Integrated conservation management of priority habitat type 9590* in the Natura 2000 site "Koilada Kedron-Kampos"

(LIFE15 NAT/CY/000850)

DELIVERABLE:

REPORT ON FLORISTIC COMPOSITION OF HABITAT TYPE 9590* WITHIN THE TARGETED NATURA 2000 SITE

(ACTION A.1.1)

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NICOSIA

BENEFICIARIES:

The present investigation was carried out by the Nature Conservation Unit of Frederick University and the external expert on Plant Communities (Ass. Professor Ioannis Tsiripidis; School of Biology, Aristotle University of Thessaloniki) under the framework of the project entitled "Integrated conservation management of priority habitat type 9590* in the Natura 2000 site "Koilada Kedron-Kampos" (LIFE15 NAT/CY/00850), which is co-funded by the LIFE programme.

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DELIVERABLE A.1.1: **Report on the floristic composition of the habitat type 9590 - *Cedrus brevifolia* forests (*Cedrosetum brevifoliae*).**

1. Introduction

The concept of habitat structure was initially adopted for the study of the effects of "the arrangement of objects in space" on ecological variables (Bell et al. 1990). Since then, Bell et al. (1990), defined habitat structure as "the amount, composition and three dimensional arrangement of physical matter (both abiotic and biotic) at a location" (Byrne 2007). However, beyond the concept and definition, research has shown that habitat structure drives directly or indirectly many ecological processes via its modification of environmental conditions and resource availability (Byrne 2007). Hence, the scientific knowledge of the composition and structure of the targeted habitat is significant in order to understand the stability and viability, as well as its natural regeneration capacity.

Under the framework of its preparatory actions, the project LIFE-KEDROS (LIFE15 NAT/CY/000850) requires the preparation of a report on the floristic composition of the targeted habitat type. Thus, this preparatory action aims to quantitatively determine and describe the species composition and structure of the targeted habitat type and the main ecological factors that may influence these attributes (e.g. soil erosion, habitat disturbance, invasive species and climate change).

2. Materials and Methods

2.1. Collection of data

The study area of the targeted habitat type is situated within the Natura 2000 site "Koilada Kedron – Kampos" (CY2000008), which is the only site where habitat type 9590* occurs. Thirty-three random stratified plots have been sampled. The different strata/vegetation classes that were taken into consideration are:

i) Pure stands of *Cedrus brevifolia* (19 plots),

ii) Mixture of *C. brevifolia* and *Quercus alnifolia* (3 plots),

iii) Mixture of *C. brevifolia* and *Pinus brutia* (5 plots) and

iv) Reforestation of *C. brevifolia* (6 plots).

In total 33 sample plots were sampled, covering the whole distribution area of the target habitat (Fig. 1; Table 1). The size of the six reforestation plots was 10 m x 10 m (100 m^2), while the size of the remaining plots was 15 m X 15 m (225 m^2). The difference in the plots' size was due to that: i) the topography within the reforestation plots is characterized by high inclination and due to this it was very difficult to move within the plot for the recording of species and other variables and ii) the heterogeneity of the anthropogenically shaped environment in the reforestations.

Table 1: Sample plots for the collection of abiotic and biotic data within the habitat type 9590*

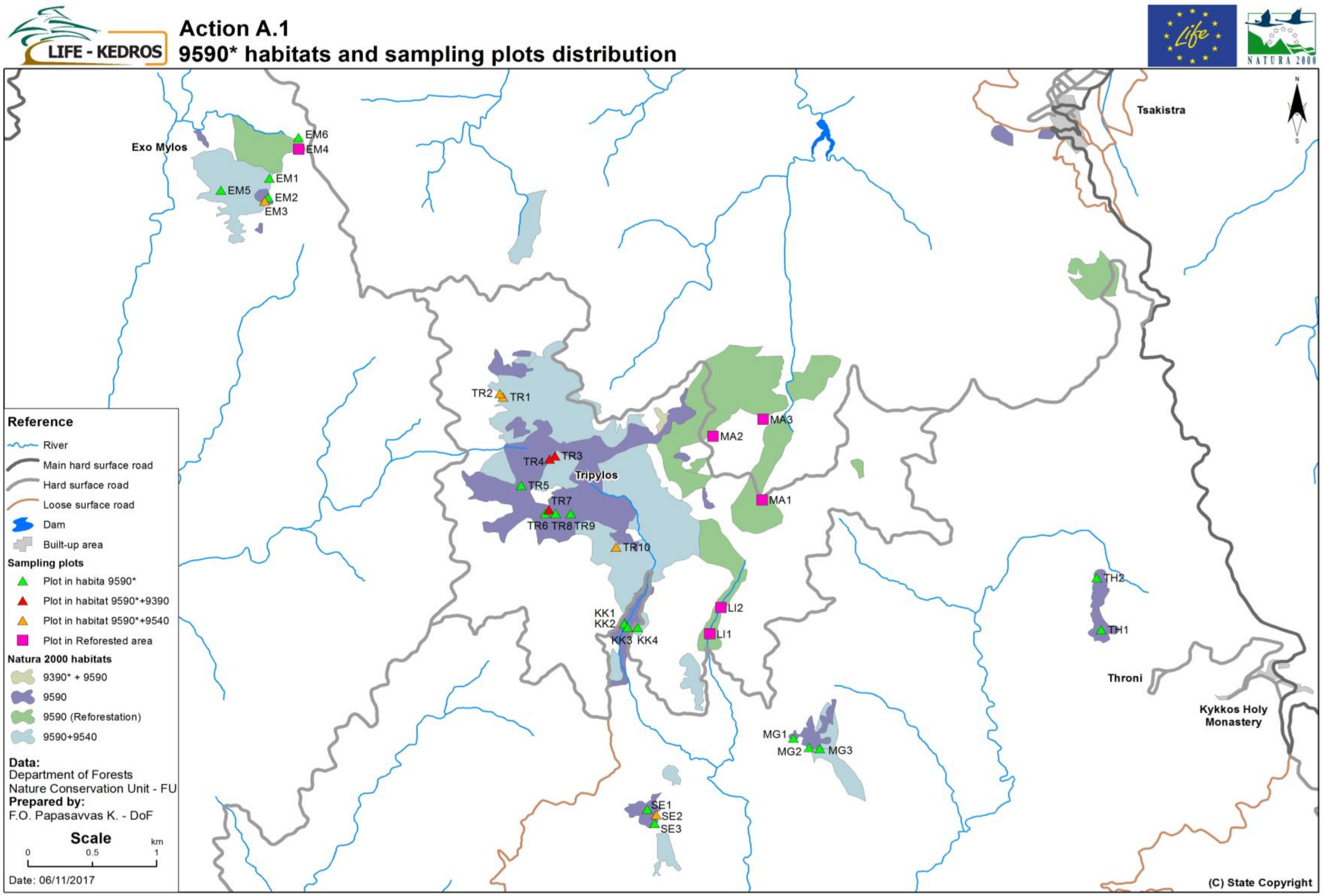
Plot No.	Location	Code	Latitude	Longitude	Altitude	Exposition [i]	Habitat type [ii]	Plot's size (m^2)
1	Matsimas	MA1	472432	3872658	1126	NW	Reforestation	100
2	Matsimas	MA2	472050	3873169	1058	NE	Reforestation	100
3	Matsimas	MA3	472438	3873305	887	SE	Reforestation	100
4	Selladi Elias	SE1	471539	3870175	1262	N	9590	225
5	Selladi Elias	SE2	471609	3870130	1282	E	9590+9540	225
6	Selladi Elias	SE3	471595	3870061	1254	SW	9590	225
7	Exo Mylos	EM1	468599	3875242	1254	W	9590	225
8	Exo Mylos	EM2	468591	3875089	1240	E	9590	225
9	Exo Mylos	EM3	468563	3875059	1232	SW	9590+9540	225
10	Exo Mylos	EM4	468829	3875475	1224	NE	Reforestation	100
11	Exo Mylos	EM5	468223	3875145	1109	S	9590	225

12	Exo Mylos	EM6	468826	3875571	1187	W	9590	225
13	Throni	TH1	475067	3871617	1154	W	9590	225
14	Throni	TH2	475033	3872034	998	N	9590	225
15	Mavroi Gkremoi	MG1	472675	3870746	1167	N	9590	225
16	Mavroi Gkremoi	MG2	472797	3870672	1165	S	9590	225
17	Mavroi Gkremoi	MG3	472878	3870661	1148	SW	9590	225
18	Koilada Kedron	KK1	471363	3871670	1059	NSWE (0 - 360°)	9590	225
19	Koilada Kedron	KK2	471359	3871667	1097	E	9590	225
20	Koilada Kedron	KK3	471385	3871634	1054	W	9590	225
21	Koilada Kedron	KK4	471464	3871636	1137	W	9590	225
22	Tripylos	TR1	470417	3873485	1302	S	9590+9540	225
23	Tripylos	TR2	470392	3873514	1300	SW	9590+9540	225
24	Tripylos	TR3	470820	3873013	1360	SE	9590+9390	225
25	Tripylos	TR4	470778	3872986	1355	NW	9590+9390	225
26	Tripylos	TR5	470559	3872776	1394	N	9590	225
27	Tripylos	TR6	470745	3872550	1383	SW	9590	225
28	Tripylos	TR7	470773	3872580	1396	NE	9590+9390	225
29	Tripylos	TR8	470826	3872550	1393	W	9590	225
30	Tripylos	TR9	470942	3872551	1401	NE	9590	225
31	Tripylos	TR10	471295	3872280	1224	SE	9590+9540	225
32	Livadi	LI1	472024	3871582	1150	W	Reforestation	100
33	Livadi	LI2	472111	3871794	1150	W	Reforestation	100

[i] N = North, S = South, W = West, E = East.

[ii] 9590 = Pure stands of *Cedrus brevifolia*, 9590 + 9540 = Mixture of *Cedrus brevifolia* and *Pinus brutia*, 9590 + 9390 = Mixture of *Cedrus brevifolia* and *Quercus alnifolia*, Reforestation = reforestation of *Cedrus brevifolia.*

Figures 1: Map of the sampling localities distribution within the boundaries of habitat 9590*.



The data collection form (Supplement 1; Δημόπουλος και Τσιριπίδης 2013) was prepared for the collection of data, within each plot, regarding the abiotic and biotic factors that contribute to the characterization of the targeted habitat type. All species in each plot were recorded using the modified Braun-Blanquet 9-grade cover-abundance scale (Wikum and Shanholtzer 1978). The data was recorded during visits to the targeted site, in May and June 2017 (Supplement 2). The identification of taxa was based on the "Flora of Cyprus" (Meikle 1977, 1981) and nomenclature followed more recent online resources (Hand et al. 2017).

2.2. Data analysis

The data sets were entered in Turboveg (ver. 2.1) (Hennekens & Schaminée 2001) and then in Juice (ver. 7.0.102) (Tichý 2002). Occurrences of *taxa* in different layers were retained in order to be able to explore the differentiation in the structure between the vegetation stands sampled. However, for two taxa, their occurrences in different layers were unified because it was considered that they may cause noise in the analysis and that their occurrence in different layers does not have any ecological meaning-interpretation. Specifically, the tree, low shrub and herb layers of *Arbutus andrachne* were unified into one layer as well the ones of tree and high shrubs of *Quercus alnifolia*.

After the unification of the above two species' layers, all taxa occurring in one only plot were omitted to reduce noise. Taxa with two occurrences in the data set were retained as it was considered that some of them may have a potential differential role.

For the classification analysis three methods were tested: modified TWINSPAN analysis (Roleček et al. 2009), and cluster analysis either using the Ward's method and Euclidean distance or the flexible beta method (b=-0.25) and the Bray-Curtis distance (Ward 1963; Lance & Williams 1967). In the modified TWINSPAN analysis three pseudospecies cut levels (0, 3 and 50) and the rule to stop further divisions if dissimilarity is lower than 0.4 were applied. The pseudospecies cut levels unify species covering three categories: those being higher than 0 and up to 3% (covers r, + and 1 in the Braun-Blanquet scale), those being higher than 3% and up to 50% (covers 2m, 2a, 2b and 3 in the Braun-Blanquet scale), and those being higher than 50% (covers 4 and 5 in the Braun-Blanquet scale). These cut levels were chosen after testing with several different schemes of cut levels. Furthermore, the dissimilarity threshold was set to a certain value in order to allow the algorithm to produce an adequate number of groups as well as relatively homogenous groups. Smaller threshold values produced a very high number of groups, while larger values very few groups.

Cluster analysis was run after applying the chord transformation on the cover of taxa. The decision on the number of clusters was assisted by means of a graph of fusion level values. These values represent the dissimilarity values where a fusion between two branches of a dendrogram occurs (Borcard et al. 2011).

Modified TWINSPAN was applied by using the JUICE software (ver. 7.0.102) (Tichý 2002), while cluster analysis by using the packages "vegan" (Oksanen et al. 2017) and "cluster" (Maechler et al. 2017), and a script in R language written by Borcard et al. (2011) (the latter was applied in order to re-order the clusters in the dendrogram).

Diagnostic taxa of the distinguished clusters were determined by using the algorithm of Tsiripidis et al. (2009). Phi coefficient (Chytrý et al. 2002) was determined for diagnostic taxa between the cluster(s) differentiated positively against those differentiated negatively or not differentiated. Furthermore, Fisher's exact test was applied to test if the relative and/or absolute constancy of the diagnostic taxa found by the algorithm of Tsiripidis et al. (2009) is significantly higher in the cluster(s) differentiated positively in comparison with those differentiated negatively or not differentiated.

The explanatory variables collected during fieldwork (see Supplement 3) were compared between the distinguished clusters by means of box and whisker plots. Furthermore, for testing for any significant differences in the explanatory variables, a Kruskal-Wallis test (Kruskal & Wallis 1952) was performed by using R (R Core Team 2017). For those variables, found to be significantly different among the distinguished clusters we used Conover-Iman test (Conover & Iman 1979) to find the specific clusters having statistical differences in the variables. The test was performed by using conover.test package in R (Dinno 2017). In total, 21 variables were used in the above-mentioned comparisons. Most variables were measured-estimated in the field, except potential direct-incident radiation and heat load that were estimated from average slope inclination, exposition of slope and geographic latitude of plots by using the third equation proposed by McCune & Keon (2002).

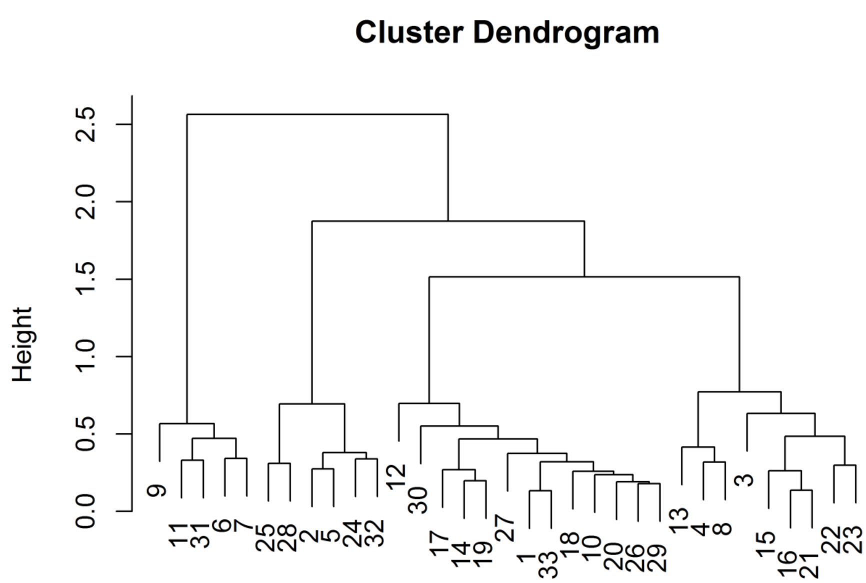
For the ordination analysis of plots Nonmetric Multidimensional Scaling (NMDS) was chosen to be applied, because it is not parametric and does not assume any particular underlying model (McCune & Grace 2002). NMDS was applied by using metaMDS function in the package "vegan"

(Oksanen et al. 2017). The environmental variables collected were projected onto the ordination space a posteriori by using the envfit function of the "vegan" package (Oksanen et al. 2017) and the squared correlation coefficients (r^2) between them and the NMDS axes were calculated.

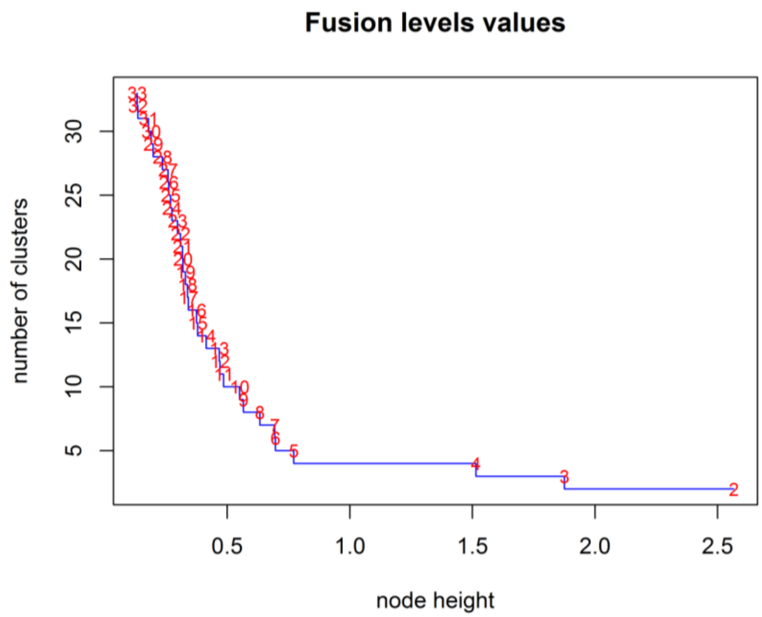
3. Results

Among the three methods used for the classification analysis the best results in terms of interpretation were produced by the Ward's and the flexible beta methods, and finally the former method was selected. The modified TWINSPAN method created many very small groups and few large groups, presenting thus the so-called effect of "chaining". This effect may be resulted because few plots are quite different from the rest ones. As TWINSPAN partitions the dissimilarity space determined by the main gradients in the data (Roleček 2009), it distinguishes mainly as groups the outliers along this gradient. The modified TWINSPAN method distinguished 10 groups on the basis of the selected options.

The cluster dendrogram (Fig. 2) as well as the graph of fusion levels values (Fig. 3) indicate that four groups can be distinguished in the data set.

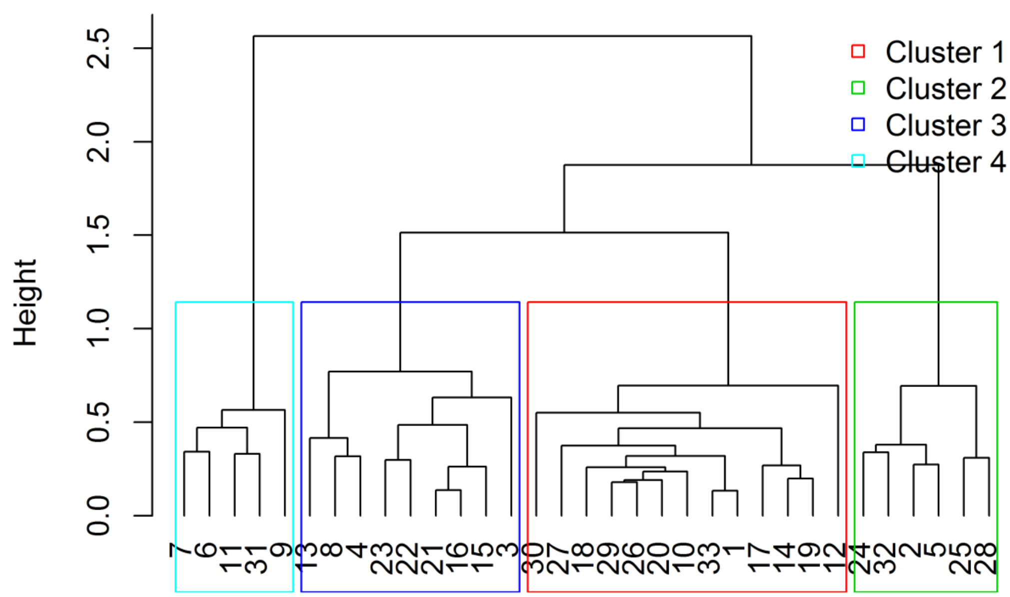


<u>Figure 2</u>: Cluster dendrogram of plots' data, made by using Ward's method and Euclidean distance.



<u>Figure 3</u>: Fusion levels values between the branches of the dendrogram of the cluster analysis.

Finally, the dendrogram, was cut to form four groups. The reordered dendrogram according to the R script of Borcard et al. (2011) is presented in Fig. 4.



<u>Figure 4</u>: Dendrogram made by using Ward's method and Euclidean distance in which clusters were reordered according to the script of Borcard et al. (2011).

In total, 39 taxa were found as differential for the four clusters according the algorithm of Tsiripidis et al. (2009) (see Table 2 and Supplement 4). The fourth cluster has 12 absolute differential taxa and clusters 3 and 1 have four, each. The second cluster is differentiated mainly negatively, as only one taxon differentiates this cluster positively. Common differential taxa were found between clusters 4 and 3 (10 taxa), clusters 4, 3 and 1 (three taxa) and clusters 3 and 1 (four taxa). However, the floristic differentiation between the clusters is not very strong as only seven taxa were found to have significant higher absolute constancy in the clusters that differentiate positively in comparison with the rest clusters (Table 2). However, this fact may also be an artifact related to the total number of plots sampled and analysed. These taxa were found to differentiate cluster 4 (two taxa), clusters 4 and 3 (three taxa) and clusters 3 and 1 (two taxa). On the other hand, all the differential taxa were found to be significant on the basis of their relative constancies.

The fourth cluster includes mainly mixed stands with *P. brutia* and *C. brevifolia*. In this vegetation type *C. brevifolia* presents lower abundance in comparison with the other three clusters. Furthermore, species indicating warmer, drier and more disturbed sites (e.g. *Asphodelus ramosus*, *Galium aparine*, *Petrorhagia dubia*, *Cistus creticus*) present their higher frequency or abundance in this cluster.

The third cluster includes also few mixed stands with *P. brutia*, as well as few disturbed sites. It comprises an intermediate stage both in terms of succession and environmental conditions between the fourth and the first clusters. Its intermediate position is also justified by the fact that it hosts common differential species with both of the above-mentioned clusters.

The first cluster represents pure and undisturbed *C. brevifolia* forests. More thermo-xerophilous species as well as indicators of disturbances are much less frequent or abundant in this cluster in comparison with the former ones. However, some thermophilous species are still growing in this vegetation type, while although high shrubs of *Q. alnifolia* are frequent they have a relatively low abundance.

The second cluster represents mixed stands of *C. brevifolia* and *Q. alnifolia*. The latter species presents its highest abundance in this cluster. Probably, because of the high abundance of the latter species and its shading effect, this cluster is poorer in species and it is mainly negatively differentiated against the former clusters.

Table 2: Synoptic table of the four clusters. Abbr.: Abbreviation of species; Layer: vegetation layer (T: tree, S1: shrub high, S2: shrub low, H: herb); p values (relative constancy): the p values calculated by the Fisher's exact test on the basis of the relative constancy, and p values (absolute constancy): the p values calculated by the Fisher's exact test on the basis of the absolute constancy. The order of clusters (1, 2, 3 and 4) has been arranged on the basis of the script of Borcard et al. (2011). Taxa occurring in one only plot were omitted.

Taxa	Abbr.	Layer	Ab. Con.	4	3	1	2	p values (relative constancy)	Phi value	4	3	1	2	p values (absolute constancy)
Number of plots				**5**	**9**	**13**	**6**			**5**	**9**	**13**	**6**	
Pinus brutia	PinBru.T	T	9	**80**	*22*	*15*	*17*	**$3.53389E^{-29}$**	57	**4**	2	2	1	**0.013272323**
Asphodelus ramosus	AspRam.H	H	15	**100**	*33*	*31*	50	**$6.06192E^{-34}$**	54	**5**	3	4	3	**0.012652948**
Galium aparine	GalApa.H	H	7	**60**	*0*	23	17	**$6.67035E^{-19}$**	47	**3**	0	3	1	0.051850541
Daucus broteri	DauBro.H	H	2	**20**	*0*	*0*	*0*	**$1.92222E^{-13}$**	40	**1**	0	1	0	0.284090909
Lactuca cyprica	LacCyp.H	H	2	**20**	*0*	*0*	*0*	**$1.92222E^{-13}$**	40	**1**	0	1	0	0.284090909
Petrorhagia dubia	PetDub.H	H	10	**60**	44	*15*	*17*	**$9.53446E^{-10}$**	32	**3**	4	2	1	0.149332592
Allium sp.	AllSpe.H	H	3	**20**	11	*0*	*0*	**$1.35278E^{-06}$**	26	**1**	1	1	0	0.399560117
Alyssum foliosum	AlyFol.H	H	2	**20**	11	*0*	*0*	**$1.35278E^{-06}$**	26	**1**	1	0	0	0.284090909
Alyssum strigosum	AlyStr.H	H	2	**20**	11	*0*	*0*	**$1.35278E^{-06}$**	26	**1**	1	0	0	0.284090909

Taxa	Abbr.	Layer	Ab. Con.	4	3	1	2	p values (relative constancy)	Phi value	4	3	1	2	p values (absolute constancy)
Asplenium ceterach	AspCet.H	H	2	**20**	11	*0*	*0*	**1.35278E^{-06}**	26	**1**	1	0	0	0.284090909
Filago pyramidata	FilPyr.H	H	2	**20**	11	*0*	*0*	**1.35278E^{-06}**	26	**1**	1	0	0	0.284090909
Velezia rigida	VelRig.H	H	2	**20**	11	*0*	*0*	**1.35278E^{-06}**	26	**1**	1	0	0	0.284090909
Aira elegans	AirEle.H	H	14	**80**	**67**	*23*	*17*	**1.0848E^{-27}**	54	**4**	**6**	3	1	**0.005666639**
Silene laevigata	SilLae.H	H	5	**40**	**33**	*0*	*0*	**6.48408E^{-26}**	47	**2**	**3**	0	0	**0.008435298**
Silene galatea	SilGal.H	H	6	**20**	**44**	*0*	*0*	**2.6155E^{-22}**	44	**1**	**4**	1	0	0.061551977
Thymus integer	ThyIntS2	S2	11	**60**	**56**	*15*	*17*	**1.57013E^{-18}**	43	**3**	**5**	2	1	**0.023977393**
Psilurus incurvus	PsiInc.H	H	4	**20**	**22**	*0*	*0*	**4.09635E^{-14}**	34	**1**	**2**	1	0	0.288196481
Pinus brutia	PinBru.H	H	3	**20**	**22**	*0*	*0*	**4.09635E^{-14}**	34	**1**	**2**	0	0	0.066715543
Sedum rubens	SedRub.H	H	6	**20**	**33**	15	*0*	**4.77958E^{-07}**	25	**1**	**3**	2	0	0.36308019
Trifolium campestre subsp. *campestre*	TriCam.H	H	6	**20**	**33**	15	*0*	**4.77958E^{-07}**	25	**1**	**3**	2	0	0.36308019
Stellaria cilicica	SteCil.H	H	5	**20**	**22**	15	*0*	**0.000160151**	19	**1**	**2**	2	0	0.628463444

Taxa	Abbr.	Layer	Ab. Con.	4	3	1	2	p values (relative constancy)	Phi value	4	3	1	2	p values (absolute constancy)
Centaurea aegialophila	CenAeg.H	H	5	**20**	**22**	*0*	17	**0.000619585**	18	**1**	**2**	1	1	0.628463444
Umbilicus rupestris	UmbRup.H	H	9	**40**	**44**	**23**	*0*	**2.07566E-16**	35	**2**	**4**	**3**	0	0.155728587
Legousia falcata	LegFal.H	H	8	**40**	**22**	**31**	*0*	**4.29094E-14**	32	**2**	**2**	**4**	0	0.296440489
Arabis verna	AraVer.H	H	9	**20**	**33**	**38**	*0*	**9.01001E-14**	31	**1**	**3**	**5**	0	0.155728587
Papaver paphium	PapPap.H	H	6	**20**	11	**31**	*0*	**2.68769E-08**	28	**1**	1	**4**	0	0.186122206
Trifolium hirtum	TriHir.H	H	4	*0*	**33**	*0*	*0*	**1.34751E-22**	52	0	**3**	1	0	0.052346041
Helichrysum italicum	HelItaS2	S2	2	*0*	**22**	*0*	*0*	**8.43522E-15**	42	0	**2**	0	0	0.068181818
Scutellaria cypria subsp. *elatior*	ScuCyp.H	H	2	*0*	**22**	*0*	*0*	**8.43522E-15**	42	0	**2**	0	0	0.068181818
Spergularia diandra	SpeDia.H	H	4	*0*	**22**	15	*0*	**2.77015E-06**	25	0	**2**	2	0	0.29516129
Cynosurus effusus	CynEff.H	H	19	*20*	**67**	**85**	*17*	**5.294E-32**	58	1	**6**	**11**	1	**0.002259556**
Cedrus brevifolia	CedBreS1	S1	19	40	**78**	**69**	*17*	**1.3203E-19**	45	2	**7**	**9**	1	**0.023977393**
Myosotis ramosissima subsp. *ramosissima*	MyoRam.H	H	6	*0*	**22**	**31**	*0*	**4.14621E-18**	39	0	**2**	**4**	0	0.076960512

Taxa	Abbr.	Layer	Ab. Con.	4	3	1	2	p values (relative constancy)	Phi value	4	3	1	2	p values (absolute constancy)
Ornithogalum chionophilum	OrnChi.H	H	17	40	**67**	**62**	*17*	**6.18443E-13**	36	2	**6**	**8**	1	0.070729152
Arbutus andrachne	ArbAndS2	T,S2,H	5	*0*	11	**31**	*0*	**1.79884E-12**	39	0	1	**4**	0	0.065674824
Pteridium aquilinum	PteAqu.H	H	4	*0*	*0*	**23**	17	**3.5526E-06**	25	0	0	**3**	1	0.275659824
Rubus sanctus	RubSanS2	S2	5	*0*	11	**23**	17	**0.000831879**	18	0	1	**3**	1	0.359958034
Viola rauliniana	VioRau.H	H	5	*0*	11	**23**	17	**0.000831879**	18	0	1	**3**	1	0.359958034
Pinus brutia	PinBruS2	S2	9	40	22	*15*	**50**	**1.15762E-05**	23	2	2	2	**3**	0.309232481
Cedrus brevifolia	CedBre.T	T	33	100	100	100	100			5	9	13	6	
Cistus creticus	CisCreS2	S2	29	100	100	77	83			5	9	10	5	
Quercus alnifolia	QueAlnS2	S2	29	100	89	85	83			5	8	11	5	
Cedrus brevifolia	CedBre.H	H	28	80	89	77	100			4	8	10	6	
Quercus alnifolia	QueAlnS1	T,S1	28	60	78	92	100			3	7	12	6	
Crepis fraasii	CreFra.H	H	26	80	89	85	50			4	8	11	3	
Crucianella imbricata	CruImb.H	H	23	100	67	69	50			5	6	9	3	

Taxa	Abbr.	Layer	Ab. Con.	4	3	1	2	p values (relative constancy)	Phi value	4	3	1	2	p values (absolute constancy)
Cerastium brachypetalum subsp. *roeseri*	CerBra.H	H	22	60	78	77	33			3	7	10	2	
Anthemis plutonia	AntPlu.H	H	19	60	67	54	50			3	6	7	3	
Cedrus brevifolia	CedBreS2	S2	19	80	33	62	67			4	3	8	4	
Valantia hispida	ValHis.H	H	19	60	78	54	33			3	7	7	2	
Quercus alnifolia	QueAln.H	H	18	40	56	54	67			2	5	7	4	
Lecokia cretica	LecCre.H	H	17	60	44	62	33			3	4	8	2	
Briza humilis	BriHum.H	H	14	20	44	46	50			1	4	6	3	
Poa bulbosa	PoaBul.H	H	14	40	56	31	50			2	5	4	3	
Geranium purpureum	GerPur.H	H	12	20	22	54	33			1	2	7	2	
Galium murale	GalMur.H	H	11	20	33	46	17			1	3	6	1	
Minuartia hybrida	MinHyb.H	H	11	20	33	38	33			1	3	5	2	
Galium peplidifolium	GalPep.H	H	10	40	11	38	33			2	1	5	2	

Taxa	Abbr.	Layer	Ab. Con.	4	3	1	2	p values (relative constancy)	Phi value	4	3	1	2	p values (absolute constancy)
Bromus sterilis	BroSte.H	H	9	40	33	15	33			2	3	2	2	
Pinus brutia	PinBruS1	S1	9	20	44	15	33			1	4	2	2	
Rubia tenuifolia	RubTenS2	S2	9	20	33	31	17			1	3	4	1	
Hypochaeris glabra	HypGla.H	H	7	20	22	15	33			1	2	2	2	
Arabis laxa	AraLax.H	H	6	20	11	23	17			1	1	3	1	
Smilax aspera	SmiAspS2	S2	3	0	11	15	0			0	1	2	0	
Arabis kennedyae	AraKen.H	H	2	0	0	0	17			0	0	1	1	
Cyclamen cyprium	CycCyp.H	H	2	0	0	15	0			0	0	2	0	
Dioscorea communis	DioComS2	S2	2	0	0	0	17			0	0	1	1	
Geranium lucidum	GerLuc.H	H	2	0	0	15	0			0	0	2	0	
Pistacia terebinthus	PisTerS1	S1	2	0	11	0	0			0	1	1	0	
Teucrium kotschyanum	TeuKotS2	S2	2	0	11	0	17			0	1	0	1	

The box and whiskers plots for those variables found to be statistical different among the clusters on the basis of the Kruskal-Wallis test are presented in Fig. 5. The box and whiskers plots for the rest variables (with no statistical differences among the clusters) are given in Supplement 5. The results of the Kruskal-Walis test are presented in Table 3. The results of Conover-Iman test (Table 4) reveal mainly the significant difference in the cover of soil and litter between the two first clusters and the latter two ones, as well as the differences in structure (cover or height of vegetation layers) between the clusters. Specifically, the first cluster has significantly lower cover of shrubs than the other clusters, higher cover of herbs than the clusters 2 and 3 and higher cover of trees than the clusters 3 and 4. Furthermore, the maximum height of shrubs is significantly higher in cluster 2 in comparison with clusters 3 and 4, and the maximum height of herbs is significantly higher in cluster 4 in comparison with the clusters 1 and 2.

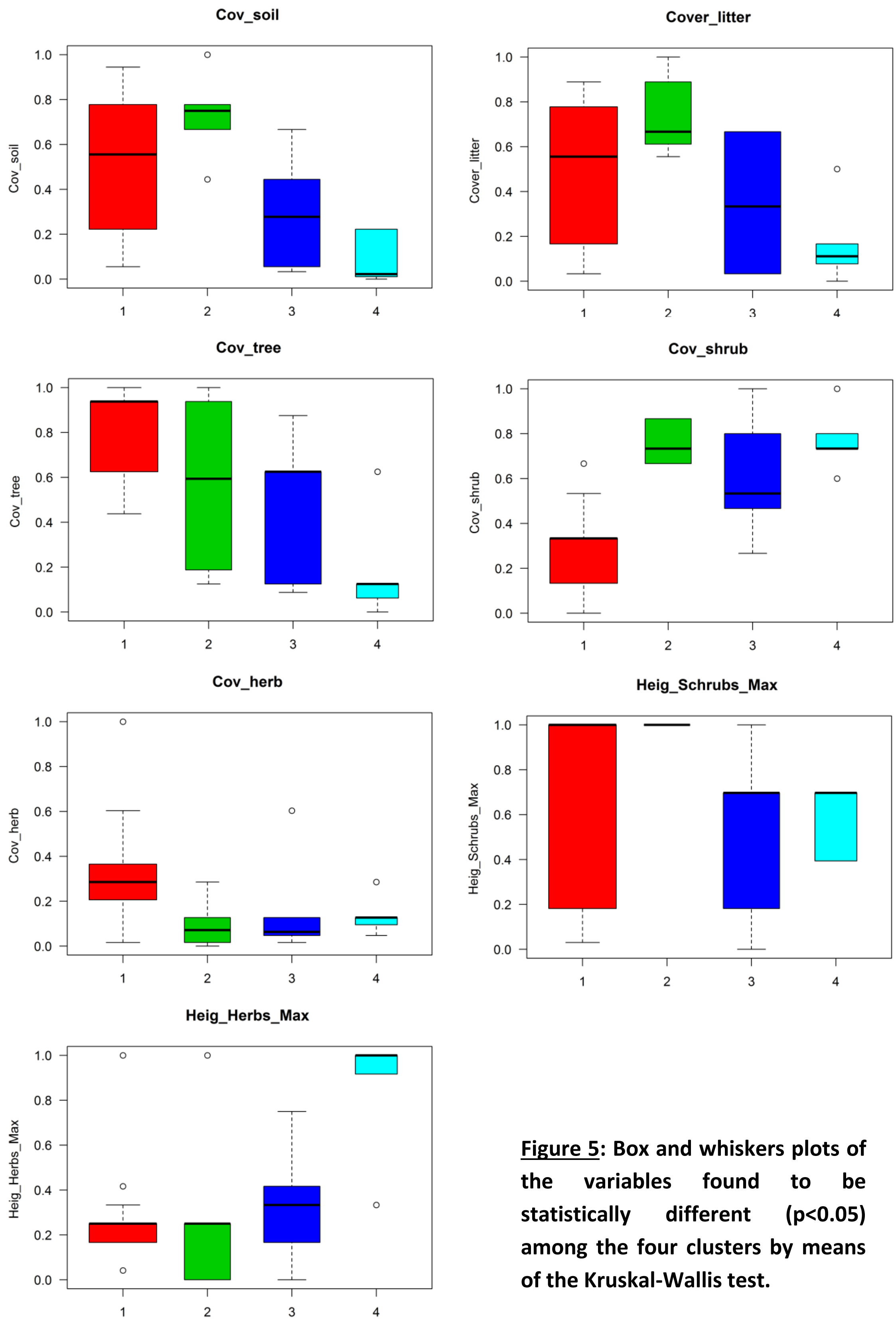
Table 3: Results of the Kruskal-Wallis test applied to the explanatory variables and among the four clusters. The chi-squared statistic and the p-values are presented; the degrees of freedom equals to three for all the variables. Variables with statistical differences among the clusters are indicated by an asterisk next to the p value.

Variable	chi-squared	p-value
Radiation	4.5406	0.2087
Heat	3.6739	0.2989
Altitude	1.4307	0.6983
Incl_Min	6.0695	0.1083
Incl_Max	2.6552	0.4479
Incl_Aver	6.9066	0.07493
Cov_Crypt	3.1491	0.3692
Substr_dist	1.2195	0.7483
Cov_boulders	2.444	0.4855
Cov_stones	0.57296	0.9026

Variable	chi-squared	p-value
Cov_soil	15.315	**0.001566***
Cover_litter	9.4486	**0.02388***
Cov_tree	12.813	**0.005059***
Cov_shrub	18.576	**0.0003345***
Cov_herb	8.9256	**0.0303***
Heig_Trees_Max	6.5076	0.08936
Max.Min_Heig_Trees	2.518	0.4721
Heig_Shrubs_Max	8.5732	**0.03554***
Heig_Herbs_Max	9.0703	**0.02837***
Reforestation	2.4717	0.4804
Mixture	2.4717	0.4804

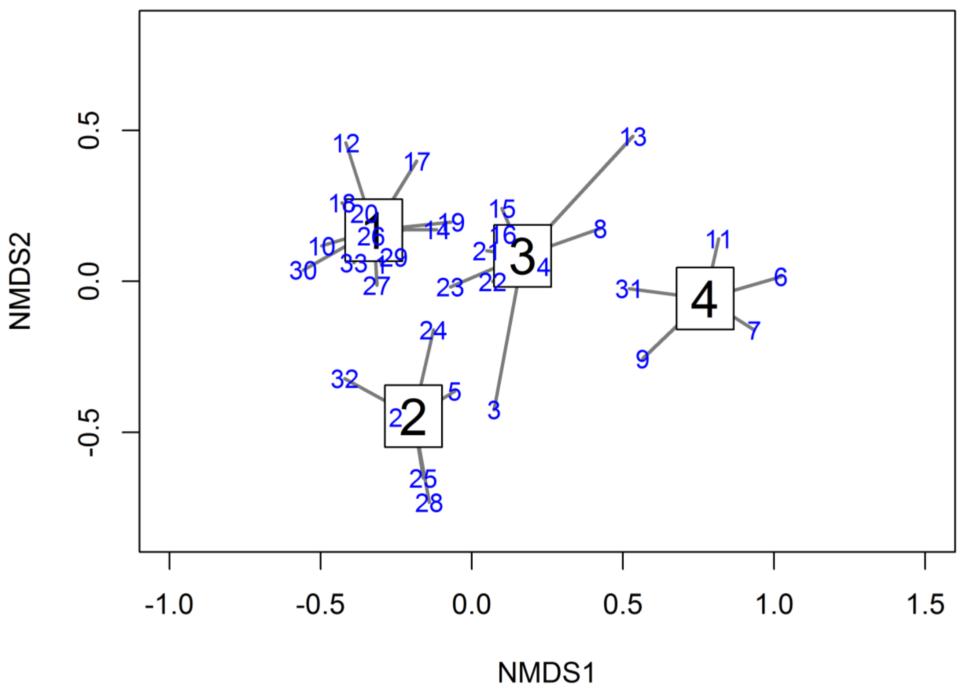
Table 4: Results of Conover-Iman test, showing the variables for which the clusters have significant differences; within brackets the p values are given.

	1	2	3
2	Cov_shrub (0.0001), Cov_herb (0.0273)	-	-
3	Cov_tree (0.0251), Cov_shrub (0.0012), Cov_herb (0.0343)	Cov_soil (0.0053), Cover_litter (0.0407), Heig_Schrubs_Max (0.0203)	-
4	Cov_soil (0.0024), Cov_tree (0.0009), Cov_shrub (0.0001), Heig_Herbs_Max (0.0105)	Cov_soil (0.0002), Cover_litter (0.0101), Heig_Schrubs_Max (0.0299), Heig_Herbs_Max (0.0210)	-

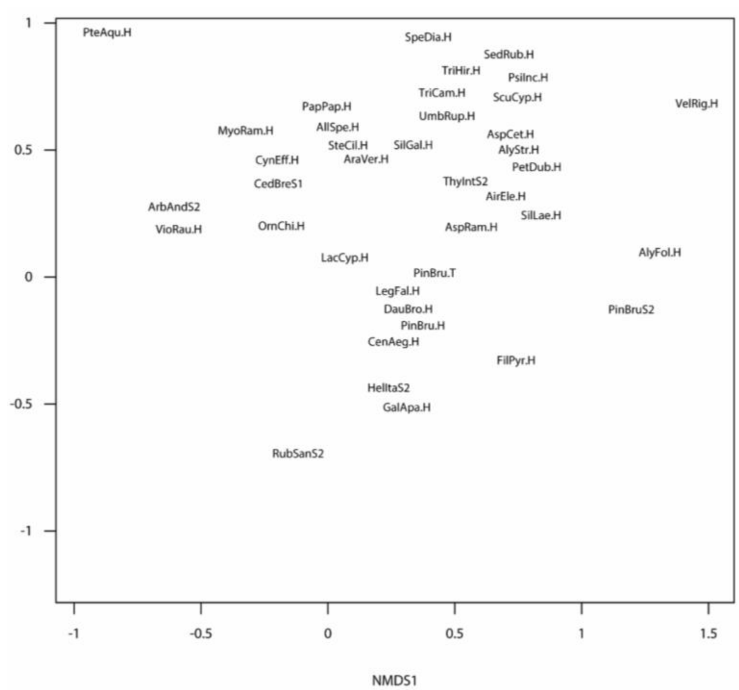


<u>Figure 5</u>: Box and whiskers plots of the variables found to be statistically different ($p<0.05$) among the four clusters by means of the Kruskal-Wallis test.

The four clusters are clearly separated in the NMDS ordination plot of Fig. 6. The clusters 4, 3 and 1 are discriminated across the first NMDS axis, while the 2nd cluster is discriminated from the rest ones on the basis of the second NMDS axis. In Fig. 7 the differential species have been plotted on the ordination space of the first two NMDS axes. The differential taxa of the clusters 4, 3 and 1 are distributed along the first NMDS axis. Specifically, the differential taxa of the fourth cluster and the common differential ones of the fourth and the third clusters are restricted at the right part of the axis. At the central part of the axis occur the common differential taxa of the 4th, 3rd and 1st clusters, and at the left part of the axis occur the common differential taxa of the 3rd and 1st clusters as well as the ones of the 1st cluster. In Fig. 8 the environmental variables were fitted a posteriori onto the ordination space of the first two NMDS axes. The significance of fitted variables was assessed by using 999 permutations of them and it is presented in Table 5, together with the direction cosines of the variables and their squared correlation coefficients (r^2). The variables found to be significant correlated with the NMDS axes are minimum ground inclination (Incl_Min), cover of soil (Cov_Soil) and litter (Cover_Litter), cover of tree (Cov_Tree) and shrub layers (Cov_Shrub), the maximum height of shrubs (Heig_Schrubs_Max), and herbs (Heig_Herbs_Max) and finally, reforestation (indicates that the sampled stands were partly planted) and mixture (indicates that vegetation represents a mixture of habitat types). Six out the above-mentioned 11 variables were found to differ significantly among the distinguished clusters also according to the Kruskal-Wallis test.



<u>Figure 6</u>: Ordination diagram of plots along the first two NMDS axes. The spiders present the distribution of the plots of the four clusters in the ordination space. Blue numbers correspond to the plots' numbers.



<u>Figure 7</u>: Ordination diagram of differential taxa along the first two NMDS axes. The position of some taxa was slightly adjusted to avoid overlapping labels.

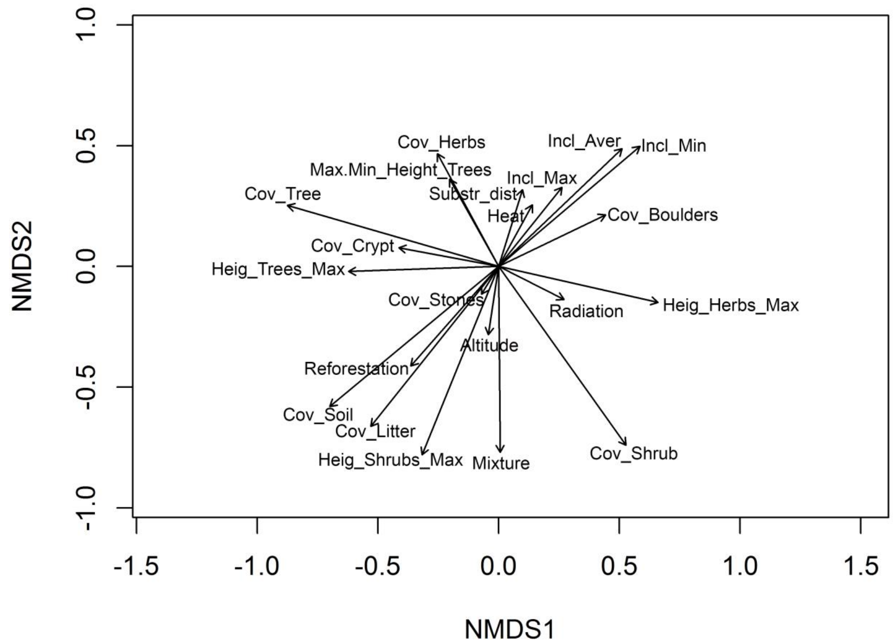


Figure 8: Explanatory (environmental) variables projected (fitted) onto the ordination space of the first two NMDS axes. Direction cosines of the variables with NMDS axes and their squared correlation coefficients are presented in Table 5.

Table 5: Environmental variables fitted onto the ordination space of the first two NMDS axes. The second and third columns present the direction cosines of the variables with the NMDS axis 1 and 2, respectively, the third column presents the squared correlation coefficients of the variables with the NMDS axes, and the fifth column the significance of fitted variables on the basis of 999 permutations. *, **, *: significance at the 0.05, 0.01 and 0.001 levels, respectively.**

Variables	NMDS1	NMDS2	r^2	Pr(>r)
Radiation	0.89333	-0.44941	0.0562	0.4097
Heat	0.47998	0.87728	0.0515	0.456
Altitude	-0.14834	-0.98894	0.0497	0.4657
Incl_Min	0.76202	0.64756	0.3602	**0.0014****
Incl_Max	0.62493	0.78068	0.1076	0.1787

Variables	NMDS1	NMDS2	r^2	Pr(>r)
Incl_Aver	0.72381	0.69	0.305	**0.0039****
Cov_Crypt	-0.98293	0.18398	0.1079	0.1744
Substr_dist	0.29826	0.95449	0.0676	0.3548
Cov_boulders	0.90081	0.43422	0.148	0.0902
Cov_stones	-0.52978	-0.84814	0.0111	0.8504
Cov_soil	-0.77034	-0.63763	0.504	**0.0001*****
Cover_litter	-0.62461	-0.78094	0.4384	**0.0006*****
Cov_tree	-0.96081	0.27722	0.5064	**0.0001*****
Cov_shrub	0.58051	-0.81425	0.5042	**0.0001*****
Cov_herb	-0.47685	0.87898	0.1722	0.0583
Heig_Trees_Max	-0.99944	-0.03334	0.236	**0.0185***
Max.Min_Heig_Trees	-0.48807	0.8728	0.1049	0.1862
Heig_Schrubs_Max	-0.37673	-0.92632	0.4327	**0.0005*****
Heig_Herbs_Max	0.97545	-0.22024	0.2796	**0.0075****
Reforestation	-0.66172	-0.74975	0.1847	**0.0439***
Mixture	0.00823	-0.99997	0.3615	**0.0018****

4. Discussion - Conclusion

Cedrus brevifolia forests habitat type are among the ones with the highest conservation value in the island of Cyprus because its keystone species (*C. brevifolia*) is an endemic taxon of Cyprus and furthermore the habitat type occurs only in Cyprus, within the area of Paphos forest. Therefore, Cyprus has the exclusive responsibility for the conservation of this habitat type. This is the first vegetation analysis that has been carried out to the whole distribution of the targeted habitat in order to investigate the structure, floristic composition and ecology of the habitat type. The study demonstrated the significant differences that occur between the different communities which the targeted habitat type includes (e.g. pure stands, mixture).

Cluster analysis of 33 plots data revealed the existence of four clusters:

i. Cluster 1 which represents mostly pure and undisturbed stands of *C. brevifolia*,

ii. Cluster 2 which represents mixed stands of *C. brevifolia* and *Q. alnifolia*,

iii. Cluster 3 which represents an intermediate stage both in terms of succession and environmental conditions between dry and disturbed forests and moister and undisturbed ones.

iv. Cluster 4 represents mainly mixed stands of *P. brutia* and *C. brevifolia,* which are dry and/or disturbed.

4.1. Environmental data

According to the Conover-Iman test, NMDS and Kruskal – Wallis test, the clusters showed significant differences in overall 11 variables and these are minimum ground inclination, average ground inclination, cover of soil, cover of litter, cover of tree layer, cover of shrub layer, maximum height of trees, maximum height of shrubs, maximum height of herbs, reforestation and mixture. The difference between the clusters is discussed below.

4.2. Species diversity

Analysis showed that plots of cluster 1 have the highest representativity concerning the targeted habitat type as they represent pure stands of *C. brevifolia*, which have limited disturbance (pressure, threats). The cover of *C. brevifolia* tree layer in the plots of this cluster ranges between 75 – 100%. Species such as *Q. alnifolia, Cistus creticus, Crepis fraasii, Crucianella imbricata, Cerastium brachypetalum* subsp. *roeseri* and *Anthemis plutonia* are common among the clusters and relatively abundant in the plots of this cluster, too. Apart of these, four additional taxa (*Viola rauliniana, Rubus sanctus, Preridium aquilinum, Arbutus andrachne*) were found common in this cluster and differentiate it from the others. *Pteridium aquilinum* was recorded mostly in the plots that were close to a river. In addition to this, in bibliography (Meikle 1985) it is referred that this species occurs in Pine forests on igneous rocks with no reference to the cedar forest. Similarly, *Rubus sanctus* was recorded mostly in plots with disturbance. Other factors such as exposition may affect the species diversity.

From the Kruskal-Wallis test (Fig. 5) results, cluster 1 has the highest mean value of cover of tree layer as well as of herb layer.

4.3. Mixture of C. brevifolia and Quercus alnifolia

Q. alnifolia is generally presented as short shrubs in the understorey of cedar forests. However, there are mixed stands of *Q. alnifolia* and *C. brevifolia* and these are represented in cluster 2, based on the analysis. In this cluster, the cover of *C. brevifolia* tree layer, within the plots, is generally almost 50% (in some plots the species has 100% cover), *P. brutia* is mostly absent from the tree layer (with one exception) and *Q. alnifolia* is relatively abundant in the canopy within the plots (50-75% per plot).

From the results of Conover – Imam test, cluster 2 is differentiated from cluster 1, due to two variables, cover of shrub layer and cover of herb layer. In addition, based on the Kruskal – Wallis test results, cluster 2 has the highest mean value of cover of soil, cover of litter and cover of shrub layer and the lowest mean value of maximum height of herbs and cover of herb layer.

4.4. Mixture of C. brevifolia and P. brutia forests

During collection of data, plots in mixed stands of *C. brevifolia* and *P. brutia* were sampled. In order to evaluate the succession of the two habitat types, *C. brevifolia* forests and *P. brutia* forests, over the years, there is a need of monitoring of the populations of these two species for few decades.

This classification results showed that trees of *P. brutia* appears also in other clusters, but in cluster 4 they present their highest frequency. The cover of tree layer of *C. brevifolia* is in most of the plots between 12.5 – 50%. At the same time, the cover of tree layer of *P. brutia* is less than 12.5%. In addition, the most common and abundant species in these plots are *Asphodelus ramosus*, *Q. alnifolia* (shrub layer), *C. brevifolia* (shrub layer), *Cistus creticus, Crepis fraasii, Aira elegans* and *Crucianella imbricata*. It is important to note that regeneration of *P. brutia* is limited in contrast to the regeneration of *C. brevifolia* which is much higher (around 5% in some plots). This is indicative that the environmental conditions are more proper for *C. brevifolia* than for *P. brutia*. However, many factors may affect this such as the exposition and the inclination.

From the Kruskal – Wallis test (Fig. 5) results, cluster 4 has the highest mean value of maximum height of herbs and cover of shrub layer but it has the lowest mean value of cover of soil, cover of litter and cover of tree layer.

According to the results of the Conover-Iman test, cluster 4 is differentiated from cluster 1 due to cover of shrub layer, cover of tree layer, cover of soil and maximum height of herbs.

4.5. Intermediate stage

In cluster 3, there is a combination of pure *C. brevifolia* stands and plots with mixture of *C. bevifolia* and *P. brutia.* The cover of tree layer of *C. brevifolia* is in most of the plots around 75% and similarly *P. brutia* is 0% with exception of two plots where its cover is between 12.5% to 25%. The most common and abundant species of this cluster are *Cistus creticus, Q. alnifolia* (shrub), *Crepis fraasii, Cerastium brachypetalum* subsp. *roeseri* and *Valantia hispida*. There is regeneration of *C. brevifolia* in all of the plots (up to 5% / plot) and some regeneration of *Q. alnifolia* (less than 5% / plot).

According to Conover-Iman test, this cluster can be differentiated from cluster 1 due to cover of tree layer, shrub layer and tree layer.

Based on the Kruskal-Wallis test results, this cluster has neither the highest nor the lowest mean value to any of the variables studied. In most cases, the mean value is an intermediate.

5. **Περίληψη** (στα Ελληνικά)

Η «Έκθεση χλωριδικής σύνθεσης του τύπου οικοτόπου 9590* εντός της περιοχής του δικτύου Natura 2000» έγινε στο πλαίσιο του έργου «Ολιστική διαχείριση του οικότοπου προτεραιότητας 9590* στην περιοχή του Δικτύου Natura 2000 Κοιλάδα Κέδρων – Κάμπος» (LIFE-KEDROS, LIFE15/NAT/CY/000850) και αποτελεί παραδοτέο της Δράσης Α.1 - Σύνθεση και δομή του οικοτόπου 9590*. Σκοπός της δράσης είναι η περιγραφή της δομής και της σύστασης του υπό μελέτη τύπου οικοτόπου για τον προσδιορισμό των συνθηκών μέσω των οποίων εξασφαλίζεται η βιωσιμότητα, η σταθερότητα και η ικανότητα φυσικής αναγέννησής του.

Η ετοιμασία της Έκθεσης περιλάμβανε: (α) εργασία πεδίου για τη συλλογή των απαραίτητων δεδομένων (βιοτικών και αβιοτικών παραγόντων) και (β) ανάλυση των δεδομένων για τη εξαγωγή συμπερασμάτων.

Κατά την εργασία πεδίου, εγκαταστάθηκαν 33 επιφάνειες σε 8 περιοχές εντός της «Κοιλάδας Κέδρων – Κάμπος». Οι επιφάνειες κάλυψαν 4 μορφές του υπό μελέτη τύπου οικοτόπου:

i. Αμιγείς συστάδες με *Cedrus brevifolia* (19 επιφάνειες, μέγεθος 15 m x 15 m)
ii. Μίξη *C. brevifolia* με *Quercus alnifolia* (3 επιφάνειες, μέγεθος 15 m x 15 m)
iii. Μίξη *C. brevifolia* με *Pinus brutia* (5 επιφάνειες, μέγεθος 15 m x 15 m)
iv. Αναδασώσεις *C. brevifolia* (6 επιφάνειες, μέγεθος 10 m x 10 m)

Τα δεδομένα χλωριδικής σύνθεσης που συλλέχθηκαν από τις επιφάνειες εισήχθησαν στην Turboveg (ver. 2.1) και στη συνέχεια επεξεργάστηκαν με το λογισμικό Juice (ver. 7.0.102). Για την ανάλυση των φυτοκοινωνιολογικών δεδομένων χρησιμοποιήθηκε η μέθοδος ταξινόμησης TWINSPAN (modified) η ανάλυση cluster , είτε χρησιμοποιώντας την μέθοδο Ward's και την Ευκλείδεια απόσταση ή την μέθοδο flexible beta (*b* = -0.25) και την απόσταση Bray-Curtis distance.

Από την ανάλυση των δεδομένων, προέκυψε ομαδοποίηση των επιφανειών σε τέσσερις (4) ομάδες (clusters), οι οποίες διαφοροποιούνται αφενός βάση της σύνθεσης των ειδών και αφετέρου βάση άλλων παραμέτρων όπως για παράδειγμα η μέση κλίση εδάφους, η κάλυψη της συστάδας των δέντρων, των θάμνων και το μέγιστο ύψος των δέντρων, των θάμνων και των ποών. Ο χαρακτηριστικός τύπος οικοτόπου 9590* συνιστά μία εκ των τριών ομάδων και περιλαμβάνει κάλυψη κέδρων 75-100%, με τη συμμετοχή των ακόλουθων χαρακτηριστικών ειδών: *Q. alnifolia, Cistus creticus, Crepis fraasii, Crucianella imbricata, Cerastium brachypetalum* subsp. *roeseri* and *Anthemis plutonia*.

6. References

Δημόπουλος Π. & Τσιριπίδης Ι. 2013. Επεξηγηματικό εγχειρίδιο χρήσης πρωτοκόλλων αξιολόγησης τύπων οικοτόπων σε περιοχές του δικτύου Natura 2000. Τμήμα Περιβάλλοντος, Υπουργείο Γεωργίας, Φυσικών Πόρων και Περιβάλλοντος, Κύπρος, Λευκωσία.

Bell SS, McCoy ED, Mushinsky HR 1990. Habitat structure: the physical arrangement of objects in space. Chapman & Hall, London.

Borcard D., Gillet F. & Legendre P. 2011. Numerical Ecology with R. Springer-Verlag, New York.

Byrne L. B., 2007. Habitat structure: A fundamental concept and framework for urban soil ecology. Urban Ecosyst 10, 255-274.

Conover W.J. & Iman R.L. 1979. On multiple-comparisons procedures. Technical Report LA-677-MS, Los Alamos Scientific Laboratory.

Dinno A. 2017. conover.test: Conover-Iman Test of Multiple Comparisons Using Rank Sums. R package version 1.1.2. https://CRAN.R-project.org/package=conover.test

Hand R., Hadjikyriakou G. N. & Christodoulou C. S. (ed.) 2017: Flora of Cyprus – a dynamic checklist. Published at http://www.flora-of-cyprus.eu/

Hennekens S. M. & Schaminée, J.H.J. 2001. TURBOVEG, a comprehensive data base management system for vegetation data. Journal of Vegetation Science 12: 589–591.

Kruskal W.H. & Wallis W.A. 1952. Use of ranks in one-criterion variance analysis. Journal of the American Statistical Association 47: 583–621.

Lance G.N. & Wiliams W.T. 1967. A general theory of classification sorting strategies, I., hierarchical systems. Computer Journal 9: 373-380.

Maechler M., Rousseeuw P., Struyf A., Hubert M. & Hornik K.2017. Cluster: Cluster Analysis Basics and Extensions. R package version 2.0.6, https://CRAN.R-project.org/package=cluster.

McCune B. & Grace J.B. 2002. Analysis of ecological communities. MJM Press, Gleneden Beach, Oregon, USA.

McCune B. & Keon D. 2002. Equations for potential annual direct incident radiation and heat load. Journal of Vegetation Science 13:603–606.

Oksanen J., Blanchet F.G., Friendly M., Kindt R., Legendre P., McGlinn D., Minchin P.R., O'Hara R.B., Simpson G.L., Solymos P., Stevens M.H.H., Szoecs E. & Wagner H. 2017. Vegan: Community Ecology Package. R package version 2.4-3, https://CRAN.R-project.org/package=vegan.

R Core Team 2017. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Roleček, J., Tichý, L., Zelený, D. & Chytrý, M. (2009), Modified TWINSPAN classification in which the hierarchy respects cluster heterogeneity. Journal of Vegetation Science 20: 596–602.

Tichý L. 2002. JUICE, software for vegetation classification. Journal of Vegetation Science 13: 451–453.

Tsiripidis, I., Bergmeier, E., Fotiadis, G. & Dimopoulos, P. 2009. A new algorithm for the determination of differential taxa. Journal of Vegetation Science 20: 233-240.

Ward J.H.Jr. 1963. Hierarchical Grouping to Optimize an Objective Function. Journal of the American Statistical Association 58: 236–244.

7. Supplement Materials

- **Supplement 1: The data collection form**
- **Supplement 2: Photos during field work.**
- **Supplement 3: Data set of environmental variables.**
- **Supplement 4: Plots' table presenting the four clusters and their differential taxa.**
- **Supplement 5: Box and whiskers plots of the explanatory variables not having significant differences among the four clusters.**

Supplement 1: The data collection form

Habitat type	**9590**	**Cedrus brevifolia forests (Cedrosetum brevifoliae)**

NATURA Site

Protocol ID		Field ID		Assessement Date	
Evaluator					
Locality					

Length		Altitude		Total area	
Width		Exposition		Inclination	
Latitude		Relief		Geological Substratum	
Longitude					

Other locality attributes

Special Protocol attributes	
Soil texture: sandy, loamy, silty	
Cover of cryptogam layer	
Adjacent vegetation (habitat) type(s)	
Substratum with significant disturbances (e.g. erosion through trampling and increase in soil compactness)	
Invasive / non native species (incl.abudance)	
Ruderal species (incl.abudance)	

Cover (%) of boulders	
Cover (%) of stones	
Cover (%) of fine soil	
Cover (%) of litter	
Cover % of tree layer	
Cover % of shrub layer	
Cover % of herb layer	
Height (m) of tree layer	
Height (m) of shrub layer	
Height (m) of herb layer	

Notes

Conservation status of Typical Species		**Conservation status of Structure and Functions**		**Conservation Degree Assessment of Structure and Functions**	

Typical and other species

Species name	Cover *Braun-Blanquet*	Cover *AFOR*	Vitality	Conservation Status	Typ.	/Oth.	/Syn.
Anthemis plutonia Meikle		/			☑	☐	☐
Arrhenatherum album subsp. cypricola H. Scholz		/			☑	☐	☐
Cedrus brevifolia (Hook. f.) A. Henry		/			☑	☐	☐
Cerastium brachypetalum subsp. roeseri (Boiss. & Heldr.) Nyman		/			☑	☐	☐
Cistus creticus L.		/			☑	☐	☐
Crepis fraasii Sch. Bip.		/			☑	☐	☐

Crucianella imbricata Boiss.		/				☑	☐	☐
Cyclamen cyprium Kotschy		/				☑	☐	☐
Lactuca cyprica (Rech. f.) N. Kilian & Greuter		/				☑	☐	☐
Lecokia cretica (Lam.) DC.		/				☑	☐	☐
Pteridium aquilinum (L.) Kuhn		/				☑	☐	☐
Quercus alnifolia Poech		/				☑	☐	☐
Stellaria cilicica Boiss. & Balansa		/				☑	☐	☐

Specific Structure and Functions

Structure and Function	Happen
Absence of ruderal and/or invasive species	
Without signs of disturbance (grazing) or regressive succession	
Occurrence of patches of different age classes with typical wood species	
Regeneration of typical tree species	
Stand stratified (tree, shrub, herb layers present)	
Canopy of woodland species not fragmented	
Litter cover > 45%	
Absence of planted species (e.g. from reforestation)	
Existence of old aged trees with spreading crown	
Cover of Cedrus brevifolia higher than 50%	
No reforestation of Cedrus brevifolia within other habitat types	
Existence of dead wood with cover higher than 5%	
Competative dominance of Cedrus brevifolia against Pinus burtia in case of mixed stands	

Prospects of Structures and Function

Future Trend		
Future Status		

Positive impacts (management actions, policy changes etc.)	Importance

Assessment of Prospects for Structure and Function

Pressures (P) and Threats (T)

Protocol Photos

File	Kind

Supplementary 2: Photos during field work.

***Figures S1a, S1b and S1c*: Data recording during field work.** The data sheet was completed with information regarding species diversity and abundance, threats and environmental abiotic factors (substrate, inclination, exposition etc.).

<u>Figure S2</u>: A measuring tape was used to calculate the size of the plot established.

<u>Figure S3</u>: In *Cedrus brevifolia* reforestation for the establishment of a plot.

<u>Figure S4</u>: Natural regeneration of *C. brevifolia* in one of the plots.

<u>Figure S5</u>: Data recording in a plot with pure stands of *C. brevifolia*.

<u>Supplement 3</u>: Data set of environmental variables. Values of each variable have been ranged between the 0 to 1. Radiation: annual direct and incident radiation; Heat: heat load; Incl_Min: minimum inclination of ground; Incl_Max: maximum inclination of ground; Incl_Aver: average inclination of ground; Cov_Crypt: cover of cryptogams; Substr_Dist: substrate disturbance; Cov_Boulders: cover of boulders; Cov_Stones: cover of stones; Cov_Soil: bare soil cover; Cover_Litter: cover of litter; Cov_Tree: cover of tree layer; Cov_Shrub: cover of shrub layer; Cov_Herb: cover of herb layer; Heig_Trees_Max: maximum height of trees; Max-Min_Heig_Trees: difference between maximum and minimum height of trees; Heig_Shrubs_Max: maximum height of shrubs; Heig_Herbs_Max: maximum height of herbs; Reforestation: reforestation has been made in the plot; Mixture: vegetation of plot represents two mixed habitat types.

Plot number	Radiation	Heat	Altitude	Incl_Min	Incl_Max	Incl_Aver	Cov_Crypt	Substr_Dist	Cov_Boulders	Cov_Stones	Cov_Soil	Cover_Litter	Cov_Tree	Cov_Shrub	Cov_Herb	Heig_Trees_Max	Max-Min_Heig_Trees	Heig_Shrubs_Max	Heig_Herbs_Max	Reforestation	Mixture
1	0.51	0.677	0.465	0	0.615	0.269	0.4	0	0	0.167	0.778	0.889	0.938	0.333	0.206	0.688	0.421	1	0.167	1	1
2	0.542	0.468	0.333	0	0.538	0.231	0.3	0	0.333	0.375	0.667	0.556	0.188	0.733	0.016	0.5	0.263	1	0	1	1
3	0.865	0.631	0	0	0.846	0.385	1	0	0	0.167	0.444	0.667	0.125	0.533	0.016	0.625	0	1	0.417	1	0
4	0.318	0.4	0.73	0.429	0.385	0.385	0.16	0	0.333	0.063	0.667	0.333	0.625	1	0.603	0	0.158	0.697	0.25	0	0
5	0.425	0	0.768	0.857	0.846	0.846	0.06	0	0.167	0.021	0.778	1	0.938	0.867	0	0.375	0.263	1	0	0	1
6	0.804	0.992	0.714	1	1	1	0.04	0	1	0.271	0.222	0.167	0	1	0.286	0	0.158	0.394	1	0	0
7	0.638	0.862	0.714	0.429	0.385	0.385	0.02	0	0	0	0.011	0.078	0.063	0.733	0.048	0.5	0.158	0.697	0.333	0	0
8	0.605	0.331	0.687	0.5	0.462	0.462	0.06	1	0	0.063	0.033	0.033	0.438	0.8	0.127	0.063	0.158	0.182	0.333	0	0

Plot number	Radiation	Heat	Altitude	Incl_Min	Incl_Max	Incl_Aver	Cov_Crypt	Substr_Dist	Cov_Boulders	Cov_Stones	Cov_Soil	Cover_Litter	Cov_Tree	Cov_Shrub	Cov_Herb	Heig_Trees_Max	Max-Min_Heig_Trees	Heig_Shrubs_Max	Heig_Herbs_Max	Reforestation	Mixture
9	0.864	0.986	0.671	0.571	0.538	0.538	0.04	0	0	0	0	0.5	0.625	0.6	0.127	0.563	0.632	0.697	1	0	1
10	0.377	0.262	0.656	0	0.923	0.423	0.2	0	0	0	0.111	0.222	0.938	0	0.286	0.813	0	0.091	0.333	1	0
11	1	0.84	0.432	0.786	0.769	0.769	0.1	1	0.333	0.167	0.022	0	0.125	0.733	0.127	0.5	0.474	0.394	1	0	0
12	0.605	0.863	0.584	0.5	0.462	0.462	1	0	0	0	0.556	0.667	0.625	0.267	1	0.813	0.421	1	0.417	0	0
13	0.462	0.84	0.519	0.786	0.769	0.769	0.2	0	0.833	0.271	0.033	0.033	0.088	0.267	0.016	0	0.158	0	0.167	0	0
14	0.156	0.264	0.216	0.571	0.538	0.538	0.4	0	1	0.167	0.222	0.056	0.625	0.333	0.286	0.188	0.316	0.182	0.25	0	0
15	0	0.13	0.545	0.714	0.692	0.692	0.2	0	0.667	0.021	0.222	0.056	0.125	0.4	0.127	0.313	0.421	0.697	0.333	0	0
16	0.999	0.85	0.541	0.714	0.692	0.692	0.04	0	0.1	0.167	0.056	0.556	0.625	0.467	0.063	0.25	0.368	0.091	0.75	0	0
17	0.819	0.997	0.508	0.929	0.923	0.923	0.06	0	0.167	0.167	0.056	0.556	0.625	0.093	0.286	0	0.158	0.03	0.167	0	0
18	0.683	0.677	0.335	0	0.615	0.269	0.6	1	0.167	0.375	0.333	0.033	0.625	0.667	0.286	1	1	0.182	0.25	0	0
19	0.499	0.13	0.409	0.714	0.692	0.692	0.08	0	1	0.167	0.222	0.111	0.438	0.467	0.286	0.5	0.579	0.394	1	0	0
20	0.499	0.85	0.325	0.714	0.692	0.692	0.2	0	0.067	0.479	0.556	0.167	0.75	0.133	0.048	0.75	0.789	0.697	0.167	0	0

Plot number	Radiation	Heat	Altitude	Incl_Min	Incl_Max	Incl_Aver	Cov_Crypt	Substr_Dist	Cov_Boulders	Cov_Stones	Cov_Soil	Cover_Litter	Cov_Tree	Cov_Shrub	Cov_Herb	Heig_Trees_Max	Max-Min_Heig_Trees	Heig_Shrubs_Max	Heig_Herbs_Max	Reforestation	Mixture
21	0.388	0.815	0.486	0.929	0.923	0.923	0.04	0	0.067	0.063	0.333	0.033	0.625	0.867	0.048	0.188	0.316	0.697	0.042	0	0
22	0.986	0.862	0.807	0.571	0.538	0.538	0.06	0	0.067	0	0.444	0.667	0.875	0.733	0.048	0.313	0.421	0.697	0.75	0	1
23	0.866	0.974	0.804	0.5	0.462	0.462	0.1	0	0.667	0.375	0.278	0.667	0.813	0.533	0.127	0.313	0.421	1	0	0	1
24	0.839	0.717	0.92	0.214	0.154	0.154	0.04	0	0	0.063	0.722	0.667	0.813	0.733	0.095	0.438	0.526	1	0.25	0	1
25	0.723	0.758	0.911	0.071	0	0	0.04	0	0.067	0.063	0.778	0.667	0.375	0.867	0.286	0.188	0.316	1	1	0	1
26	0.556	0.597	0.986	0.214	0.154	0.154	0.04	1	0	0.688	0.667	0.556	1	0.2	0.365	0.5	0.579	1	0.25	0	0
27	0.831	1	0.965	0.857	0.846	0.846	0	0	0	0.375	0.889	0.778	1	0.333	0.603	0.375	0.474	1	0.25	0	0
28	0.278	0.14	0.99	0.571	0.538	0.538	0.3	0	0.667	0.688	0.444	0.611	0.125	0.667	0.127	0.188	0.211	1	0.25	0	1
29	0.763	0.799	0.984	0.071	0	0	0.02	0	0	0	0.889	0.889	0.938	0.333	0.127	0.063	0.211	1	0.167	0	0
30	0.542	0.468	1	0.286	0.231	0.231	0.3	0	0	0.583	0.611	0.533	1	0.533	0.365	0.625	0.368	1	0.167	0	0
31	0.804	0.338	0.656	1	1	1	0.2	0	0.667	1	0.222	0.111	0.125	0.8	0.095	0.063	0.105	0.697	0.917	0	1
32	0.683	0.854	0.512	0	0.615	0.269	0.3	0	0	0.063	1	0.889	1	0.667	0.048	0.813	0	1	0.25	1	0

Plot number	Radiation	Heat	Altitude	Incl_Min	Incl_Max	Incl_Aver	Cov_Crypt	Substr_Dist	Cov_Boulders	Cov_Stones	Cov_Soil	Cover_Litter	Cov_Tree	Cov_Shrub	Cov_Herb	Heig_Trees_Max	Max-Min_Heig_Trees	Heig_Shrubs_Max	Heig_Herbs_Max	Reforestation	Mixture
33	0.669	0.858	0.512	0	0.692	0.308	0.4	0	0	0.021	0.944	0.833	0.938	0.133	0.016	0.625	0.158	1	0.042	1	0

<u>Supplement 4</u>: Plots' table presenting the four clusters and their differential taxa. Taxa occurring in one only plot were omitted. The order of clusters (1, 2, 3 and 4) has been arranged on the basis of the script of Borcard et al. (2011).

Plot number	Layer	7	6	11	31	9	13	8	4	23	22	21	16	15	3	30	27	18	29	26	20	10	33	1	17	14	19	12	24	32	2	5	25	28
Cluster number		4	4	4	4	4	3	3	3	3	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2
Pinus brutia	T	1	b	.	+	1	.	.	.	b	b	.	.	.	.	.	.	.	.	.	.	.	a	.	.	.	.	a	a	.	.	.	.	.
Asphodelus ramosus	H	r	1	+	+	1	.	a	.	.	1	.	1	.	.	.	+	.	+	.	.	.	.	.	.	.	1	a	1	.	.	r	+	.
Galium aparine	H	+	+	.	.	+	.	.	.	.	.	.	.	.	.	+	+	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	+
Daucus broteri	H	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Lactuca cyprica	H	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.	.
Petrorhagia dubia	H	.	1	.	+	+	1	+	.	.	.	.	+	r	.	.	+	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	r	.
Allium sp.	H	.	.	.	.	r	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.
Alyssum foliosum	H	+	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Alyssum strigosum	H	.	+	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Asplenium ceterach	H	.	.	r	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Filago pyramidata	H	.	.	.	.	+	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

Plot number	Layer	7	6	11	31	9	13	8	4	23	22	21	16	15	3	30	27	18	29	26	20	10	33	1	17	14	19	12	24	32	2	5	25	28
Cluster number		4	4	4	4	4	3	3	3	3	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2
Velezia rigida	H	.	1	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Aira elegans	H	m	+	+	.	+	1	+	+	+	+	.	.	+	.	.	.	.	.	1	+	.	.	.	.	.	+	.	.	.	.	.	r	.
Silene laevigata	H	r	.	+	.	.	.	1	.	+	.	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Silene galatea	H	.	.	.	1	.	r	.	.	.	.	1	+	1	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.
Thymus integer	S2	.	.	+	1	1	+	b	.	.	.	1	a	1	.	.	.	.	.	.	.	.	.	.	.	+	1	.	.	.	.	r	.	.
Psilurus incurvus	H	.	1	.	.	.	+	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.
Pinus brutia	H	r	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Sedum rubens	H	.	+	.	.	.	1	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	r	.	r	.	.	.	.	.	.	.
Trifolium campestre subsp. *campestre*	H	r	.	.	.	.	+	.	+	.	.	.	.	r	.	.	.	+	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.
Stellaria cilicica	H	.	.	.	.	+	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	1	.	.	r	.	.	.	.	.	.
Centaurea aegialophila	H	.	.	.	r	.	.	1	.	.	r	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.
Umbilicus rupestris	H	.	r	r	.	.	+	.	+	+	.	.	.	+	.	.	.	.	.	.	r	.	.	.	.	+	r	.	.	.	.	.	.	.

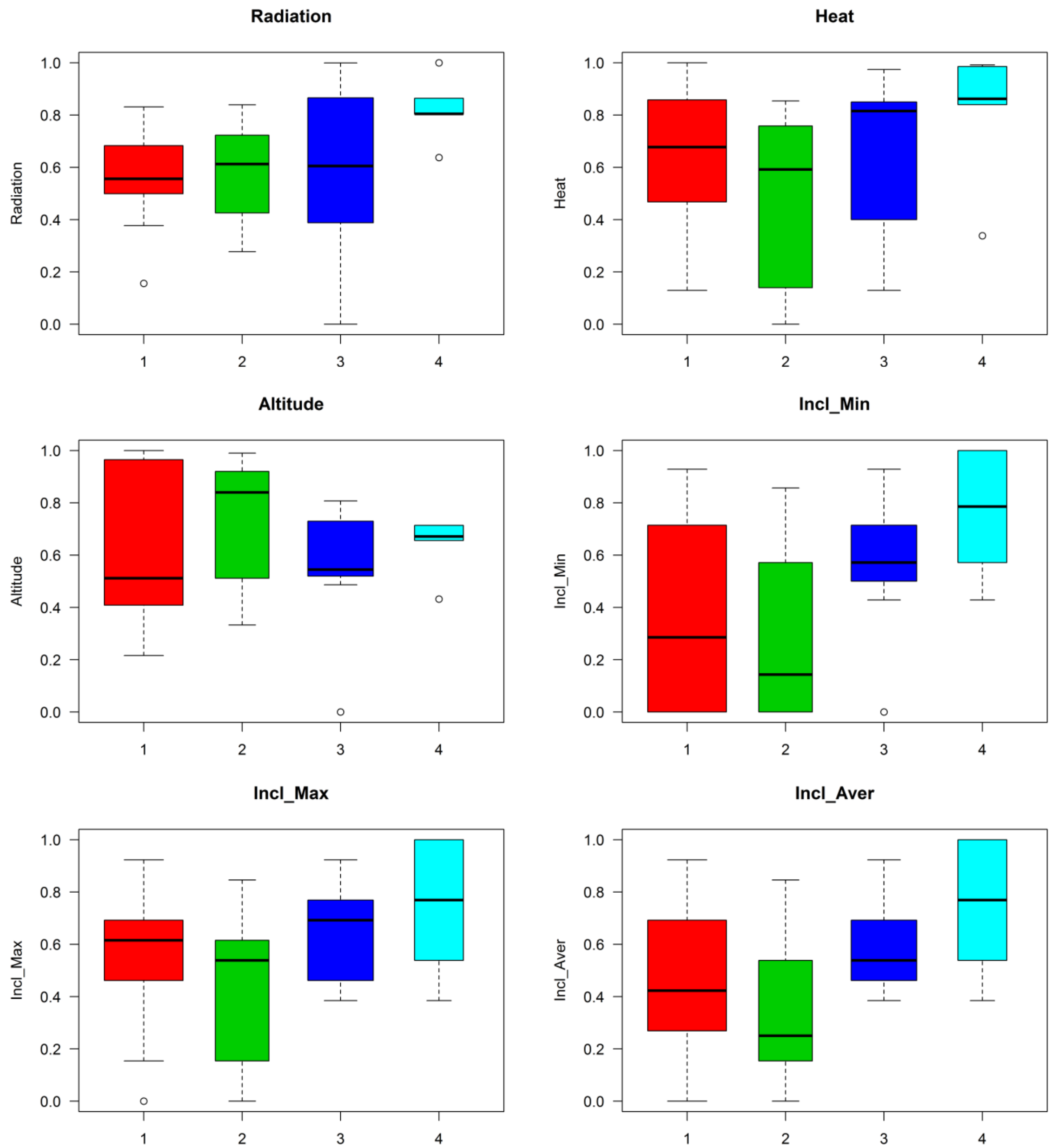
Plot number	Layer	7	6	11	31	9	13	8	4	23	22	21	16	15	3	30	27	18	29	26	20	10	33	1	17	14	19	12	24	32	2	5	25	28
Cluster number		4	4	4	4	4	3	3	3	3	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2
Legousia falcata	H	+	.	.	.	+	.	.	.	+	+	.	.	.	.	.	+	.	.	.	+	.	.	.	r	.	+	.	.	.	.	.	.	.
Arabis verna	H	1	.	.	.	.	.	.	+	.	+	.	.	+	.	.	.	+	.	.	.	r	.	r	1	.	+	.	.	.	.	.	.	.
Papaver paphium	H	.	.	+	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	1	.	.	.	+	1	1	.	.	.	.	.	.	.
Trifolium hirtum	H	.	.	.	.	.	+	.	.	r	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.
Helichrysum italicum	S2	.	.	.	.	.	.	.	.	.	.	.	+	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Scutellaria cypria subsp. *elatior*	H	.	.	.	.	.	r	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Spergularia diandra	H	.	.	.	.	.	+	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.
Cynosurus effusus	H	.	.	.	.	+	1	+	+	+	.	.	+	+	.	+	1	r	.	.	+	+	r	+	1	1	+	+	.	.	.	.	.	+
Cedrus brevifolia	S1	a	.	r	.	.	r	.	a	a	+	r	r	r	.	a	a	a	+	a	a	.	.	.	1	r	a	.	+	.	.	.	.	.
Myosotis ramosissima subsp. *ramosissima*	H	.	.	.	.	.	.	.	r	.	.	.	.	+	.	.	+	+	.	.	.	.	.	.	r	.	r	.	.	.	.	.	.	.
Ornithogalum chionophilum	H	.	.	+	.	r	.	r	r	+	.	r	r	r	.	.	r	.	+	+	r	.	.	.	+	r	+	+	.	.	.	.	.	+
Arbutus andrachne	T,S2,H	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	r	.	.	.	.	b	a	.	.	+	.	.	.	.	.	.	.

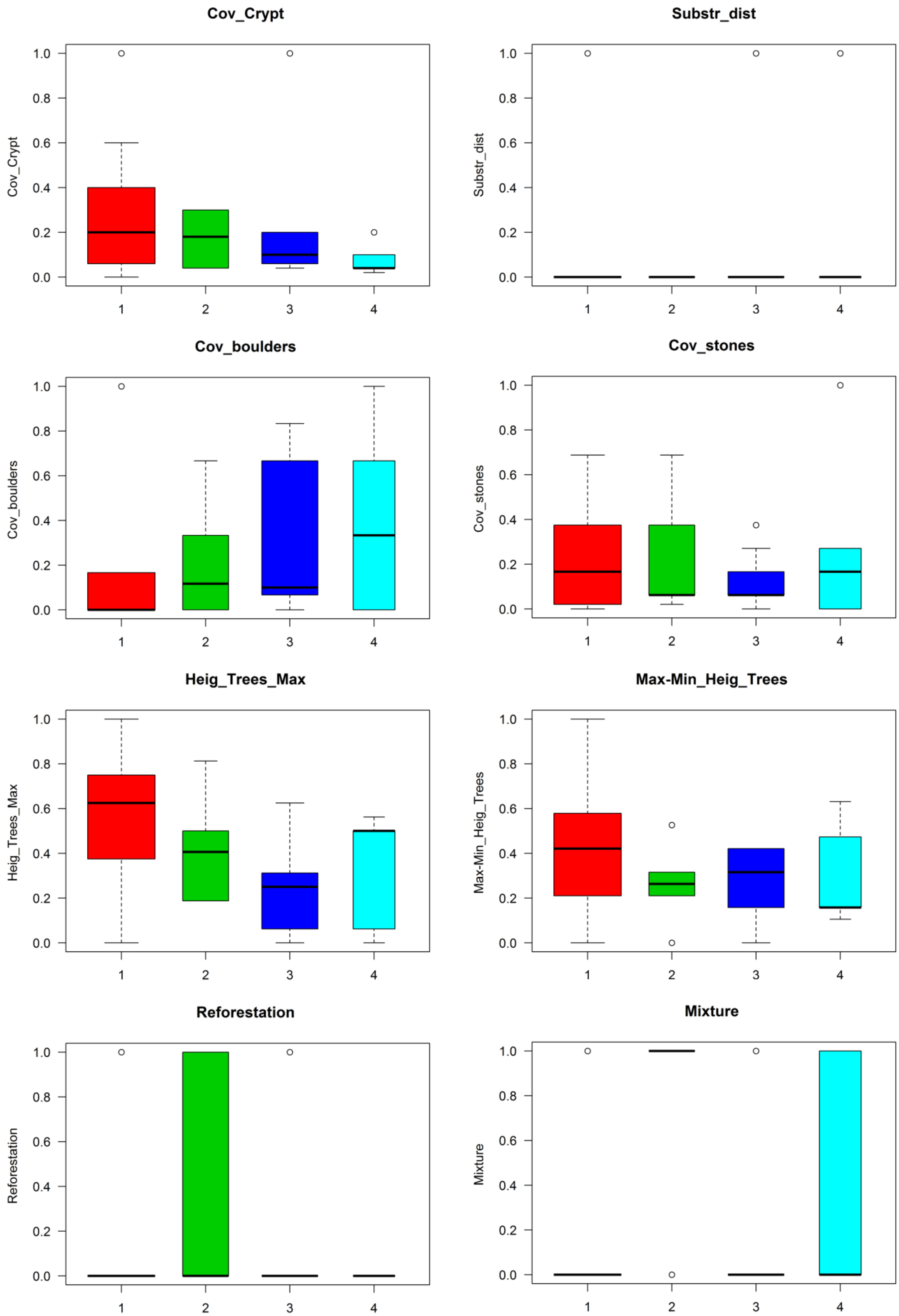
Plot number	Layer	7	6	11	31	9	13	8	4	23	22	21	16	15	3	30	27	18	29	26	20	10	33	1	17	14	19	12	24	32	2	5	25	28
Cluster number		4	4	4	4	4	3	3	3	3	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2
Pteridium aquilinum	H	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	a	.	.	+	.	.	.	.	.	.	3	.	+	.	.	.	.
Rubus sanctus	S2	.	.	.	.	.	.	.	.	.	.	.	.	.	b	.	.	+	.	.	.	1	.	+	.	.	.	.	.	1	.	.	.	.
Viola rauliniana	H	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	+	.	.	+	.	.	.	.	1	.	.	.	.	.	.	.	.	r
Pinus brutia	S2	a	b	.	.	.	r	.	.	.	.	.	.	.	+	.	.	r	.	.	.	.	+	.	.	.	.	.	+	.	r	.	+	.
Cedrus brevifolia	T	a	b	b	3	b	b	4	4	4	4	4	4	3	3	5	5	4	5	5	5	5	5	5	4	4	4	4	4	5	3	3	3	b
Cistus creticus	S2	4	5	4	4	3	b	4	4	b	3	3	3	b	b	.	a	.	a	.	+	+	+	a	a	b	b	+	b	.	a	b	a	1
Quercus alnifolia	S2	+	a	a	a	r	r	r	a	a	a	a	1	1	.	3	a	.	+	+	r	.	a	a	1	a	a	a	a	+	a	a	.	a
Cedrus brevifolia	H	1	.	+	1	+	1	r	+	1	1	+	+	+	.	+	.	1	.	r	1	.	1	1	1	1	1	r	+	1	r	+	r	+
Quercus alnifolia	T,S1	a	.	.	a	b	.	.	b	b	b	a	a	a	b	a	b	a	b	b	a	b	b	b	.	a	a	a	3	4	3	3	4	3
Crepis fraasii	H	1	.	+	+	a	+	1	+	+	1	1	+	1	.	b	a	1	1	a	a	b	1	.	.	1	1	1	a	.	.	.	a	1
Crucianella imbricata	H	1	+	+	+	1	+	+	.	+	+	.	+	+	.	.	1	r	+	1	.	.	r	+	+	.	+	r	+	.	.	.	+	+
Cerastium brachypetalum subsp. *roeseri*	H	1	1	a	.	.	1	+	1	1	+	.	+	+	.	+	b	+	1	a	+	.	.	+	1	1	1	.	.	.	.	.	+	+

Plot number	Layer	7	6	11	31	9	13	8	4	23	22	21	16	15	3	30	27	18	29	26	20	10	33	1	17	14	19	12	24	32	2	5	25	28
Cluster number		4	4	4	4	4	3	3	3	3	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2
Anthemis plutonia	H	+	.	1	.	r	r	+	+	.	.	1	+	+	.	.	r	+	a	1	a	.	.	.	1	.	a	.	1	.	.	.	1	+
Cedrus brevifolia	S2	b	a	.	a	r	r	r	.	a	.	.	.	.	.	b	b	a	a	1	+	.	.	r	.	.	+	.	a	.	.	a	r	a
Valantia hispida	H	.	.	1	+	+	1	1	1	+	.	+	+	1	.	.	1	.	+	1	r	.	.	.	1	+	1	.	.	.	.	.	1	1
Quercus alnifolia	H	r	.	.	.	r	.	r	.	+	r	+	r	.	.	.	.	1	.	.	+	1	r	+	.	r	+	.	.	+	+	+	.	+
Lecokia cretica	H	r	.	+	.	1	.	1	+	.	.	.	r	1	.	r	+	r	.	1	.	+	.	.	r	.	r	1	.	+	.	.	.	r
Briza humilis	H	.	.	1	.	.	1	.	1	.	.	.	+	+	.	.	.	r	+	1	.	.	.	.	1	1	+	.	.	.	.	r	r	+
Poa bulbosa	H	1	1	.	.	.	1	+	+	+	.	.	.	+	.	.	+	.	+	.	.	.	.	+	1	.	.	.	.	.	.	r	+	r
Geranium purpureum	H	.	.	.	+	.	.	.	+	.	.	.	.	+	.	1	+	+	.	1	.	+	.	.	.	+	+	.	.	r	.	.	.	+
Galium murale	H	.	.	.	.	+	.	.	+	.	+	.	.	+	.	.	.	+	+	1	.	.	.	.	+	+	.	+	.	.	.	.	.	+
Minuartia hybrida	H	.	1	.	.	.	+	.	1	.	.	.	+	.	.	.	+	1	+	.	.	.	.	.	+	.	r	.	.	.	.	.	+	+
Galium peplidifolium	H	+	.	.	.	+	.	.	1	.	.	.	.	.	.	+	1	.	.	1	.	1	.	.	.	.	1	.	.	r	.	.	.	+
Bromus sterilis	H	.	.	.	+	+	.	+	1	+	.	.	.	.	.	1	a	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1

Plot number	Layer	7	6	11	31	9	13	8	4	23	22	21	16	15	3	30	27	18	29	26	20	10	33	1	17	14	19	12	24	32	2	5	25	28
Cluster number		4	4	4	4	4	3	3	3	3	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2
Pinus brutia	S1	a	.	.	.	.	.	.	a	a	+	r	.	.	.	.	.	1	.	.	.	.	.	.	.	.	r	.	.	.	a	.	+	.
Rubia tenuifolia	S2	.	.	.	1	.	.	.	.	.	.	r	.	+	+	.	.	r	.	.	.	.	r	+	.	.	+	.	.	.	+	.	.	.
Hypochaeris glabra	H	.	.	+	.	.	.	.	.	.	.	.	+	+	.	+	.	.	.	.	.	.	.	.	.	.	r	.	+	.	.	.	.	+
Arabis laxa	H	.	.	.	+	.	.	.	.	+	.	.	.	.	.	.	+	.	r	.	.	.	.	.	.	1	.	.	+	.	.	.	.	.
Smilax aspera	S2	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	1	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.
Arabis kennedyae	H	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+
Cyclamen cyprium	H	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.	.
Dioscorea communis	S2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.
Geranium lucidum	H	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	r	.	.	.	.	.	.
Pistacia terebinthus	S1	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	a	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Teucrium kotschyanum	S2	.	.	.	.	.	.	.	.	.	.	.	.	.	a	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.

Supplement 5: Box and whiskers plots of the explanatory variables not having significant differences among the four clusters.




Cov_Crypt
Substr_dist
Cov_boulders
Cov_stones
Heig_Trees_Max
Max-Min_Heig_Trees
Reforestation
Mixture
0.0
0.2
0.4
0.6
0.8
1.0
1
2
3
4