in the relevés from the Falakros mount (with exception of one relevé noted 8210 "Calcareous rocky slopes with chasmophytic vegetation"), but the relevés from the Pangeo and Menikion mounts have been codified 6170 "Alpine and subalpine calcareous grasslands".

The habitat type with code 62A0 is defined as follow in the Eur28 interpretation manual: Xeric grasslands of the sub-Mediterranean zones of Trieste, Istria and the Balkan peninsula, where they coexist with steppic grasslands of the Festucetalia valesiacae (6210), developing in areas

of lesser continentality than the latter and incorporating a greater Mediterranean element. It Includes the Chrysopogono-Centaureetum cristata community.

The species of the VG 17 take part of the Festuco-Bromion, as it appears in the European classification, but Stipa pennata is assumed to be typical of the habitat type 6170 and Hieracium pannosum typical of the Betula pendula woods (91K0, Daphis 2001), so let's assume that they can be part of the Daphno-Festucetalia, but especially on limestone and non-argillic soils (see profiles). That can explain its presence at rather low altitude, the light soil (non-argillic) can have a better hydric reserve than the argillic because of restrained evaporation in hot season. Furthermore, Quezel (1964) placed *Stipa pennata* as characteristic of the Stipeto-morinion alliance, that is the lowest just after the tree limit (1500m).

The VG 9 has also a quite large altitude range but more especially on limestone and on argillic soil. Half of its species are cited to be part of the European classification's Festuco-Bromion, but in Greece they are cited as typical species of high mountain pastures (6170, 6230). So we should assume that the VG 9 is also part of the Daphno-Festucetalia, especially on limestone and rocky surface soils (see profiles). This do not forbit this VG to leave together with VG of the Festuco-Bromion in intermediate altitudes, as VG 9 is adapted on difficult argillic soils that can lose their water storage more rapidly in summer than lighter soils.

The VG 21 can also be found at middle altitude (1100 m) on limestone substrate, with more than 25% rocky surface and not on argillic substrate. Although *Alysum montanum* and *Thalictrum minus* are in the European list of the Festuco-Brometea's characteristic species, this VG have been noted as 6170 habitat type "Alpine and subalpine calcareous grasslands" (of the Daphno-Festucetalia) in the 2014-2015 relevé's campaign. So, let's assume that the VG 21 belongs to the Daphno-festucetalia.

Although the VG 10 (Achillea millefolium & Festuca valesiaca) is most frequent on limestone it is particularly present on serpentine (RG 3). It occurs also on acid geological substrates. Festuca valesiaca is part of the characteristic species of the Festuco-Brometalia as found in the European and Greek phytosociological classification (Dafis at al., 2001).

3.2.7 GRASSLANDS OF RATHER LOW ALTITUDE

VG 19: *Allium sphaerocephalon* 30, *Alyssum minus* 30, *Avena sterilis* 30, *Hypericum olympicum*

VG 8: *Carex caryophyllea* 46 *Scabiosa columbaria* 31 *Eryngium campestre* 29 *Medicago minima* 27 *Allium flavum* 26 *Potentilla argentea* 15 *Hieracium macranthum*

VG 13: *Chrysopogon gryllus* 39 *Poa bulbosa* 4 *Armeria rumelica*

VG 15: *Dianthus gracilis* 36 *Satureja pilosa* 35 *Artemisia alba*

VG 14: *Koeleria cristata* 36 *Minuartia verna* 32 *Potentilla detommasii* 16 *Thesium alpinum* 11 *Thesium divaricatum* 5 *Viola macedonica*

VG 1: *Stipa capillata* 83 *Teucrium capitatum* 74 *Helianthemum salicifolium* 48 *Xeranthemum inapertum* 47 *Dichanthium ischaemum* 45 *Melica ciliata* 39 *Crupina crupinastrum* 29 *Thesium humile* 28 *Allium pallens* 28 *Verbascum pulverulentum* 26 *Scabiosa webbiana* 23 *Satureja montana* 23 *Centaurea grisebachii* 17 *Lomelosia argentea* 5 *Verbascum graecum*

VG 12: *Artemisia campestris* 39 *Erysimum diffusum* 27 *Chondrilla juncea* 16 *Petrorhagia illyrica* 14 *Thymus sibthorpii* 6 *Achillea chrysocoma* 5 *Paronychia rechingeri*

They range from 500 to 1500m (1800m for Koeleria cristata). The substrate is mainly basic, but it is frequently of tertiary deposits and alluvions. They are mainly on argillic soils with a substantial amount of rocky surface between.

The VG 1 has been sometime noted in relevés with code 6220: "Pseudo-steppe with grasses and annuals of the Thero-Brachypodietea", that is a eu-mediterranean group in the bioclimatic classification, and sometime, on the same substrate, with code 62A0, that means "Eastern sub-mediteranean dry grasslands (Scorzoneratalia villosae) ". But this VG is linked to the VG 9 (with altitude range from 1100 to 2000m) in the cluster analysis between the VGs. The VG 9 is clearly not eu-mediterranean and by its floristic composition can be included in the oro-mediterranean bioclimatic storage. Also, the trees of the site where the relevés have been noted as 6220 are *Quercus trojana,* that is ordered in the Quercetalia pubescenti-petraea in Dafis et al. (2001). At last, *Melica ciliata,* that is in the VG 1 is one characteristic of the Stipeto-morinion of the Dahno-festucetalia (Quezel, 1964, Musarella et a., 2020). All the others VGs of this groupments' group (1, 8, 12, 13, 14, 15) have been found in relevés characterized with the habitat code 62A0. Only the VG 14 has been characterized with a habitat code, that is 6170 "Alpine and subalpine calcareous grasslands" only for one relevé at 1800 m, and has the strongest link with the VG. 9 in the groupments' Group. So, it is logic to attribute to this groupement's group the habitat code 62A0. Their floristic composition conducts us to ordinate this groupment's group in to the Festuco-Brometalia.

The first species of VG 8 are cited as characteristic ones of the upwards order in the Eur28 classification. This VG is not tightly link with a particular substrate, so it can represent generally the order. The VG 13 (*Chrysopogon gryllus* and *Poa bulbosa*) can be found in the same RG with VG 8 and its species are also among the ones of the Festuco-Brometalia but at a lower altitude and especially on tertiary deposits and marbles at least for *Chrysopogon gryllus*.

The VG 15 Can be found in the same RG with the VG 8, but especially on argillic soils.

The VG 14 also can be found in the same RG with the VG 8, but especially on limestone, tertiary deposits and serpentine.

The VG 1 is particularly localized on marbles at the lowest altitude of the sample, at the same site (Vegoritida and Petron lakes). It can be found also on alluvial and tertiary deposits.

The VG 12 is found on the same RG as the VG 1, especially on alluvions and colluvions, without rocky surfaces.

Last, the VG 19, although its species are very common, is very local.

The Festuco-brometalia were associated with the Natura habitat type 6170 when there were not yet 62A0. The last code has been attributed after the balkanic countries other than Greece interred in the UE. 6170 refers to "Semi-natural dry grasslands and scrubland facies on calcareous substrates (Festuco-Brometalia)" and are "present in almost the entire European continent".

3.2.8 SHRUBLANDS ON MIDDLE ALTITUDE

VG 2: *Fumana procumbens* 73 *Juniperus oxycedrus* 43 *Silene radicosa* 36 *Euphorbia myrsinites* 23 *Acinos alpinus*

This VG has been codified 5210 "Arborescent matorral with Juniperus spp." This VG range from 600 to 1500m, mainly on marble (Vegoritida lake) and limestone, but also on gneiss on the Titaros mount. Let's remark the high rate of shrubs in this VG. It is encountered in the same RG as the VG 1. They are ordinated in the Quercetalia pubescenti-petraea in Dafis et al. (2001), and more precisely in the Erico-Pinetalia order.

4 CONCLUSION

Our study shows the pertinence of Natura 2000 habitat types because it can be linked to environmental variable's classes.

For example, an altitude around 1500m has been found to be a limit between, **downwards,** the habitat types 62A0 "Eastern sub-mediteranean dry grasslands (Scorzoneratalia villosae) " and 5210 "Arborescent matorral with Juniperus spp." and, **upwards,** the habitat types 6170 "Alpine and subalpine calcareous grasslands", 4090 "Endemic oro-Mediterranean heaths with gorse", 4060 "Alpine and boreal heaths" and 6230 "Species-rich Nardus Grasslands, on silicious substrates in mountain areas". This limit corresponds also to the limit given in Mountousis et al. (2022) [17] between "mountainous and "subalpine grasslands", these authors founding the last more productive.

Our results showed also the tight link between the Daphno-Festucetalia and limestone and confirmed the tight bond between the Nardetalia and acidic substract. For the Festuco-Brometalia the substrate is mainly basic, but it is frequently of tertiary deposits and alluvions.

Our study confirms also the links between habitat types and phytosociological taxa at order level:

- The habitat type 62A0 "Eastern sub-mediteranean dry grasslands" corresponds to Festuco-brometalia.
- The habitat types 6170 and 4090 correspond both to Daphno-festucetalia
- The habitat type 6230 corresponds to the Nardetalia
- The habitat types 7140 and 7230 correspond both to the Phragmitetalia
- The habitat types 5210 and 4060 correspond both to the Erico-pinetalia.

Concerning the lower levels of the phytosociological classification, it was possible to find a correspondence between the VG5 (Saxifraga scardica-Thymus boissieri-Sesleria tenerrima) and one association from Quezel (1967, 1973), the association with *Sesleria coerulens* (*Sesleria tenerrima* = *Sesleria coerulans var. tenerrima* Fritsch) and *Thymus boissieri* of the Astragalo-seslerion alliance.

It was not possible to do this for any other association or alliance for a reason explained by Musarella et al. [18] who have stated that "the species proposed [by Quezel] as characteristics of the alliances are distributed indifferently in all three syntaxa, often with high frequency values. Therefore, it can be easily deduced that a single association cannot be clearly and unambiguously attributed to a specific alliance."

So, at the alliance and association level, it would be very interesting to give ecological significance to the Greek mountain rangelands phytosociological taxa defined by Quezel, but also to those, numerous, defined by Musarella.

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