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Non-inferential Probabilistic Method for designing Typical Species of Northern Greece Oak Forest Natura 2000 Habitat Types

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ABSTRACT: Conservation status of the Natura 2000 Habitat Types is assessed through parameters that include the presence or absence of Typical Species. The EEC and the Greek application guidance documents do not mention a clear definition of «Typical Species» and most of the Habitat Types' Typical Species lists published for the whole Greece have common species with others. Moreover, they can contain till 48 species without indication on which species is more typical than another for a Habitat type. Taking the example of oak forests habitat types, this paper exposes a method to find the Typical Species which are sufficiently linked with a Habitat Type to be exclusive. It also exposes the way to give ecological profiles for the Typical Species, and by that way to inform on habitat types ecology. This permitted to propose a list of maximum 8 ranked Typical Species for three Habitat Types and a new partial organization of the North Greece oak forest's Natura 2000 Habitat Types.

KEYWORDS: Frequency analysis, Cluster analysis, Ecological profiles, Habitat types, Typical species, North Greece Oak forests.

1 INTRODUCTION

In the frame of 92/43/EEC European Union Directive, habitat types, although described by 13 environmental criteria, biotic and abiotic, are in fact mainly defined in Greece by the presence of Typical Species, and their conservation status is assessed through "parameters" such as area, range, structure, function, future prospects, pressures and threats. In this frame, the assessment of habitat structure and function requires also to check the presence of Typical Species from a given list.

There is no clear definition of what a is "Typical Species" (TS) in the guidance for the 92/43/EEC Directive application [7] and the Greek Explanatory Implementation Manual for the Conservation Degree Assessment of Habitat Types (HT) [6]. According to these guides, TS may be not stable for the same HT along the sites in Europe or even in a country, and each HT is composed by vegetation units determined by ecological factor that may have not the same strength from a Site of Community Interest (SCI) to another. In this way, Habitat Types have variants depending on local conditions, and the 92/43/EEC Directive imposes this variability to be dealt with. But at least, we should rely on Typical Species that should be typical for a habitat type rather than another, that are defined in the phytosociological method [4] as "différentielles".

Unfortunately, most of the Habitat Types' TS lists published [12] for Greece have common species with others. There is no distinction among the TS between the "caractéristiques exclusives" [4], that should be absent in the most of relevés not belonging to the HT and the "transgressives" [4] that can be present in two HT.

Another problem comes since in these lists of TS, all the species are at the same level, there is no distinction between them in what species is more typical than another. We should rely on link measurements to decide which species are to consider first as typical. It is important because the lists given by [12] can contain till 48 typical species, and the longer is the TS's list, the lower is the information given by one TS [8]. This paper proposes a method to use the exact probabilities to find the species that live in each HT and are exclusive characteristics.

Also, a better knowledge of the factors that impulse the differences between habitat types and knowledge of the TS that are the most sensible to these factors should be useful [10]. In this way we should be able to indicate a few TS that are operational ecological indicators, firstly, of a Habitat Type, and secondly, of the ecological status of each habitat.

Taking the example of oak forests habitat types, this paper exposes a method to indicate the Typical Species which are sufficiently linked with a Habitat Type to be exclusive. It also exposes the way to give ecological profiles for the habitat types through the TS. This will permit to quickly check the conservation status in each field plot, based on the presence or absence of few Species with increased knowledge on the relation between these species and habitats' environmental variables.

2 MATERIAL AND METHOD

On purpose of Special Environmental Studies of the Thessalian Natura 2000 sites, we used 3202 vegetation and environmental variables field samples (relevés) on surfaces from the previous evaluation campaign in North Greece (2014-2015) concerning 38 sites in Thrace, Macedonia and Thessaly. In these samples the presence of each Species is noted, and also its abundance, its vitality and in which vegetation strata it is the most abundant. Aside of the Habitat Type where was the relevé, the status of 16 environmental variables was also noted on the plots: Altitude, exposition, slope, topographic situation, granulometric soil type, geological substratum, surface cover of different size and types of elements (boulders, stones, gravels, fine soil, litter) and vegetation layers (trees, shrubs, herbs and mosses) Only process of Species' presence and on three variables is presented here: habitat type, geology and altitude.

2.1 PHYTOSOCIOLOGICAL PROCESSING METHOD BY FREQUENCY ANALYSIS

Phytosociology is based on the probability to find in the same relevé two or more given plant Species. Characteristic Species of a vegetation unit has tight link with at least one another species because theoretically, two species can constitute a vegetation unit. The difficulty left is to know the reason of this link. M. Godron [8], [9] in France calculated the probability for a species to be found with other Species which together characterize a habitat type in one or another phytosociological taxon. This method is not based on a statistic coefficient as Phi, that has been used to be a threshold for a species to be or not a Typical Species for a Habitat Type in phytosociological processing of the relevés in the Greek Natura 2000 network [6,14]. The process adopted by us is to calculate the exact probability of finding two Species together in a relevé, it is not inferential, it is called "Frequency Analysis" and is based on Fisher's exact probabilities.

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 I quantity given by the probability of the table 1 is:

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

The unit of Information I is named binon [8], [10] and since this information is given by a species on another species it is named Mutual Information (MI). This information is the value of the spatial links between the species and is far more practical to use than probailities for distance visualization or mean calculations, as occurs further in this paper. The links between the species gives a dendrogram named "archipel" [10] for the clusters of Species linked by distances in MI each to one to another. An 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 MI 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. The fidelity of Species to a phytosociological unit can be measured by this method.

One important advantage of the frequency analysis method is to be applied at site scale (with around 100 relevés) because it provides information with few relevés, as shown in Bendali & Nellas [2].

2.2 PHYTO-ECOLOGICAL PROCESSING METHOD BY FREQUENCY ANALYSIS

Our method seeks not only to give hierarchy in the typical character of a species in the HT but also to give ecological sense to this hierarchy. The ecological meaning of the abovementioned links between Species need coded variables of the environment and the frequencies of Species in the variable classes. This process is called phyto-ecological process [11], [10].

Table 2. Combination number of presences and absences of a Species and variable class in the relevés

Variable V		Presence of class V (i)	Presence of all other classes of V	Total
Species S	Presence	a	b	a+b
	Absence	c	d	c+d
	Total	a+c	b+d	n

The probability of this table is calculated with the same formula as in table 1. The calculation of MI (in binons) is also made for each class V (i) and repeated for all the classes of a variable. The result of these calculations gives the ecological profile for each Species or groups of Species on a variable (see the tables paragraph 2-3). We should apply this method for as many variable as necessary to verify the effect of the variables on the plant Species' repartition.

In this paper we used three variables: Habitat type, Geology and Altitude.

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 TYPICAL SPECIES AND HABITATS TYPES FROM THE 2014-2015'S EVALUATION CAMPAIGN

The following table gives the list of Typical Species (TS) given by the ecological profiles' method for each one on Habitat Type (HT) using the 3202 relevés of the 2014-2015's conservation status evaluation campaign. The number written aside the name of the species is the strength of the link between presences of the species and presence of the Habitat Type. This link is given in Mutual Information (MI) calculated in binons as explained in the 1.2 paragraph.

Table 3. Typical Species and Mutual Information (in binons) for some Habitat Types

91M0 Pannonian-Balkanic turkey oak – sessile oak forests	**91F0 Riparian mixed forests of *Quercus robur and Ulmus sp.* along the great rivers (Ulmenion minoris)**	**9250 *Quercus trojana* forests**	**9280 *Quercus frainetto* woods**	**934A *Quercus coccifera* forests**	**9340 *Quercus ilex* and *Quercus rotundifolia* forests**
Quercus frainetto 635 Silene italica 468 Clinopodium vulgare 430 Carpinus orientalis 381 Lathyrus laxiflorus 329 Veronica chamaedrys 316 Brachypodium sylvaticum 296 Luzula forsteri 291 Fraxinus ornus 253 Potentilla micrantha 236 Cornus mas 208 Quercus petraea 184 Quercus pubescens 178 Sorbus torminalis 146 Viola alba 103 Poa nemoralis 60 Carex flacca 52 Acer monspessulanum 31	Quercus robur 49 Ulmus minor 32 Ulmus procera 27 Agrostis stolonifera 20 Periploca graeca 17 Rumex sanguineus 14 Galium aparine, Rubus ulmifolius 13 Calystegia sepium 12 Cornus sanguinea, Fraxinus angustifolia 11 Alnus glutinosa, Ballota nigra 10	Quercus trojana 225 Carpinus orientalis 140 Juniperus oxycedrus 100 Asparagus acutifolus 89 Quercus pubescens 40 Acer monspessulanum 35 Fraxinus ornus 21 Clinopodium vulgare 24 Silene italica 17	Fagus sylvatica 291 Pteridium aquilinum 178 Poa nemoralis 170 Dactylis glomerata 125 Luzula forsteri 118 Potentilla micrantha 104 Sorbus torminalis 23 Fraxinus ornus 21	Hippocrepis emerus 148 Quercus coccifera 127 Cyclamen heder 93 Cardamine graeca, Ruscus aculeatus 92 Clematis flammula 87 Rubia peregrina 86 Tamus communis 78 Pistacia terebenthus 65 Quercus pubescens 48	Quercus ilex 294 Arbutus unedo 212 Phillyrea latifolia 202 Erica arborea 171 Rubia peregrina 131 Smilax aspera 94 Fraxinus ornus 79 Cercis siliquastrum 77 Quercus pubescens 38 Quercus coccifera 31

In table 3, the amounts of MI for each Species are high and they inform on the attribution of a relevé to a HT. We can have an idea of the link's strength, for example between the two last TS and the HT 91F0 (*Alnus glutinosa* and *Ballota nigra*). This link by a MI of 10 I means a probability of 1/1000 chances to be in the HT by hazard, and the link between *Agrostis stolonifera* and the same HT, which is 20, means 10^{-6} chances to be by hazard.

The table shows that the first Habitat's Typical Species corresponds to the dominant species for four HT but not for the 9280 ("*Quercus frainetto* woods") nor the 934A (*Quercus coccifera* forests). For the last one, *Quercus coccifera*, the dominant species is still in second place, with the highest MI in this HT but for the 9280, *Quercus frainetto* do not appear at all between the TS and the first TS is *Fagus sylvatica* (beech).

If the riparian mixed forests (91F0) have completely different TS from the other oak forests, the others Habitat Types have a lot of TS in common. For example, *Carpinus orientalis* is the second TS and the third for the 91M0. *Fraxinus ornus* is the 7th TS for the 9250 and for the 9340, the 8th for the 9280 and the 9th for the 91M0. *Quercus pubescens* is the 5th TS for the 9250, the 9th for the 9340 and also the 934A, and the 12th for the 91M0.

3.2 Cluster Analysis Of The Relevés From The 2014-2015's Evaluation Campaign

The results of the cluster analysis on the 3202 relevés gave three Phytosiciological clusters (PC) that can be related with forest oaks among 91 clusters (near the half having only 2 species). The 8 first species for the strength of the link are presented here with indication of Mutual Information (MI) in parentheses between the species and a previous one.

PC1: *Luzula forsteri - Veronica chamaedrys (511) - Clinopodium vulgare (446) - Silene italica (433) - Potentilla micrantha (432) - Lathyrus laxiflorus (365) - Brachypodium sylvaticum (328) - Quercus frainetto (309).*

The 8 first species of this PC are characteristic species of the the Quercion frainetto alliance, as it is mentioned in the greek Technical guide to recognize the HT by their species composition, with reference to the phytosociological classification [5]. See also [1]. They are mentioned as the most common species of the Greek "thermophilous deciduous" forests in Bergmeier & Dimopoulos [3].

PC2: *Arbutus unedo - Erica arborea (297) - Quercus ilex (201) - Phillyrea latifolia (196) - Rubia peregrina (170) - Quercus coccifera (158) - Smilax aspera (139) - Cercis siliquastrum (73).*

We recognize easily in the 8 first species of this PC the 9340 HT's characteristic species and characteristic of the Quercion ilicis alliance in which this HT have been classified by the above guide [5,1].

PC3: *Carpinus orientalis - Fraxinus ornus (240) - Sorbus torminalis (168) - Quercus pubescens 166) - Cornus mas (163) - Quercus trojana (119) - Ostrya carpinifolia (102) - Acer monspessulanum (67).*

The 8 first species of this PC are characteristic species of the Ostrio-carpinion phytosociological alliance, as they have been mentioned in the upward guide [5,1].

The comparison between the above results of the phytosociological analysis by cluster of distance in MI and the results in the table 3 shows that the HT 91M0 (Pannono-Balcanic oak forests) contains at least two PC, the Quercion frainetto and the Ostrio-carpinion.

To understand why the above phytosociological treatment separated the oak forests in three groups and not in two or six according to the number of oak forest's HT, we should examine the ecological profiles on some environmental variables.

3.3 Ecological Profiles Of Habitat Type's Typical Species On Geology And Altitude

Using the same method of frequency analysis to find the links between species (above paragraph), and between species and Habitat Types (paragraph 2-1), we present here ecological profiles of the PC's species on geology, as it has been noted in the 3202 relevés. (Ecological profiles have been calculated on 16 geological classes, but we presented on profiles's tables only the results for classes that have shown an average MI superior to 5 I or inferior to -5 I for the PC).

At the end of the tables a line gives the mean MI for each variable class and the cluster.

Table 4. Ecological profiles of the PC1 on geology

Geological class		**Coastal deposits**	**Alluvions**	**Tertiary deposits**	**Gneiss and granite**	**Schist**	**Other siliceous**	**Limestone**	**Marble**
Total frequency of the class		426	455	123	828	320	236	563	110
Name of the species	Total Specie's frequency	Mutual Information (in binons) between the species and the geological class							
Luzula forsteri	378	-81	-80	8	114	51	-4	-27	-20
Veronica chamedrys	613	-134	-131	23	101	67	**5**	-19	-33
Clinopodium vulgare	362	-77	-77	31	41	44	4	-11	-12
Silene italica	257	-54	-52	28	15	88	-1	-35	-8
Potentilla micrantha	380	-81	-87	-8	117	66	-4	-19	-20
Lathyrus laxifolius	253	-53	-52	8	51	48	3	-24	-13
Brachypodium sylvaticum	711	-152	-5	30	13	27	9	-5	-23
Quercus frainetto	892	-191	-180	49	74	206	2	-51	-47
Mean MI of the cluster		**-103**	**-83**	**21**	**66**	**75**	**2**	**-24**	**-22**

These ecological profiles for geology show that the PC1, that represents the phytosociological alliance Quercion frainetto, has strong probabilities to be on gneiss, granite, schist and on tertiary deposits, and strong probabilities not to be on Coastal deposits, alluvions, limestone and marble.

Table 5. Ecological profiles of the PC2 on geology

Geological class		**Coastal deposits**	**Alluvions**	**Tertiary deposits**	**Gneiss and granite**	**Schist**	**Other siliceous**	**Limestone**	**Marble**
Total frequency of the class		426	455	123	828	320	236	563	110
Name of the species	Total Specie's frequency	Mutual Information (in binons) between the species and the geological class							
Arbutus unedo	211	-44	-47	-12	91	15	12	-24	-11
Erica arborea	209	-44	-47	-12	74	22	14	-22	-11
Quercus ilex	173	-50	-53	-14	5	229	-12	-5	-12
Phillyrea latifolia	115	-24	-26	-3	14	59	4	-14	-6
Rubia peregrina	103	-21	-23	-6	7	18	-11	24	-5
Quercus coccifera	104	-36	-38	-4	-4	-3	-19	143	-9
Smilax aspera	77	-16	-9	-4	11	36	-9	-3	-4
Cercis siliquastrum	23	-5	-5	1	-7	32	-3	3	-1
Mean MI of the cluster		**-30**	**-31**	**-7**	**24**	**51**	**-3**	**13**	**-7**

The upward ecological profiles show that the species of the PC2 that represents the phytosociological alliance Quercion ilicis, has strong probabilities to be on gneiss, granite and schists but lower than the PC1, and not on tertiary deposits. They have strong probabilities not to be on Coastal deposits and alluvions, lower also than for PC1. They have quite strong probabilities to be on limestone, but just for *Quercus coccifera* and *Rubia peregrina,* and strong probabilities not to be on this geological formation for *Arbutus unedo* and *Erica arborea.*

Table 6. Ecological profiles of the PC3 on geology

Geological class		**Coastal deposits**	**Alluvions**	**Tertiary deposits**	**Gneiss and granite**	**Schist**	**Other siliceous**	**Limestone**	**Marble**
Total frequency of the class		426	455	123	828	320	236	563	110
Name of the species	Total Specie's frequency	Mutual Information (in binons) between the species and the geological class							
Carpinus orientalis	335	-71	-57	18	-17	25	52	11	6
Fraxinus ornus	478	-101	-102	-4	40	51	21	6	-25
Sorbus torminalis	173	-36	-39	-3	28	23	10	-5	-9
Quercus pubescens	437	-92	-40	25	12	10	-4	31	-11
Cornus mas	130	-27	-29	-2	9	15	33	-6	-7
Quercus trojana	104	-22	-23	70	-45	-16	-3	5	71
Ostrya carpinifolia	124	-26	-28	-7	7	-3	4	44	-6
Acer monspessulanum	37	-8	-8	5	-12	6	5	14	-2
Mean MI of the cluster		**-48**	**-41**	**13**	**3**	**14**	**15**	**13**	**2**

The upward table shows that species of the PC3 have strong probabilities to be on limestone with exception of *Cornus mas* and *Sorbus torminalis* that have strong probabilities to be on shists and other silicious rocks with *Fraxinus ornus* and *Carpinus orientalis (but not on granite and gneiss for the last). Carpinus orientalis, Quercus pubescens* and *Quercus trojana* have also strong probabilities to be on tertiary deposits. Note the strong probability of *Quercus trojana* to be on marbles.

The ecological profiles on geology permit to:

- Define two sub-types of pannono-balkanic oak forests 91M0: the sub-type with Quercus frainetto, that corresponds to the Quercion frainetto alliance that can be encountered on non calcaric geological substratum, confirming [1], and the sub-type with Quercus pubescens, corresponding to the Ostryo-carpinion alliance and encountered on calcaric geological substratum. This alliance corresponds to the Fraxino orni-Ostryon of [3], and more particularily to the Phillyreo-Carpinetum and Dryopterido pallidae-Ostryetum carpinifoliae associations.
- Constitute the 934A HT with dominant species Quercus coccifera as sub-type on limestones of the 9340 HT with dominant species Quercus ilex, confirming also [1].

To include 934A in 9340 do not exclude Quercus coccifera to constitute vegetal formations in Ostrio-carpinion. This species is then in low formation, not forests, and named “Pseudo-maquis” with code 5350.

To go further in the HT's ecological characterization, we should examine the profile of the PC on altitude. We present downwards these ecological profiles till 1600 m, although calculations have been made till 2300 m. After 1600 m, all the IM values are negative for the PC presented here.

Table 7. Ecological profiles of the PC1 on altitude

Altitude class (inferior limit)		**0**	**10**	**100**	**200**	**300**	**400**	**500**	**600**	**700**	**800**	**900**	**1000**	**1100**	**1200**	**1300**	**1400**	**1500**	**1600**
Total frequency of the class		445	256	145	70	60	138	236	256	150	162	152	121	126	130	154	136	99	90
Name of the species	Total Species' frequency	MI (in binons) between the species and the altitude class																	
Luzula forsteri	378	-84	-28	-3	7	4	-3	-5	9	102	52	35	21	3	-7	-15	-24	-14	-16
Veronica chamedrys	613	-140	-52	-6	3	4	-7	-13	4	63	32	33	21	17	10	14	4	3	-5
Clinopodium vulgare	362	-81	-29	-3	7	5	-3	-6	7	98	53	22	8	4	-8	-5	-12	-11	-15
Silene italica	257	-56	-27	6	15	3	-13	-5	10	98	21	24	9	4	-12	-15	-13	-12	-11
Potentilla micrantha	380	-85	-29	-3	-3	6	3	-6	10	68	38	31	26	6	-7	-5	-9	-9	-13
Lathyrus laxifolius	253	-56	-15	5	6	3	3	-7	9	54	19	26	14	3	-8	-5	-13	-12	-11
Brachypodium sylvaticum	711	-119	4	22	21	46	6	6	7	11	13	21	4	-5	4	-4	-7	-8	-19
Quercus frainetto	892	-200	-45	119	191	61	4	5	10	70	96	19	-6	-21	-55	-45	-58	-42	-38
Mean MI of the cluster		**-103**	**-28**	**17**	**31**	**17**	**-1**	**-4**	**8**	**70**	**41**	**26**	**12**	**1**	**-10**	**-10**	**-16**	**-13**	**-16**

The upward table shows that the PC1, representing the Quercion frainetto, has a little probability to be in altitude lower than 600 m and upper than 1100 m, with exception for *Quercus frainetto* and *Brachypodium sylvaticum,* that have a strong probabilty to be present in altitudes from 100 m to 400 m, and *Veronica chamaedrys* that has a strong probability to be encountered till 1400 m. The Quercion frainetto alliance belongs to the sub-mediterranean (Υπό-μεσογειακός) according to [13] or supra-mediterranean according to [1], with more annual rainfall and lesser summer drought than the eu-mediterranean (ευ-μεσογειακός) according to [13] or simply mediterranean (méditerranéen) according to [1] bioclimatic storage.

Table 8. Ecological profiles of the PC2 on altitude

Altitude class (inferior limit)		**0**	**10**	**100**	**200**	**300**	**400**	**500**	**600**	**700**	**800**	**900**	**1000**	**1100**	**1200**	**1300**	**1400**	**1500**	**1600**
Total frequency of the class		445	256	145	70	60	138	236	256	150	162	152	121	126	130	154	136	99	90
Name of the species	Species' frequency	MI (in binons) between the species and the altitude class																	
Arbutus unedo	211	-17	31	54	103	71	-3	-7	-4	-7	-16	-15	-12	-12	-13	-15	-13	-10	-9
Erica arborea	209	-22	8	26	47	66	7	-3	10	12	-16	-9	-12	-12	-13	-15	-13	-10	-9
Quercus ilex	173	6	20	69	80	38	3	6	-20	-17	-18	-17	-14	-14	-15	-17	-15	-11	-10
Phillyrea latifolia	115	-13	52	75	25	8	-3	-3	-14	-8	-9	-8	-6	-7	-7	-8	-7	-5	-5
Rubia peregrina	103	-5	13	13	3	16	4	28	4	-5	-8	-7	-6	-6	-6	-7	-7	-5	-4
Quercus coccifera	104	-37	10	6	7	4	16	140	3	-9	-10	-12	-10	-10	-10	-9	-11	-8	-7
Smilax aspera	77	15	44	13	12	3	-5	-9	-10	-5	-6	-5	-4	-5	-5	-6	-5	-4	-3
Cercis siliquastrum	23	7	7	9	2	2	1	-2	-3	-2	-2	-2	-1	-1	-1	-2	-1	-1	-1
Mean MI of the cluster		**-8**	**23**	**33**	**35**	**26**	**3**	**19**	**-4**	**-5**	**-11**	**-9**	**-8**	**-8**	**-9**	**-10**	**-9**	**-7**	**-6**

The above profiles on altitude show that the PC2's species, representing the Quercion ilicis and the TH 9340 have a strong probability to not be in altitude upper than 800m. This illustrates the association of the Quercion ilicis with the eumediterranean (ευ-μεσογειακός) according to [13], méditerranean according to [1] and meso-méditerranean according to [5] bioclimatic storage, characterized by a severe summer drought, but also by moderate winter temperatures.

Table 9. Ecological profiles of the PC3 on altitude

Altitude class (inferior limit)		**0**	**10**	**100**	**200**	**300**	**400**	**500**	**600**	**700**	**800**	**900**	**1000**	**1100**	**1200**	**1300**	**1400**	**1500**	**1600**
Total frequency of the class		445	256	145	70	60	138	236	256	150	162	152	121	126	130	154	136	99	90
Name of the species	Species' frequency	MI (in binons) between the species and the altitude class																	
Carpinus orientalis	335	-74	-24	24	99	42	14	38	4	17	9	4	-9	-20	-20	-24	-21	-16	-14
Fraxinus ornus	478	-86	-17	19	77	36	26	7	11	11	12	7	-3	-5	4	-19	-26	-22	-20
Sorbus torminalis	173	-38	-14	3	18	14	16	-3	8	18	10	8	-3	-3	-4	-6	-8	-8	-7
Quercus pubescens	437	-85	-14	54	29	16	80	13	4	10	4	17	5	-9	-19	-24	-28	-20	-18
Cornus mas	130	-28	-12	-3	13	26	17	-3	11	10	16	3	-2	-8	-3	-5	-8	-6	-5
Quercus trojana	104	-23	-13	-7	-3	-3	-7	48	3	46	40	2	-6	-6	-6	-7	-7	-5	-4
Ostrya carpinifolia	124	-27	-15	-8	3	16	-4	-11	-10	3	16	11	3	3	41	5	4	-3	-2
Acer monspessulanum	37	-8	-2	-2	1	5	10	4	2	8	11	-3	-2	-2	-2	-3	-2	-2	-2
Mean MI of the cluster		**-46**	**-14**	**10**	**30**	**19**	**19**	**12**	**4**	**15**	**15**	**6**	**-2**	**-6**	**-1**	**-10**	**-12**	**-10**	**-9**

The table 9 shows that the PC3, representing the Ostrio-carpinion has a large altitudinal domain, from 100 to 1000m, with exception from *Quercus trojana*, with probabilities not to be present lower than 500m, and *Ostrya carpinifolia* having a bimodal altitude distribution, from 200 to 400 m, and then from 700 to 1400 m. The Ostrio-carpinion is also associated with the sub-mediterranean according to [13] or supra-mediterranean according to [1,5].

3.4 Discussion And Proposition For A New Partial Classification Of Oak Forest Habitat Types In Northern Greece

The upwards ecological profiles give an analytic view of vegetation classification, helping the interpretation of synthetical ones as Detrended Correspondence Analysis used in [3] for identifying plant communities of Greek thermophilous deciduous forests. These profiles confirm the importance of geology and altitude as the first ordination axis for these plant communities is linked with soil type, and the second with climate.

We showed that *Quercus frainetto* (and *Brachypodium sylvaticum*), of the PC1, has a strong probability to be in the same altitude as the Quercion ilicis, represented by the PC2. This should be related with the fact that these species have also strong probability to be on tertiary deposits, present at low altitude in Norther Greece. These soils are deep, and they can store water to dispose it during summer, compensating the atmospheric drought that hinder *Quercus frainetto* and the most PC1's species to live at low altitude on other geological substratum that have poor water reserve. Let us remember that alluvial substrata, on which *Quercus frainetto* has a very negative link, are generally cultivated and do not support forests in Greece anyway. So, *Quercus frainetto* cannot be considered in north Greece as differential species between the sub-mediterranean or supra-mediterranean bioclimatic storage and the eu-mediterranean one, but rather an indicative of non-calcaric soils in these storages.

Also the profiles on geology showed a difference between the PC3 (Ostrio-carpinion) and the PC1 (Quercion frainetto) with the PC2 (Quercion ilicis) coming from the fact that PC3 has a tolerance to calcareous substrata that have not the PC1 and the majority of the PC2's species. The Ostrio-carpinion is an alliance of the sub or supra-mediterranean storage, but, like *Quercus frainetto*, *Carpinus orientalis* or *Quercus pubescens*, of the PC3, can be found on deep tertiary deposits in low altitude. So, we propose a new partial classification of oak forests' habitat types based on bioclimatic storages and geology. In this classification the habitat types are represented by typical species in reduced number issued from our phytosociological cluster analysis.

Table 10. Proposed oak forest habitat types classification in Northern Greece and their Typical Species ranked in accordance with Mutual Information in the cluster

91M01 Pannonian-Balkanic oak forests with *Quercus frainetto*	91M02 Pannonian-Balkanic oak forests with *Quercus pubescens*	9340 *Quercus ilex* Forests
1-Luzula forsteri	1-Carpinus orientalis	1-Arbutus unedo
2-Veronica chamaedrys	2-Fraxinus ornus	2-Erica arborea
3-Clinopodium vulgare	3-Quercus pubescens	3-Quercus ilex
4- Silene italica	4-Quercus trojana	4-Phillyrea latifolia
5-Potentilla micrantha	5-Ostrya carpinifolia	5-Rubia peregrina
6-Lathyrus laxiflorus	6-Acer monspessulanum	6-Quercus coccifera
7-Brachypodium sylvaticum		7-Smilax aspera
8-Quercus frainetto		8-Cercis siliquastrum

The Typical Species proposed in the oak forests Habitat types are those of the Phytosociological Clusters: PC1 for the 91M01, PC3 for the 91M02 and PC2 for the 9340, ranked in accordance with their higher Mutual Information with another species of the cluster.

The distinction between the two 91M0 types is based on geological substratum given by the ecological profiles: 91M01 is encountered on non calcaric substratum, and 91M02 is encountered on calcaric subtratum. This is in accordance with [1] and [3]. Let us precise that the proposed 91M02 corresponds to the 41.733 Corine 91 codification “Hellenic woods with Quercus pubescens”.

For the 9250 (*Quercus trojana* forests), we did not find typical species other than Quercus trojana itself. This species is linked with the PC3 (Ostrio-carpinion). The 9250 have been classified by [5] in the Quercion frainetto after having been in the Ostrio-Carpinion orientalis (Horvat). We propose to institute the *Quercus trojana* forests as a sub-type of 91M02.

Concerning the 9340, the accordance with PC2 is quite perfect and its typical species are the same as noted on field during the 2014-2015 evaluation campaign.

Concerning the 934A (Quercus coccifera forests), we suggest instituting it as a sub-type of 9340 exclusively on limestones.

For the other oak forest’s types (91F0 and 9280), the cluster analysis revealed that the Typical Species noted during the evaluation campaign and presented in table 3 are transgressive:

- In Northern Greece, the 91F0 has Typical Species of ripisylves, and *Quercus robur* is linked first with *Fraxinus angustifolia,* these species belonging to a general cluster where the strongest links are between *Planatus orientalis*, *Rubus ulmifolius* and *Clematis vitalba*.
- The Habitat Type 9280 is a hybrid between oak and beech forests. The Typical Species noted during the evaluation campaign (table 3) belong either to the oak clusters (PC1: *Luzula forsteri*, *Potentilla micrantha*, *Pteridium aquilinum*, PC3: *Sorbus torminalis*, *Fraxinus ornus*) or beech forests cluster (*Fagus sylvatica*, *Poa nemoralis*, *Dactylis glomerata*). In fact this HT have been classified by [5] in two classes: the Querco-Fagetea (Br. bl.), represented by the Fagion sylvatica and the Cephalanthero-Fagion (Tx.1955), and the Quercetea pubescentis, represented by the Quercion frainetto. Unspite the name of this HT *(Quercus frainetto* woods), they are beech woods and *Quercus frainetto* has a very weak link with those woods in the sample we studied, but we cannot, with our cluster anaysis, clarify the phytosociological status of the “*Quercus frainetto* woods” in Northern Greece. We think that they are a transition Habitat Type between oak and beech forests, and since they are more beech than oak forests by the dominant species, to facilitate the non-phytosociologists land management professionals, for example in cartography, we suggest to name them “Inferior Limit Beech Forests”.

4 Conclusion

Frequency analysis gives three results:

- Ordinated list of Typical Species noted within their 8 Habitat Types during the 2014-Ordinated 2015 evaluation campaign in 3202 relevés in Northern Greece, with the strength of the link between the species and the habitat.
- Phytosociological clusters of 8 species from cluster analysis of the 3202 upwards relevés and their correspondence with the above Habitat Types through the correspondence between phytosociological alliances' Characteristic Species and Habitat Types' Typical Species as they have been showed in the previous result.
- Phytosociological clusters' ecological profiles on geological substratum and altitude from the same sample, that gave the links between the cluster's species and the geological substratum and altitude classes. More precisely this work has permitted to propose:

  1. The subdivision of the 91M0 oak type (Pannonian-Balkanic oak forests) in two types: one on non-calcaric substratum that corresponds to the phytosociological alliance of Quercion frainetto, the other on calcaric substratum corresponding to the phytosociological alliance of Ostrio-carpinion.
  2. The constitution of the 9280 (*Quercus trojana* forests) as a sub-type, especially on marbles, of the 91M02 that corresponds to the phytosociological alliance of Ostrio-carpinion.
  3. The constitution of the 934A (*Quercus coccifera* forests) as a subtype on calcaric substratum of 9340 that corresponds to the phytosociological alliance of Quercion ilicis.

References

[1] M. Barbero, P. Quezel, « Les groupements forestiers de Grèce Centro-Méridionale », Ecologia mediterranea, 2, 1976.

[2] F. Bendali, N. Nellas, "Conservation status assessment method for habitat types at Site of European Community Interest scale", International Journal of Innovation and Applied Studies Vol. 17 No. 2, pp. 548-555, 2016.

[3] Bergmeier, E. and Dimopoulos, P. "Identifying plant communities of thermophilous deciduous forests in Greece: Species composition, distribution, ecology and syntaxinomy", Plant Biosystems, vol 144, No 2, pp. 228-254, 2008.

[4] Braun-Blanquet, J. « Les groupements végétaux de la France méditerranéenne. » Macabet Frères, Vaison la Romaine, 1952.

[5] S. Dafis, E. Papasteriadou, T. Lazaridou, M. Tsiafouli, «Αναγνώριση και περιγραφή των τύπων οικοτόπων σε περιοχές ενδιαφερόντος για τη διατήρηση της φύσης» Τεχνικός οδηγός χαρτογράφησης, Ministry of Environment, Thessaloniki, 2001.

[6] Dimopoulos P., Tsiripidis I., Xystrakis F., Panitsa M., Fotiadis G., Kallimanis A.S. and Kazoglou I., Deliverable A6. Explanatory Implementation Manual for the Conservation Degree Assessment of Habitat Types – 1st edition, Ministry of Environment, Energy and Climate Change, OIKOM Ltd - E. Alexandropoulou - A. Glavas, Athens, 38 p., 2014 (in Greek).

[7] Evans D. and Arvela M., Assessment and reporting under Article 17 of the Habitats Directive. Explanatory Notes & Guidelines for the period 2007-2012. Final draft. European Topic Centre on Biological Diversity, 123 p., 2011.

[8] Godron, M., "Application de la théorie de l'information à l'étude de l'homogénéité et de la structure de la végétation", Oecol. Plant., vol. 2, pp. 187-197. 1966.

[9] Godron, M., Andrieu, J., "Mise en évidence statistique d'un continuum a facettes dans les Baronnies", in F. Alexandre et A., Genin, Continu et discontinu dans l'espace géographique, Tours: Presses universitaires François Rabelais, pp. 145-170, 2008.

[10] Godron, M., Ecologie et évolution du monde vivant, Paris: Ed. de l'Harmattan, 1982 p., 2012.

[11] Gounot, M. "L'exploitation mecanographique des releves pour la recherche des groupes écologiques", Bulletin du Service de la Carte Phytogeographique. B, vol 4, no. 2, pp. 147-177, 1959.

[12] Kotzageorgis, G., Mantzavelas, A., Hadjicharalambous, E., Defingou, M., Gioutlakis, M., Papagrigoriou, S., Alexandridou, E. (Editors), "Deliverable B4: Manual on the updated Database of the monitoring project, 1st edition". YPEKA, Athens, Joint venture of Enveco S.A, Omikron Ltd., Karolidis Theodoros, Fyselias Spyridon, Consultant EKVY, 83 p., 2014 (in Greek).

[13] Mavrommatis, G. « Carte de la végétation de la Grèce » Institut de Recherches Forestière, Athènes, 1978.

[14] I. Tsiripidis, F. Xystrakis.A. Kallimanis, M. panitsa and P. Dimopoulos, "A bottom–up approach for the conservation status assessment of structure and functions of habitat types", Rendiconti Lincei. Scienze Fisiche e Naturali, 2018.