



Gamma-diversity of vascular plant taxa of the surrounding of Lake Sünnet (Bolu, NW Turkey) compared with other regions in Bolu

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Abstract

This paper reports the gamma-diversity of vascular plant taxa (ferns, fern allies and seed plants) of the surrounding of Lake Sünnet (Bolu, Turkey). The vascular flora of the surrounding of Lake Sünnet was compiled from the fieldworks done between 2006 and 2009. The studies resulted in 324 taxa belonging to 67 families and 216 genera. The number of endemic species was found to be 35, corresponding to an endemism ratio of 10.8%. The richest families were *Lamiaceae*, *Asteraceae*, *Fabaceae*, *Boraginaceae*, and *Rosaceae*. The richest genera were found as *Astragalus*, *Vicia*, *Salvia*, *Centaurea*, and *Viola*. Distribution of the species according to phytogeographical regions resulted in 16.4% as Euro-Siberian elements (including Euxines), 13.3% as Mediterranean elements, and 10.2% as Irano-Turanian elements. The study site was compared with floristic composition of 11 other neighboring regions. TWINSpan analysis classified 12 sites into four main community types. Detrended Correspondence Analysis (DCA) resulted in three clusters and Gökçeler Mountain. In UPGMA cluster analysis there are two clusters and Gökçeler Mountain was also placed separately.

Key words: Bolu, Sünnet, Flora, TWINSpan, DCA

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Sünnet Gölü çevresinin (Bolu, Türkiye) damarlı bitki taksonu gamma-çeşitliliği ve Bolu'daki diğer alanlarla karşılaştırılması

Özet

Bu çalışmada Sünnet Gölü çevresinin (Bolu, Türkiye) damarlı bitki gamma-çeşitliliği araştırılmıştır. Alanın damarlı bitki florası 2006 ve 2009 yılları arasında yapılan arazi çalışmaları sonucu tespit edilmiştir. Çalışma sonucu 67 familya ve 216 cinse ait 324 takson kaydedilmiştir. Alanda tespit edilen endemik türlerin sayısı 35, endemizm oranı ise %10.8 olmuştur. En zengin familyalar *Lamiaceae*, *Asteraceae*, *Fabaceae*, *Boraginaceae* ve *Rosaceae*'dir. En büyük cinsler ise *Astragalus*, *Vicia*, *Salvia*, *Centaurea* ve *Viola* olmuştur. Türlerin fitocoğrafik alanlara göre dağılımı ise %16.4 Avrupa-Sibirya (Öksin alanını içerecek şekilde), %13.3 Akdeniz ve %10.2 İran-Turan elementi şeklinde olmuştur. Çalışma alanının floristik bileşimi 11 farklı komşu alanla karşılaştırılmıştır. TWINSpan analizi karşılaştırılan 12 alanı dört ana komünite tipi altında sınıflandırmıştır. Detrended Correspondence Analizi (DCA), alanları üç farklı küme ve Gökçeler Dağı şeklinde gruplandırmıştır. UPGMA küme analizi sonucu Gökçeler Dağı haricindeki diğer alanlar iki küme altında toplanmıştır.

Anahtar kelimeler: Bolu, Sünnet, Flora, TWINSpan, DCA

1. Introduction

Lake Sünnet is located in Bolu province of North Western Turkey at 40°26.352 N, 30°57.440 E (Figure 1 and Figure 2). Lake Sünnet is found in A3 square according to geographical divisions in Flora of Turkey (Davis, 1965-1985). The study area contains the surroundings of the Sünnet Lake and the Sünnet Village (Figure 1). The altitude of

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the studied area ranges from 800 m to 1200 m and there is a lake is at 1030 m. The highest peak of the region is at 1470 m and there are several hills around 1450 m (Hoşgören and Ekinci, 2004). The lake is formed by landslides and traces of those landslides are presently visible in the area (Hoşgören and Ekinci, 2004). Sünnet area is 76 km away from Bolu, 16 km from Göynük and 35 km to Mudurnu. There is a hotel near the Lake and as a consequence the area is busy especially at the weekends.

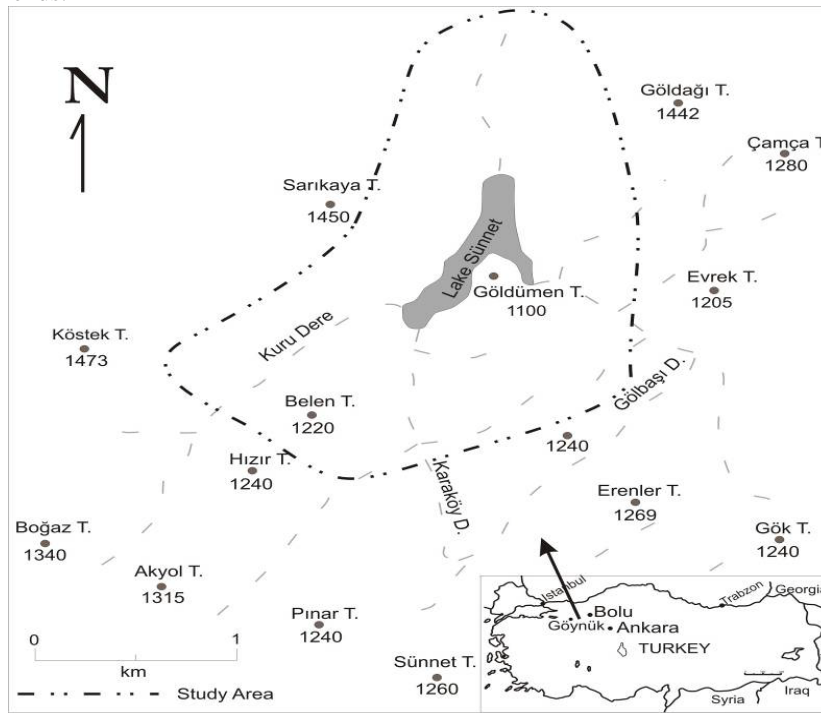


Figure 1. Geographical location of the study area

In terms of phytogeographical regions, northern part of the Bolu province is in the Euxinian province of Euro-Siberian phytogeographical region, and southern parts in Irano-Turanian phytogeographical region. However, south western parts of the province near the Sakarya river basin have Mediterranean floristic and phytogeographical influence characterized by *Pinus brutia* Ten. forests. The Mediterranean phytogeographical region is represented in NW Turkey mainly along the Black Sea coast and in the inner parts where the Sakarya River and small streams contributing to it form deep valleys. The altitude in this area can descend as low as 240 m. Because of this the study area lies on the intersection of the three phytogeographical regions (Davis, 1971).

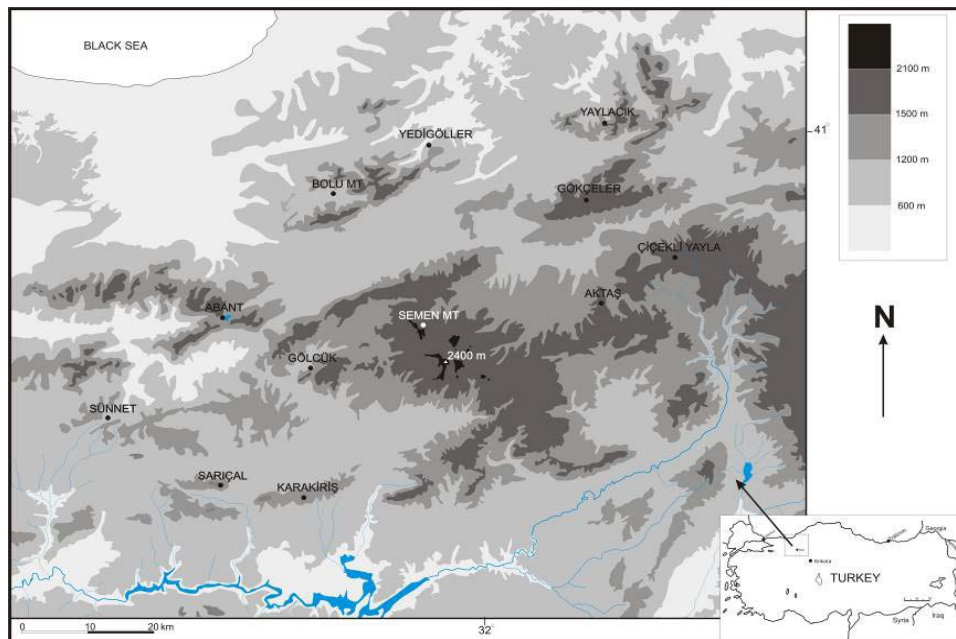


Figure 2. Geographical location of the study area and compared 11 sites. Detailed information about each region is given in Table 1

In terms of geology of the area, during the early Jurassic terrestrial areas were underwater. Oldest formations in the area are limestone from the early Cretaceous period. The area was deeper during the Late Cretaceous. During Paleocene, region became shallower and even terrestrial again. Later, terrestrial areas were protected since Late Eocene-Oligocene. The present structure of the area is a result of terrestrial erosion since Paleocene (Oral, 1985).

Climatic data were obtained from Bolu Meteorological station which is at 742 m altitude, with coordinates 40°44' E and 31°31' N. According to the meteorological data gathered between 1975 and 2009 (35 years) mean annual precipitation for Bolu is 454 mm and the mean annual temperature is 10.4 °C. Mean maximum temperatures are highest in July as 19.7 °C. Mean lowest temperatures recorded in January as 0.9 °C. Highest rainfall is received in December and the lowest rainfall is in August and September. Figure 3 shows the climatic diagram of Bolu. Bolu is basically under the influence of Western Black Sea and Black Sea climate. However, western and south western parts have Marmara and Central Anatolian climate. Therefore, Bolu occupies a transition zone of different types of climates. Southern parts of Bolu have higher elevations and decreased precipitation and a continental climate (Bolu Yıllığı, 1998). The study of Sensoy et al. (2008) showed that Sünnet Area has C1 Semidry-Less humid climate according to Thornthwaite climate classification.

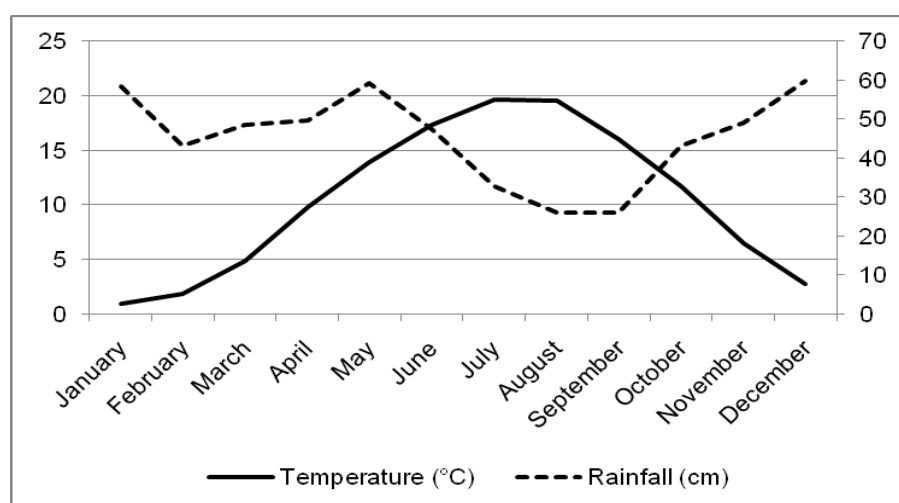


Figure 3. Climatic diagram of Bolu, Turkey. Data obtained from Bolu Meteorological station between 1975 and 2009.

The natural vegetation in the area is mainly composed of *Pinus nigra* subsp. *nigra* var. *caramanica* forests with a sparse underground vegetation cover. There are also rocky scrub composed of *Paliurus spina-christii*, *Cornus mas* and *Corylus avellana* var. *avellana* bushes. There are marshy habitats around the lake and along the small tributaries in the area.

There are different measures of biodiversity. Alpha-diversity (within habitat diversity) concerns different groups of organisms interacting and competing for the same resources or sharing the same environment (Whittaker, 1972). Beta-diversity (between-habitat diversity) is the response of organisms to spatial heterogeneity and is expressed in terms of similarity index between communities. Both alpha and beta-diversity contributes to Gamma-diversity which is concerned about species richness on the regional scale (Whittaker, 1972). Gamma-diversity described for vascular plants of a region corresponds to local floras.

Davis (1975) stated that Bolu is among the moderately known areas in terms of plant biodiversity though several studies dealing with the flora and vegetation of the area have been published ever since (see Table 1). Nevertheless, there is no floristic or vegetation analysis so far known from the surroundings of Lake Sünnet. Therefore, the aims of the present study are to determine the gamma-diversity of vascular plants of the surrounding of Lake Sünnet and to compare it with species composition of the neighbouring sites.

2. Materials and methods

The floristic inventory was generated by several fieldworks from March to end of October between 2006 and 2009. During the identification of the plant specimens, "Flora of Turkey and the East Aegean Islands (Davis, 1965-1985; Davis et al., 1988; Güner et al., 2000) was used as a main reference source. Doubtful identifications were checked from "Flora Europaea" (Tutin et al., 1964-1980). Voucher specimens are deposited in the herbarium of Abant İzzet Baysal University (AIBU). Authors of plant names are abbreviated according to Brummitt and Powell (1992).

There are disturbed areas around the hotel and farm house immediately on the edges of the lake and in the nearby Sünnet village. Cultivated and naturalized plants from these disturbed areas were not included in the floristic list.

2.1. Data Analysis

The presence/absence matrix was created containing species list of 12 regions in Bolu. Detailed information about the analyzed 12 regions is given in Table 1 and their geographical positions are indicated in Figure 2. It was not possible to compare the sizes of the 12 regions because detailed information about the boundary of study area was lacking in some of the original publications. Original matrix containing all the species of 12 regions included 1696 species. However, when the species occurring only in one or two areas were excluded, the list is reduced to 586 species. As a result, species occurring at least in three regions were included in the analysis. Unweighted Pair Group Method with Arithmetic Mean Analysis (UPGMA) was performed with Sorensen's Coefficient using the program MVSP (Multivariate Statistical Package) version 3.13n (Kovach, 2005). Detrended correspondence analysis (DCA), an indirect gradient analysis and two-way indicator species analysis (TWINSPAN, Hill, 1979) were made by utilizing the computer program Community Analysis Package Version 4.0 (Henderson, 2007). TWINSPAN was used to classify 12 regions according to their floristic similarity. It was not possible to compare the size of the areas of 12 regions because no information was given in the relevant original publications.

Table 1. Definition of the compared areas. Altitude range indicates the areas where plants collected

Name of the area	Reference	Protection Status	Date of assignment	Altitude (m)	Coordinates
Sünnet (Göynük, Bolu)	(present study)	Forest resort	-	800-1200	40°25' N, 30°57' E
Yedigöller (Bolu)	(Ekim and İlarlan, 1982)	National Park	1965	480-1489	40°48'-40°56'N 31°43'-31°47'E
Abant (Bolu)	(Türker and Güner, 2003)	Nature Park	1988	1320-1700	40°37'-40°42'N 31°29'-31°38'E
Gölcük (Bolu)	(İkinci and Güner, 2007)	Kökez Nature Reserve	1997	800-1300	40°39' N, 31°37'E
Gökçeler Mountain (Gerede-Eskipazar)	(Uluğ, 1999)	-	-	800-1700	40°51' N, 32°20' E
Gerede Aktaş (Bolu)	(Akman and Ketenoğlu, 1979)	-	-	1100-1600	40°40' N, 32°19' E
Bolu Mountains (Bolu, Düzce)	(Akman and Yurdakulol, 1981a)	-	-	220-1700	40°44' N, 31°25' E
Çiçekliyayla Mountain (Çankırı-Gerede-Kızılcahamam)	(Pakpınar, 1995)	-	-	1200-1800	40°46' N, 32°39' E
Karakiriş Mountain (Seben-Nallıhan)	(Aksoy, 2001)	-	-	540-1550	40°11'-40°22'N 31°21'-31°43'E
Semen Mountains (Bolu)	(Akman and Yurdakulol, 1981b)	-	-	700-2100	40°31' N, 30°52' E
Yaylacık Research Forest (Mengen)	(Kaptanoğlu, 1995)	Research forest	1987	400-1654	40°59'-41°00'N 32°05'-32°18'E
Sarıçal Mountain (Nallıhan-Ankara)	(Yılmaz, 1996)	-	-	700-1740	40°15'-40°19'N 31°10'-31°21'E

3. Results

The vascular flora (ferns, fern allies and seed plants) of the surrounding of Lake Sünnet was compiled from fieldworks done between 2006 and 2009. The studies resulted in 324 taxa belonging to 67 families and 216 genera. The list of the taxa presented in Appendix 1 which follows in alphabetical orders of families, genera, and species. Endemic taxa are indicated by an asterisk (*). Table 2 lists the total number of taxa, percentage of endemic species and phytogeographical elements in Sünnet region and in 11 other compared neighbouring sites.

The forest vegetation of the area is dominated by *Pinus nigra* J.F.Arnold subsp. *nigra* var. *caramanica* (Loudon) Businský. There are wetlands around the Lake mainly dominated by three *Equisetum* L. species and *Eleocharis palustris* (L.) Roem. & Schult. Dominant floating and submersed aquatic species are *Polygonum amphibium* L., *Potamogeton natans* L., and *Myriophyllum spicatum* L.

The richest families were *Lamiaceae*, *Asteraceae*, *Fabaceae*, *Boraginaceae*, and *Rosaceae*. Table 3 lists largest 10 families of the Sünnet area and of the other compared 11 areas. The richest genera found in Sünnet area are with their number of species in parenthesis *Astragalus* (7), *Vicia* (7), *Salvia* (6), *Centaurea* (5), and *Viola* (5), respectively.

Distribution of the species according to the phytogeographical regions resulted in 16.4% being as Euro-Siberian elements, 13.3% as Mediterranean elements, and 10.2% as Irano-Turanian elements. Table 2 shows the floristic properties of the present study and the compared 11 other neighboring regions. The number of endemic species was 35 with an endemism ratio of 10.8%.

Table 2. Floristic properties of the Sünnet area and of the compared studies

	Sünnet	Gölcük	Abant	Yedigöller	Bolu Mt.	Semen Mt.	Aktaş	Karakiriş	Çiçekliyayla	Yaylacık	Sarıçal	Gökçeler
Total taxa	324	475	677	236	276	286	315	511	358	300	321	284
Endemic species %	10.8	3.5	8.1	6.7	5.0	4.1	5.0	13.5	15.0	4.29	9.9	3.9
Euro-Sib. (incl. Euxine el. %)	16.4	30.8	29.3	32.4	31.8	27.6	15.6	13.5	27.2	36.3	10.9	16.5
Medit. %	13.3	5.2	5.6		5.3	7.6	7.6	7.83	4.0	7.26	9.3	3.2
Ir.-Tur. %	10.2	1.5	4.7	2.3	2.6	3.8	7.6	26.22	12.0	1.65	12.7	9.5
Multiregional or phytogeographic region unknown (%)	60.1	62.5	60.4	65.3	60.3	61.0	69.2	52.44	56.8	54.79	67.1	70.8

Table 3. Comparison of largest families of 12 regions. Information about each region is given in Table 1

Sünnet	Gölcük	Abant	Yedigöller	Bolu Mt.	Semen Mt.
<i>Lamiaceae</i> 32 (9.9)	<i>Asteraceae</i> 43 (9.3)	<i>Asteraceae</i> 68 (10.3)	<i>Rosaceae</i> 26 (11.0)	<i>Fabaceae</i> 28 (10.4)	<i>Fabaceae</i> 27 (9.5)
<i>Asteraceae</i> 32 (9.9)	<i>Poaceae</i> 43 (9.3)	<i>Poaceae</i> 55 (8.3)	<i>Fabaceae</i> 25 (10.6)	<i>Asteraceae</i> 25 (9.3)	<i>Asteraceae</i> 21 (7.4)
<i>Fabaceae</i> 30 (9.3)	<i>Fabaceae</i> 40 (8.7)	<i>Fabaceae</i> 46 (6.9)	<i>Rosaceae</i> 13 (4.7)	<i>Lamiaceae</i> 22 (7.9)	<i>Rosaceae</i> 21 (7.4)
<i>Boraginaceae</i> 18 (5.6)	<i>Rosaceae</i> 25 (5.4)	<i>Lamiaceae</i> 45 (6.8)	<i>Lamiaceae</i> 13 (5.5)	<i>Rosaceae</i> 18 (6.4)	<i>Lamiaceae</i> 19 (6.7)
<i>Rosaceae</i> 13 (4.0)	<i>Lamiaceae</i> 22 (4.8)	<i>Rosaceae</i> 35 (5.3)	<i>Apiaceae</i> 11 (4.7)	<i>Poaceae</i> 16 (5.9)	<i>Poaceae</i> 18 (6.3)
<i>Brassicaceae</i> 13 (4.0)	<i>Brassicaceae</i> 18 (3.9)	<i>Scrophulariaceae</i> 32 (4.8)	<i>Poaceae</i> 11 (5.5)	<i>Scrophulariaceae</i> 11 (4.0)	<i>Brassicaceae</i> 17 (5.9)
<i>Liliaceae</i> 11 (3.4)	<i>Caryophyllaceae</i> 17(3.7)	<i>Brassicaceae</i> 31 (4.7)	<i>Caryophyllaceae</i> 10 (4.2)	<i>Campanulaceae</i> 10 (3.7)	<i>Scrophulariaceae</i> 16 (5.6)
<i>Apiaceae</i> 10 (3.1)	<i>Apiaceae</i> 17 (3.7)	<i>Caryophyllaceae</i> 23 (3.5)	<i>Liliaceae</i> 7 (3.0)	<i>Ericaceae</i> 10(3.7)	<i>Caryophyllaceae</i> 14 (4.9)
<i>Caryophyllaceae</i> 9 (2.8)	<i>Scrophulariaceae</i> 14 (3.0)	<i>Liliaceae</i> 21 (3.2)	<i>Brassicaceae</i> 6 (2.5)	<i>Apiaceae</i> 8 (2.8)	<i>Ranunculaceae</i> 11 (3.8)
<i>Ranunculaceae</i> 9 (2.8)	<i>Boraginaceae</i> 13 (2.8)	<i>Ranunculaceae</i> 21 (3.2)	<i>Scrophulariaceae</i> 6 (2.5)	<i>Caryophyllaceae</i> 8 (2.8)	<i>Rubiaceae</i> 9 (3.1)

Table 3. (continued)

Aktaş	Karakiriş	Çiçekliyayla	Yaylacık	Sarıçal	Gökçeler
<i>Fabaceae</i> 35 (11.2)	<i>Asteraceae</i> 72 (14.1)	<i>Asteraceae</i> 50 (14.0)	<i>Asteraceae</i> 32 (10.6)	<i>Asteraceae</i> 48 (15.0)	<i>Asteraceae</i> 31(10.9)
<i>Asteraceae</i> 26 (8.3)	<i>Fabaceae</i> 61 (11.9)	<i>Fabaceae</i> 33 (9.0)	<i>Fabaceae</i> 25 (8.3)	<i>Fabaceae</i> 33 (10.2)	<i>Fabaceae</i> 29 (10.2)
<i>Scrophulariaceae</i> 26 (8.3)	<i>Lamiaceae</i> 39 (7.6)	<i>Lamiaceae</i> 32 (9.0)	<i>Lamiaceae</i> 21 (6.9)	<i>Lamiaceae</i> 30 (9.3)	<i>Caryophyllaceae</i> 26 (9.2)
<i>Poaceae</i> 17 (5.4)	<i>Poaceae</i> 35 (6.8)	<i>Poaceae</i> 23 (6.0)	<i>Rosaceae</i> 21 (6.9)	<i>Brassicaceae</i> 24 (7.4)	<i>Brassicaceae</i> 21 (7.4)
<i>Lamiaceae</i> 16 (5.1)	<i>Rosaceae</i> 27 (5.3)	<i>Brassicaceae</i> 19 (5.0)	<i>Poaceae</i> 16 (5.3)	<i>Rosaceae</i> 15 (4.6)	<i>Lamiaceae</i> 15(5.3)
<i>Rosaceae</i> 16 (5.1)	<i>Brassicaceae</i> 20 (3.9)	<i>Apiaceae</i> 19 (5.0)	<i>Scrophulariaceae</i> 15 (5.0)	<i>Scrophulariaceae</i> 15 (4.6)	<i>Rosaceae</i> 15(5.3)
<i>Caryophyllaceae</i> 16 (5.1)	<i>Boraginaceae</i> 16 (3.1)	<i>Caryophyllaceae</i> 17 (4.5)	<i>Brassicaceae</i> 14 (4.6)	<i>Boraginaceae</i> 13 (4.0)	<i>Scrophulariaceae</i> 13 (4.6)
<i>Brassicaceae</i> 15 (4.8)	<i>Apiaceae</i> 15 (3.0)	<i>Rosaceae</i> 15 (4.0)	<i>Apiaceae</i> 12 (4.0)	<i>Liliaceae</i> 12 (3.7)	<i>Boraginaceae</i> 12 (4.2)
<i>Boraginaceae</i> 14 (4.5)	<i>Liliaceae</i> 15 (3.0)	<i>Boraginaceae</i> 14 (4.0)	<i>Boraginaceae</i> 10 (3.3)	<i>Caryophyllaceae</i> 10 (3.1)	<i>Poaceae</i> 10 (3.5)
<i>Liliaceae</i> 12 (3.8)	<i>Scrophulariaceae</i> 13 (2.5)	<i>Rubiaceae</i> 11 (3.0)	<i>Caryophyllaceae</i> 8 (2.6)	<i>Ranunculaceae</i> 10 (3.1)	<i>Ranunculaceae</i> 10 (3.5)

TWINSPAN analysis classified 12 regions into two groups based on floristic composition at the first level (Figure 4). The analysis stopped at the second level classifying areas into four groups. Group 1 comprises Yaylacık, Yedigöller, Bolu and Semen Mountains. Group 2 contains Gölcük, Aktaş, and Abant regions. Group 3 contains Sünnet, Karakiriş, and Sarıçal Mountains. Group 4 encompasses Gökçeler and Çiçekliyayla Mountains. The characteristic species *Centranthus longiflorus* Steven and *Astragalus lydius* Boiss. found in Groups 3 and 4. The characteristic species *Agrostis stolonifera* L. (Group 2) found only in Gölcük, Aktaş, Çiçekliyayla, and Abant. *Abies nordmanniana* Spach subsp. *bornmuelleriana* (Mattf.) Coode & Cullen characteristic species (Groups 1, 2, and 4) is known to prefer higher amounts of rainfall compared to pine species found in the rest of the areas. This species is absent in three of the areas; Sünnet, Karakiriş, and Sarıçal Mountains. These three areas occur in the southern parts of Bolu characterized with decreased precipitation.

The results obtained from DCA are shown in Figure 5. Only species composition was used to analyze 12 sites. The Eigen values of the Axis 1 and 2 were 0.26 and 0.13, respectively. DCA analysis resulted in three groups. The first cluster on the right of the graph comprises four sites (Yedigöller, Yaylacık, Semen and Bolu Mountains) occupying Northern parts of the area characterized by increased rainfall and mostly with broadleaf deciduous forests of *Fagus orientalis* Lipsky and *Carpinus betulus* L. The second cluster in the middle of the graph includes Abant, Aktaş, and Gölcük area. Third cluster on the left of the graph contains Sünnet, Sarıçal, Karakiriş, and Çiçekliyayla. These areas located on the southern slopes of the Koroğlu Mountain ranges. Finally, Gökçeler Mountain was placed separately in the upper left part of the graph. In UPGMA, there are two clusters and Gökçeler Mountain was placed separately (Figure 6). The first cluster contains Sarıçal, Karakiriş, Çiçekliyayla, and Sünnet areas. The same pattern is observed in DCA analysis. The second cluster comprises Yedigöller, Yaylacık, Abant, Gölcük, Aktaş, Bolu and Semen Mountains. In DCA we see further grouping within this cluster

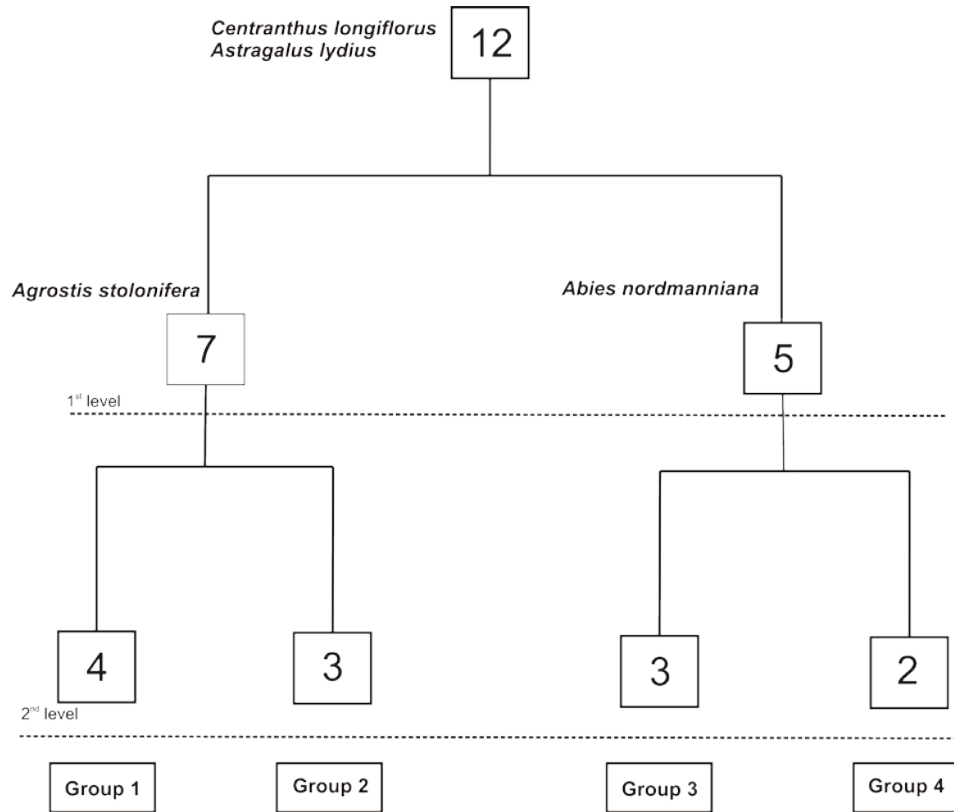


Figure 4. Dendrogram obtained from the TWINSPLAN analysis of 12 compared sites listed in Table 1

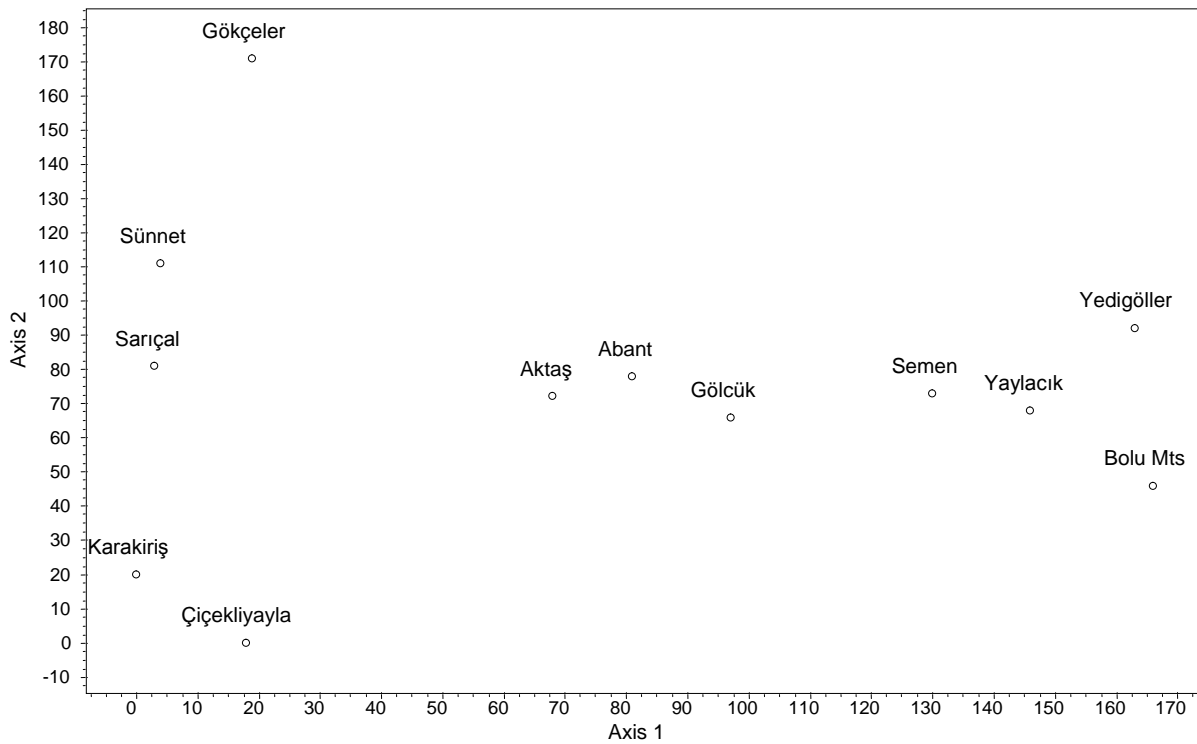


Figure 5. Detrended correspondence analysis (DCA) ordination of 12 sites listed in Table 1

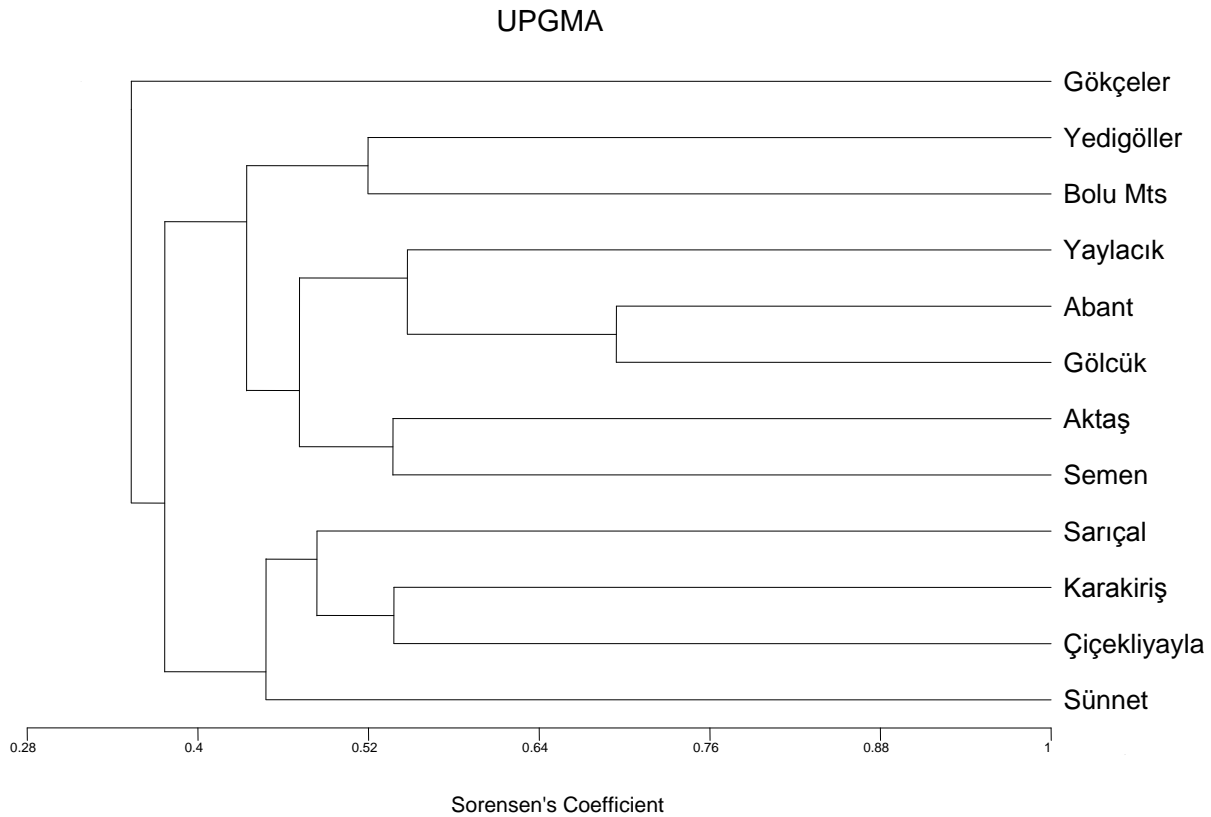


Figure 6. Dendrogram of UPGMA cluster analysis based on Sorensen's Coefficient

4. Conclusions

Surrounding of Lake Sünnet has the highest amount of Mediterranean elements among the compared areas. Parallel to this finding the richest families in the area were *Lamiaceae* and *Asteraceae* (both with 32 species). *Asteraceae* with approximately 25000 species is the largest dicotyledonous family of the world but *Lamiaceae* has only 6700 to 6870 species with the main concentration area being the Mediterranean region (Heywood, 2007; Mabberley, 1997). Third richest family of Sünnet area is *Fabaceae* with 30 species. This family is also the third largest family of the world with around 19000-19700 species (Heywood, 2007). *Fabaceae* and *Asteraceae* are both cosmopolitan families. We see *Asteraceae* among the largest three families except in Yedigöller National Park which is to a large extent covered by mesophytic forests. It is interesting that *Poaceae* another cosmopolitan family with 9500 species (Mabberley, 1997) is not found within the largest 10 family of Sünnet region and also in geographically closest region Sarıçal Mountains. Sünnet and Sarıçal Mountains share the same three richest families. The fourth richest family of Sünnet area is *Boraginaceae*, a family with main concentration areas in the Mediterranean region. In the other compared areas this family is either not included in the largest 10 family list or is near to the end of the list.

In terms of largest genera *Astragalus* is in the first order. This is the largest genus of Turkey with ca. 455 species and more than half of them are endemic. This genus is mainly found in Irano-Turanian phytogeographic region of Turkey (Duran and Aytac, 2005). *Salvia*, the largest genus of the *Lamiaceae* family is the third richest genus of Sünnet area. There are ca. 89 *Salvia* species in Turkey and half of them are endemic (Karabacak et al., 2009). South western Asia is one of the diversity centres of the genus (Tepe et al., 2006). *Centaurea* in the fourth order for Sünnet is one of the richest genera of Turkey with species number reaching to 195 (Köse et al., 2010). It is found mainly in the Mediterranean and Irano-Turanian regions and have an endemism ratio of 60% in Turkey (Uzunhisarcıklı et al., 2007).

Turkey has more than 3700 endemic taxa with an endemism ratio of 34.5% (Özhatay, 2002). On the other hand, average endemism ratio in European and NW Turkey is less than 10% and A3 Square where Sünnet and majority of the compared sites are located has 9.75% endemism ratio (Özhatay et al., 2005). Sünnet area with an endemism ratio of 10.8 is in the third order after Çiçekliyayla (15%), and Karakiriş (13.5%). Among the compared areas Gölcük has the lowest endemism ratio (3.5%) which occupies northern slopes of Köroğlu Mountains and dominantly covered by *Abies nordmanniana* forests. This area has high amount of Euro-Siberian elements. Yaylacık region has the highest amount of Euro-Siberians (36.3%) and very low rate of endemism 4.29%, too. Our data indicates that there is a negative relationship between percentages of Euro-Siberians and endemics. Of the 35 endemic species of Sünnet area more than

half (20 species) are Irano-Turanian elements, four species are Mediterranean, and only three species are Euxinian elements. It is known that Turkey's endemics are mainly from the Mediterranean and Irano-Turanian phytogeographical regions of the country (Ekim and Güner, 2000). Among the compared areas Karakiriş Mountain has the largest proportion of Irano-Turians. This mountain is situated on the border of Bolu and Ankara, occupies the transition zone between Euro-Siberian and Irano-Turanian phytogeographical region. Sarıçal (12.7%) and Çiçekliyayla Mountains (12.0%) also have high amount of Irano-Turians. Sünnet has 10.2% Irano-Turians. The rest of the areas have lower than 10% Irano-Turanian elements. There is a clear-cut difference between areas facing to northern and southern slopes of Koroğlu Mountains. The mountain ranges of Bolu reaching to 2499 m at Koroğlu peak prevent the moisture penetration from Black Sea.

DCA and UPGMA both analyses showed a very similar pattern of clustering for the compared sites. DCA analysis resulted in three groupings and Gökçeler Mountain was the deviating site from the three other groups. UPGMA cluster analysis also differentiates Gökçeler Mountain from the two other clusters. Dominant vegetation of Gökçeler Mountain is mixed forests of *Abies nordmanniana* Spach subsp. *bornmuelleriana* (Mattf.) Coode & Cullen together and *Pinus sylvestris* L. with *Juniperus communis* L. Mean annual temperature of the area is 7.6 °C and average temperature of the coldest month is -5.9°C. Therefore, the area has lower average temperatures than the other compared areas (Uluğ, 1999). In TWINSPLAN analysis Gökçeler Mountain grouped together with Çiçekliyayla Mountain which is the geographically closest area.

Aquatic and wetland habitats of the Lake Sünnet comprised less number of vascular plant species than the other wetlands of Bolu. Recent studies concerning other aquatic organisms in the Lake Sünnet also showed a lower species diversity compared to similar lakes. Findings of Külköylüoğlu et al. (2010) about Ostracoda (Crustacea) species in Lake Sünnet indicated that the numbers of species (9 living species) was lower than the average numbers of species (13.2) reported for other lakes in Turkey. This low species richness is explained by the changes in climate and precipitation regimes and due to human activities (Külköylüoğlu et al., 2010).

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Appendix 1. List of plants recorded from Sünnet Area (Bolu, Turkey).

PTERIDOPHYTA

Equisetaceae

Equisetum telmateia Ehrh.

Equisetum palustre L.

Equisetum arvense L.

Hypolepidaceae

Pteridium aquilinum (L.) Kuhn

GYMNOSPERMAE

Cupressaceae

Juniperus excelsa M.Bieb

Juniperus oxycedrus L. subsp. *oxycedrus*

Juniperus foetidissima Willd.

Pinaceae

Pinus nigra J.F.Arnold subsp. *nigra*

var. *caramanica* (Loudon) Businsky

ANGIOSPERMAE

Acanthaceae

**Acanthus hirsutus* Boiss.

Aceraceae

Acer hyrcanum Fisch & Mey.

Alismataceae

Alisma lanceolatum With.

Anacardiaceae

Pistacia terebinthus L. subsp. *terebinthus*

Rhus coriaria L.

Apiaceae

**Astrantia maxima* Pall.

subsp. *haradjianii* (Grintz.) Rech.

Bupleurum falcatum L. subsp. *cernuum* (Ten.) Arc.

**Eryngium bithynicum* Boiss.

Laser trilobum (L.) Borkh.

Physospermum cornubiense (L.) DC:

Pimpinella anthriscoides Boiss. var. *anthriscoides*

Sanicula europea L.

Seseli peucedanooides Koso-Pol.

Torilis japonica DC.

Turgenia latifolia (L.) Hoffm.

Apocynaceae

Vinca herbacea Waldst. & Kit.

Araliaceae

Hedera helix L.

Aristolochiaceae

Aristolochia pontica Lam.

Asteraceae

Achillea millefolium L. subsp. *pannonica* (Scheele) Hayek

Anthemis cretica L. subsp. *anatolica* (Boiss.) Grierson

**Anthemis fumariifolia* Boiss.

Bellis perennis L.

Centaurea solstitialis L. subsp. *solstitialis*

Centaurea urvillei DC. subsp. *urvillei*

Centaurea triumfettii All.

Centaurea thirkei Sch.Bip.

Centaurea virgata Lam.

**Cirsium lappaceum* Fisch.
subsp. *tenuilobum* (K.Koch) P.H.Davis & Parris

Crepis alpestris (Jacq.) Tausch

Doronicum orientale Hoffm.

Echinops ritro L.

**Hieracium beypazariense* Hub.-Mor.

Inula britannica L.

Jurinea consanguinea DC.

Jurinea mollis Rchb.

Lactuca saligna L.

Leontodon hispidus L. var. *hispidus*

Onopordum tauricum Willd.

Petasites hybridus (L.) Gaertner

Scariola viminea (L.) F.W.Schmidt

Scorzonera cana (C.A.Mey.) Hoffm. subsp. *cana*

Senecio vernalis Waldst. & Kit.

Tanacetum parthenium Sch.Bip.

Tanacetum armenum Sch.Bip.

Taraxacum serotinum Poir.

Taraxacum macrolepium Schischkin

Tragopogon coloratus C.A.Mey.

**Tripleurospermum hygrophilum* (Bornm.) Bornm.

Tussilago farfara L.

Xeranthemum annuum L.

Boraginaceae

**Alkanna orientalis* Boiss.
var. *leucantha* (Bornm.) Hub.-Mor.

Anchusa leptophylla Roem. & Schult. subsp. *leptophylla*

**Anchusa leptophylla* Roem. & Schult.
subsp. *incana* (Ledeb.) D.F.Chamb.

Anchusa azurea Mill. var. *azurea*

Brunnera orientalis I.M.Johnst.

Buglossoides arvensis (L.) I.M.Johnst.

Cerintho minor L. subsp. *auriculata* (Ten.) Domac

Cynoglossum montanum L.

Heliotropium europaeum L.

Lithospermum purpureoaeeruleum L.

**Moltkia aurea* Boiss.

Myosotis diminuta Grau

Myosotis alpestris F.W.Schmidt

Myosotis lithospermifolia Hornem.

Myosotis sicula Guss.

Neatostema apulum (L.) I.M.Johnst.

Onosma aucheranum DC.

Onosma tauricum Pall.

Brassicaceae

Aethionema arabicum (L.) Andrz.

Alyssum sibiricum Willd.

**Alyssum pateri* Nyár subsp. *pateri*

Arabis caucasica Willd. subsp. *caucasica*

Arabis turrita L.

**Aubrieta pinardii* Boiss.

Capsella bursa-pastoris (L.) Medik

Conringia orientalis (L.) Andrz.

Fibigia clypeata (L.) Medik

Iberis taurica DC.

Isatis buschiana Schischkin

Nasturtium officinale R.Br.

Thlaspi perfoliatum L.

Campanulaceae

Asyneuma limoniifolium (L.) Janch. subsp. *limoniifolium*

Campanula persicifolia L.

**Campanula lyrata* Lam. subsp. *lyrata*

Campanula rapunculoides L.
subsp. *cordifolia* (K.Koch) Damboldt

Legousia pentagonia Thell.

Caprifoliaceae

**Lonicera caucasica* Pallas subsp. *orientalis* (Lam.) Chamb.

Lonicera etrusca Santi var. *hispidula* Boiss.

Sambucus ebulus L.

Sambucus nigra L.

Viburnum lantana L.

Viburnum opulus L.

Caryophyllaceae

Dianthus calocephalus Boiss.

**Dianthus balansae* Boiss.

**Dianthus cibrarius* Clem.

Holosteum marginatum C.A.Mey.

**Minuartia erythrosepala* (Boiss.) Hand.-Mazz.
var. *cappadocica* (Boiss.) McNeill

**Saponaria chlorifolia* (Poir.) G.Kunze

Silene swertiifolia Boiss.

Silene cappadocica Boiss.

Silene dichotoma Ehrh. subsp. *dichotoma*

Cistaceae

Cistus creticus L.

Cistus laurifolius L.

Helianthemum nummularium (L.) Miller subsp. *nummularium*

Helianthemum canum (L.) Baumg.

Convolvulaceae

Calystegia silvatica Griseb.

Convolvulus scammonia L.

**Convolvulus galaticus* Rost ex Choisy

Cornaceae

Cornus sanguinea L. subsp. *australis* (C.A.Mey.) Jav.

Cornus mas L.

Corylaceae

Corylus avellana L. var. *avellana*

Crassulaceae

Sedum album L.

Sedum sartorianum Boiss. subsp. *sartorianum*

Cucurbitaceae

Bryonia alba L.

Cyperaceae

Carex hirta L.

Carex panicea L.

Carex distachya Desf. subsp. *distachya*

Carex otrubae Podp.

Eleocharis palustris (L.) Roem. & Schult.

Scirpus sylvaticus L.

Dioscoreaceae

Tamus communis L. subsp. *communis*

Dipsacaceae

Cephalaria aristata K.Koch

Dipsacus laciniatus L.

Pterocephalus plumosus Coult.

Scabiosa columbaria L. subsp. *ochroleuca* (L.) Coulter
var. *webbiana* (Don) V.A.Matthews

Ericaceae

Arbutus andrachne L.

Euphorbiaceae

Euphorbia helioscopia L.

Euphorbia lathyris L.

Fabaceae

Anthyllis vulneraria L. subsp. *praepropera* (Kerner) Bornm.

Astragalus ponticus Pall.

Astragalus densifolius Lam.

**Astragalus gilvus* Boiss.
Astragalus angustifolius Lam. subsp. *angustifolius*
var. *angustifolius*

Astragalus caucasicus Pall.

**Astragalus lydius* Boiss.

Astragalus ornithopodioides Lam.

Chamaecytisus hirsutus Link

Cicer montbretii Jaub. & Spach

Colutea cilicica Boiss.

Coronilla varia L.

Coronilla scorpioides W.D.J.Koch

Genista lydia Boiss. var. *lydia*

Genista sessilifolia DC.

Lathyrus cicera L.

**Lathyrus tukhtensis* Czecz.

Lathyrus laxiflorus Kuntze subsp. *laxiflorus*

Ononis arvensis L.

Scorpiurus muricatus L. var. *subvillosus* (L.) Fiori

Trifolium fragiferum L. var. *pulchellum* Lange

Trifolium repens L. var. *repens*

Trifolium pratense L. var. *pratense*

Vicia peregrina L.

Vicia hybrida L.

Vicia pannonica Crantz var. *purpurascens* (DC.) Ser.

Vicia sativa L. subsp. *sativa*

Vicia sibthorpii Boiss.

Vicia hirsuta (L.) Gray

Vicia cassubica L.

Fagaceae

Quercus petraea (Mattuschka) Liebl. subsp. *petraea*

Quercus pubescens Willd.

Gentianaceae

Centaurium erythraea Rafn. subsp. *rumelicum* (Velen) Melderis

Geraniaceae

Erodium acaule Bech. & Thell.

Geranium lucidum L.

**Geranium ibericum* Cav. subsp. *jubatum* (Hand.-Mazz.) P.H.Davis

Globulariaceae

Globularia trichosantha Fisch. & C.A.Mey.

Globularia cordifolia L.

Haloragidaceae

Myriophyllum spicatum L.

Iridaceae

**Crocus ancyrensis* Maw

Crocus olivieri J.Gay. subsp. *olivieri*

Gladiolus italicus Miller.

**Iris purpureobracteata* B.Mathew & T.Baytop

Lamiaceae

Acinos rotundifolius Pers.

Ajuga chamaepitys (L.) Schreb. subsp. *chia* (Schreb.) Arcangeli

Lamium purpureum L. subsp. *purpureum*

Lamium amplexicaule L.

Lamium garganicum L. subsp. *laevigatum* Arcangeli

Lycopus europaeus L.

Melissa officinalis L. subsp. *officinalis*

Mentha pulegium L.

Nepeta cataria L.

Origanum sipyleum L.

Origanum vulgare L. subsp. *hirtum* (Link) Ietsw.

Origanum vulgare L. subsp. *vulgare*

**Phlomis armeniaca* Willd.

Phlomis pungens Willd. var. *pungens*

**Phlomis russeliana* Lag. ex Benth.

Salvia tomentosa Mill.

Salvia verticillata L. subsp. *verticillata*

**Salvia cyanescens* Boiss. & Balansa

Salvia sclarea L.

Salvia forskahlei L.

Salvia tomentosa Mill.

Scutellaria albida L. subsp. *albida*

Scutellaria orientalis L. subsp. *pinnatifida* Edmondson

Sideritis lanata L.

Sideritis montana L. subsp. *montana*

**Sideritis amasiaca* Bornm.

Stachys annua L. subsp. *cilicica* (Boiss.) R.Bhattacharjee

Teucrium polium L.

Teucrium montanum L.

Teucrium scordium L. subsp. *scordium*

Thymbra spicata L. var. *spicata*

Liliaceae

Allium ampeloprasum L.

Allium orientale Boiss.

Allium pallens L. subsp. *pallens*

Asparagus officinalis L.

Colchicum bivonae Guss.

Gagea granatelli (Parl.) Parl.

Gagea villosa (M.Bieb.) Duby var. *villosa*

Muscari armeniacum Leichtlin ex Baker

Muscari comosum (L.) Mill.

Ornithogalum fimbriatum Willd.

Ornithogalum comosum L.

Linaceae

Linum hirsutum L. subsp. *anatolicum* (Boiss.) Hayek

**Linum flavum* L. subsp. *scabrinerve* (P.H.Davis) P.H.Davis

Loranthaceae

Viscum album L. subsp. *saustriacum* (Wiesb.) Vollman

Lythraceae

Lythrum salicaria L.

Malvaceae

Malva neglecta Wallr.

Morinaceae

Morina persica L. var. *persica*

Oleaceae

Jasminum fruticans L.

Ligustrum vulgare L.

Onagraceae

Epilobium hirsutum L.

Epilobium palustre L.

Orchidaceae

Cephalanthera damasonium (Miller) Druce

Cephalanthera rubra (L.) Rich.

Comperia comperiana (Steven) Asch. & Graebn.

Ophrys mammosa Desf.

Orchis purpurea Hudson

Orchis pallens L.

Paeoniaceae

Paeonia mascula (L.) Mill.

subsp. *arietina* (G.Anderson) Cullen & Heywood

Paeonia peregrina Mill.

Papaveraceae

Chelidonium majus L.

Corydalis solida (L.) Swartz subsp. *solida*

Fumaria officinalis L.

Fumaria asepalae Boiss.

Papaver fugax Poir. var. *fugax*

Papaver rhoeas L.

Plantaginaceae

Plantago lanceolata L.

Plumbaginaceae

**Acantholimon acerosum* (Willd.) Boiss. var. *brachystachyum* Boiss.

Plumbago europaea L.

Poaceae

Alopecurus aequalis Sobol.

Brachypodium sylvaticum P.Beauv.

Bromus sterilis L.

Hordeum murinum L. subsp. *murinum*

Pennisetum orientale Rich.

Poa bulbosa L.

Vulpia fasciculata (Forssk.) Fritsch

Polygalaceae

Polygala anatolica Boiss. & Heldr.

Polygala vulgaris L.

Polygonaceae

Polygonum amphibium L.

Polygonum arenastrum Bor.

Rumex crispus L.

Potamogetonaceae

Potamogeton natans L.

Primulaceae

Anagallis foemina Miller

Androsace maxima L.

Cyclamen intaminatum (Meikle) Grey-Wilson

Cyclamen coum Miller var. *coum*

Lysimachia vulgaris L.

Primula vulgaris Huds. subsp. *vulgaris*

Ranunculaceae

Adonis flammae Jacq.

Clematis vitalba L.

Clematis viticella L.

**Delphinium venulosum* Boiss.

Helleborus orientalis Lam.

Nigella arvensis L. var. *glauca* Boiss.

Ranunculus repens L.

Ranunculus reuterianus Boiss.

Ranunculus arvensis L.

Resedaceae

Reseda lutea L. var. *lutea*

Rhamnaceae

Paliurus spina-christii Mill.

**Rhamnus thymifolius* Bornm.

Rosaceae

Cerasus avium Moench

Cotoneaster nummularius Fisch. & C.A.Mey.

Crataegus orientalis M.Bieb. var. *orientalis*

Fragaria vesca L.

Potentilla rupestris L.

Potentilla reptans L.

Potentilla supina L.

Prunus spinosa L. subsp. *dasyphylla* (Schur) Domin

Prunus x domestica L.

Pyrus elaeagnifolia Pall.

Rosa canina L.

Sanguisorba minor Scop. subsp. *muricata* (Spach) Briq.

Sorbus umbellata Fritsch var. *umbellata*

Rubiaceae

Asperula arvensis L.

Asperula involucrata Wahlenb.

Cruciata taurica (Pall.) Ehrend.

Galium incanum Sibth. & Sm. subsp. *elatius* (Boiss.) Ehrend.

Galium tricornutum Dandy

Galium spurium L. subsp. *spurium*

Rutaceae

Haplophyllum thesioides (Fisch. ex DC.) G.Don

Salicaceae

Populus nigra L. subsp. *nigra*

Salix alba L.

Salix pentandra L.

Scrophulariaceae

**Digitalis lamarckii* Ivanina

Digitalis ferruginea L. subsp. *ferruginea*

Rhinanthus angustifolius C.C.Gmel. subsp. *grandiflorus* (Wallr.) D.A.Webb

Verbascum orientale (L.) All.

Veronica anagallis-aquatica L.

Veronica pectinata L. subsp. *pectinata*

Veronica persica Poir.

Solanaceae

Hyoscyamus niger L.

Solanum dulcamara L.

Thymelaeaceae

Daphne pontica L.

Typhaceae

Typha shuttleworthii W.Koch & Sonder

Valerianaceae

Centranthus longiflorus Steven

Valeriana dioscoridis Sm.

Valerianella pumila (L.) DC.

Valerianella carinata Lois.

Valerianella turgiga (Stev.) Betcke

Violaceae

Viola odorata L.

Viola tricolor L.

Viola arvensis Murray

Viola canina L.

Viola alba Besser