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Geographic distribution of Turkish Oaks

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Abstract: Distribution of Turkish *Quercus* L. has a crucial value since Turkey is a transition place between Europe and Asia and located at the meeting point of three phytogeographical regions. To compare the diversity of species and to find the distribution patterns of oaks, species richness of the most current distributions were studied. Relationships of phytogeographical regions and presence of the Anatolian Diagonal relevant to oak distributions were also investigated. Analyses were performed on Davis' grid square system. The highest richness of *Quercus* species were found at north-western Turkey which were located in the meeting place of Asia and Europe. The lowest richness scores were found at eastern and south-eastern Anatolia. Moreover, latitude, longitude and altitude histograms showed a correlation with species richness. However, the presence of Anatolian Diagonal is partially supported.

Additional key words: Species richness, cluster analysis, principal component analysis, *Quercus*, Turkey

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Introduction

Turkey is located in a considerably important region among Balkan, Caucasus, and the Middle-East. The country is an important transition place between Europe and Asia. It has been under the influence of numerous climatic regions and three phytogeographic regions due to its geomorphologic structure.

The genus *Quercus* L. belongs to the Fagaceae family. Oaks appear frequently as dominant species in the Mediterranean area of the Northern hemisphere (Manos et al. 2001). According to Govaerts and Frodin (1998), an approximate number of 531 species and natural hybrids compose oaks. The group is considered to be one of the highest economic value wooden plants around the world. *Quercus* is a dominant tree in central and east Anatolia (İnal 1953; Kayacık 1977). There are 24 *Quercus* taxa in Turkey. Twenty-three of them were reported in Flora of Turkey and East Aegean Islands (Hedge and Yaltırık 1982) within three sections; *Quercus* L., *Ilex* Loudon., and *Cerris* Loudon. Recently, a new taxon, *Q. trajona* P.B. Webb subsp. *yaltirikii* Ziel., Petrova and D. Tomazewski was added to *Cerris* section (Zielinski et al. 2006).

Country is composed of Anatolian and Thrace peninsulas where the three phytogeographic regions intersects (Davis 1971); Euro-Siberian, Irano-Turanian and Mediterranean (Fig. 1). Each region contains sub groups; Irano-Turanian region is divided into Central Anatolia, East Anatolia and Mesopotamia. Mediterranean region is divided into west Anatolia, Taurus and Amanus districts. Euro-Siberian region is divided into Euxine province and Colchic sector. Due to cultivation, the type of phytogeography of inland Thrace could not be determined accurately. According to Davis (1971), this region is "probably Central European/Balkan province of Euro-Siberian region". However, the region is included in the Mediterranean region in Çolak and Rotherham (2006). Beside the phytogeographic regions, there is another well known issue; "Anatolian Diagonal" (Fig. 1) which separates a number of plants and insect species into western

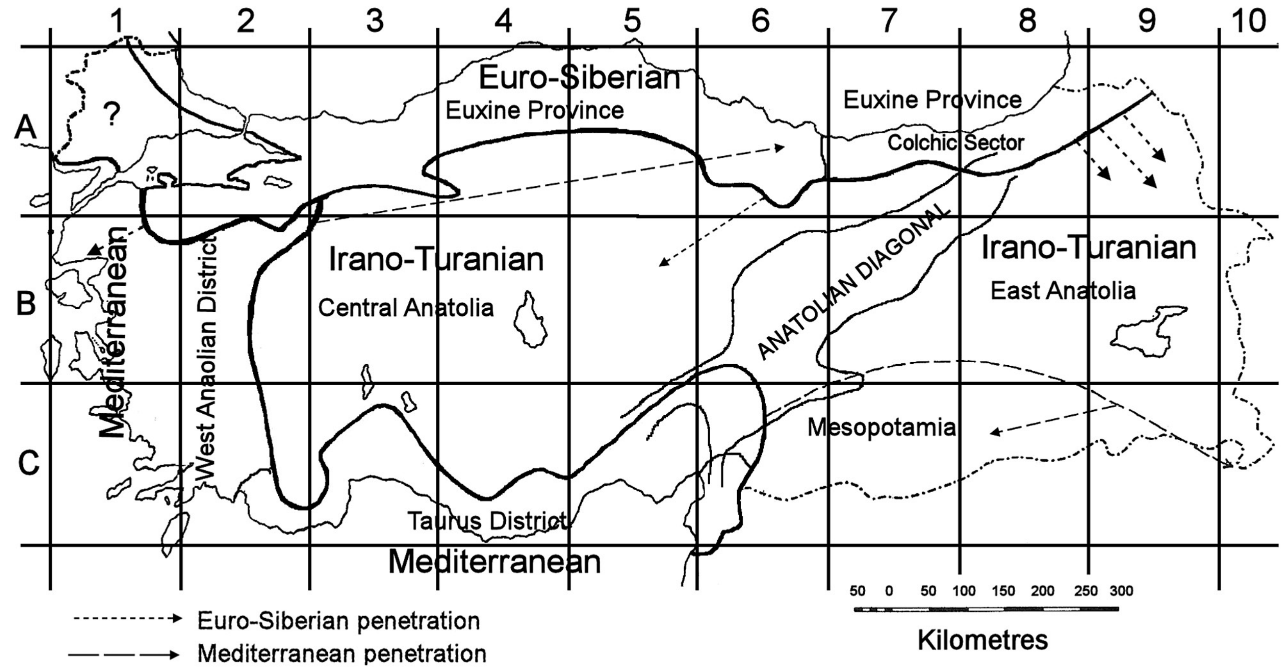

Fig. 1. Phytogeographical areas of Turkey after Davis (1971)

and eastern Anatolia (Davis 1971; Ekim and Güner 1986; Çıplak and Demirsoy 1991; Çıplak et al.1993).

Distribution of today's plant vegetation was affected by the climatic conditions at the beginning of Holocene. About 8,000 years ago, today's plant zones occurred in Anatolia (Atalay 1992; 1994; and 1995; Bottema and Woldring 1984; van Zeist and Bottema 1991). During the last glacial period, coastal plants such as *Pinus sylvestris* and *Picea* sp. which grow in cold climate in eastern Black Sea gradually moved up. Their place occupied by the broad leaved forests such as *Quercus* and *Fagus* that are living in the shaded coastal areas. At the end of the Tertiary and during the Pleistocene, the Hircano-Euxine area was a refuge area for *Zelkova* Spach, *Pterocarya* Kunth, *Diospyros* L., *Albizia* Durazz. and many other species. This area is also considered to be a differentiation center for some plants such as *Quercus* L., *Sorbus* L. and *Acer* L. (Zohary 1973).

Turkey was divided into 29 grid-squares geographically by Davis (1965–1988) – the author of "*Flora of Turkey and East Aegean Islands*". Each grid covers 2° latitude and longitude. Distribution of *Quercus* taxa is addressed according to these grids including A1to C10 (Table 1).

In this study, distributions of oak species over grid squares were analyzed by using GIS and multivariate analyzing techniques. Grid-wise species richness was calculated to measure and compare the diversity of species. Distribution patterns of oaks were explained by Cluster Analysis and Principal Component Analysis. Relationships among the distribution of taxa according to phytogeographical regions of Turkey were investigated. Latitude, longitude and altitude histograms based on *Quercus* localities were also used to analyze their status. Additionally, our expectation from this study is to provide a ground for further GIS analysis, exploration and conservation of the *Quercus* taxa in Turkey.

Table 1. *Quercus* sections and their distributions, according to Flora of Turkey

Species	Species Distribution
SECTION *QUERCUS* L.	
Q. pontica C. Koch	A8
Q. robur L.	A1-2, A4-5, B3-9, C4-5, C9-10
Q. hartwissiana Steven	A1-8, B2, B7-8
Q. macranthera Fisch & Mey. ex Hohen	A3-9, B4-8
Q. frainetto Ten.	A1-3, B1-2, C1
Q. petraea Liebl	A1-9, B1-3, B6-9, C5-6, C10
Q. vulcanica Kotschy	B3, C3-4
Q. infectoria Olivier	A1-7, C9-10
Q. pubescens Willd.	A1-7, B1-7, C1-5
Q. virgiliana Ten.	A1, A3-5
SECTION *CERRIS* LOUDON	
Q. cerris L.	A1-6, B1-7, C1-6
Q. ithaburensis Decne. subsp. *macrolepis* (Kotschy) Hedge & Yalt.	A1-2, A4, B1-4, C1-5
Q. brantii Lindley	B6-9, C6-10
Q. libani Olivier	B6-7, C7
Q. trajona P. B. Webb	A1-2, B1-3, C2-5
SECTION *ILEX* LOUDON	
Q. ilex L.	A2-3, A5-6, B1, C1
Q. aucheri Jaub & Spach	C1-3
Q. coccifera L.	A1-4, A6-7, B1-4, C1-4

Methods

A total number of 3293 localities were obtained from three different sources:

1. Georeferencing of 247 localities from the "*Flora of Turkey and East Aegean Islands*" (Hedge and Yaltırık 1982) were obtained using Google Earth by means of GPS coordinates.
2. GPS coordinates of 575 map points without localities were extracted from distribution maps of both "*Flora of Turkey and the East Aegean Islands*" (Hedge and Yaltırık 1982) and "*Oaks of Turkey*" (Yaltırık 1984).
3. Between 2001 and 2009, 2471 specimens were recorded from 288 localities by GPS device during the expeditions. To avoid bias in sampling process, every grid square was divided into quarters. Localities were obtained during the trips from one quarter to another, for every grid square.

Species Richness: Its simplicity, capability of measuring taxonomic diversity and wide utilization directed us to use species richness method (Gaston 1996). Species richness based on grid squares was computed by DIVA-GIS version 7.1.

Cluster Analysis: Euclidean distance measure was used to calculate dissimilarities between the grid squares of studied taxa. In order to calculate a distance matrix over the dissimilarities of species among the grids, the distribution data were coded in binary format. A dendrogram was generated by average linkage classification method based on the dissimilarity matrix. Cluster Analysis was performed by NTSYSpc software version 2.1.

Principal Component Analysis: To reveal ordination of taxa composition per grid cell more clearly, Principal Component Analysis (PCA) was used. PCA was performed by STATISTICA software version 6. Multivariate ordination focuses here on the co-variation of distributions.

Localities of *Quercus* were plotted as histograms in order to show the geographical distributions by longitude, latitude and altitude.

Results

Species richness

Species richness was calculated according to the diversity of the oak species based on the grid squares. The species richness was mapped on Figure 2 by intensity of gray color. Grid squares with the same level of gray color contained the same number of taxa. However, the taxa involved in those grids may have different compositions. According to the map, A1, A2, and A3 squares showed the richest composition with the number of species ranging from 13 to 15. Grid square B10 contained no oak species. A9, C7 and C8 squares represented the least number of taxa ranging 1–3. Species richness was found to increase from South-Eastern to North-Western Turkey with a break in oak distribution through B4 and B5 grids.

Map points on Fig. 2 showed frequency of localities. Although the species richness was not based on the number of localities, there seemed to be a correlation between them.

Distribution of each oak species was compared with Anatolian Diagonal (Davis 1971). Since the *Ilex* Section was only found at the Mediterranean region and coastal areas, their occurrences were not compared with the Anatolian Diagonal. In the *Quercus* Section, some of the infraspecific taxa showed tendency in distribution with respect to Diagonal. However, since this study was based on the species level rather than infraspecific taxa, this issue was not considered. Distribution of species in *Cerris* Section showed a considerable relation with Anatolian Diagonal. Such as, *Quercus brantii* Lindley and *Q. libani* Olivier distributed eastern part of the diagonal. On the contrary, *Q. ithaburensis* Decne. subsp. *macrolepis* (Kotschy) Hedge & Yalt., *Q. cerris* L. and *Q. trojana* P. B. Webb. ranged west part of the diagonal.

Cluster analysis

In the dendrogram (Fig. 3) resulted by cluster analysis, A1-A5 grid squares were separated from all oth-

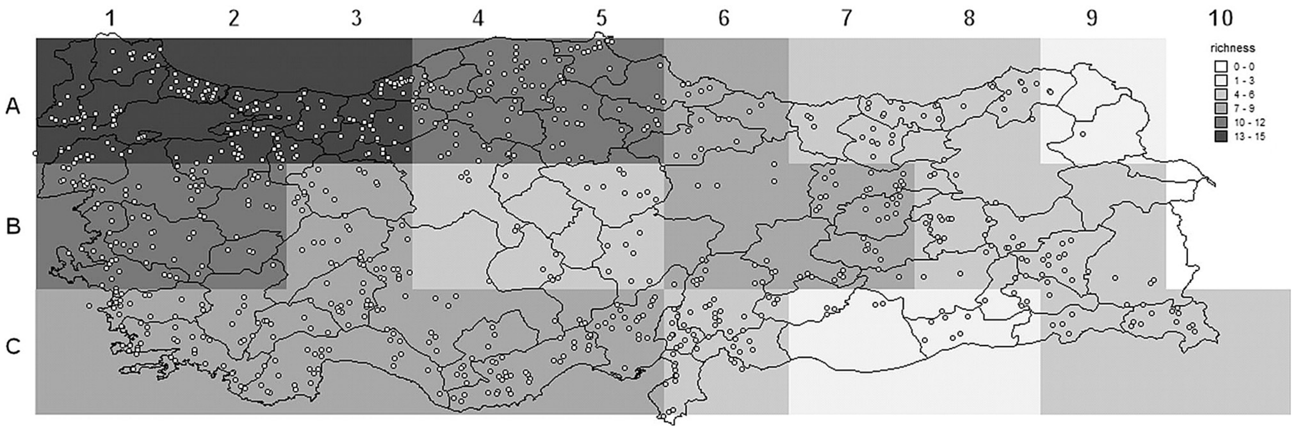

Fig. 2. *Quercus* species richness based on the Davis's grid square system

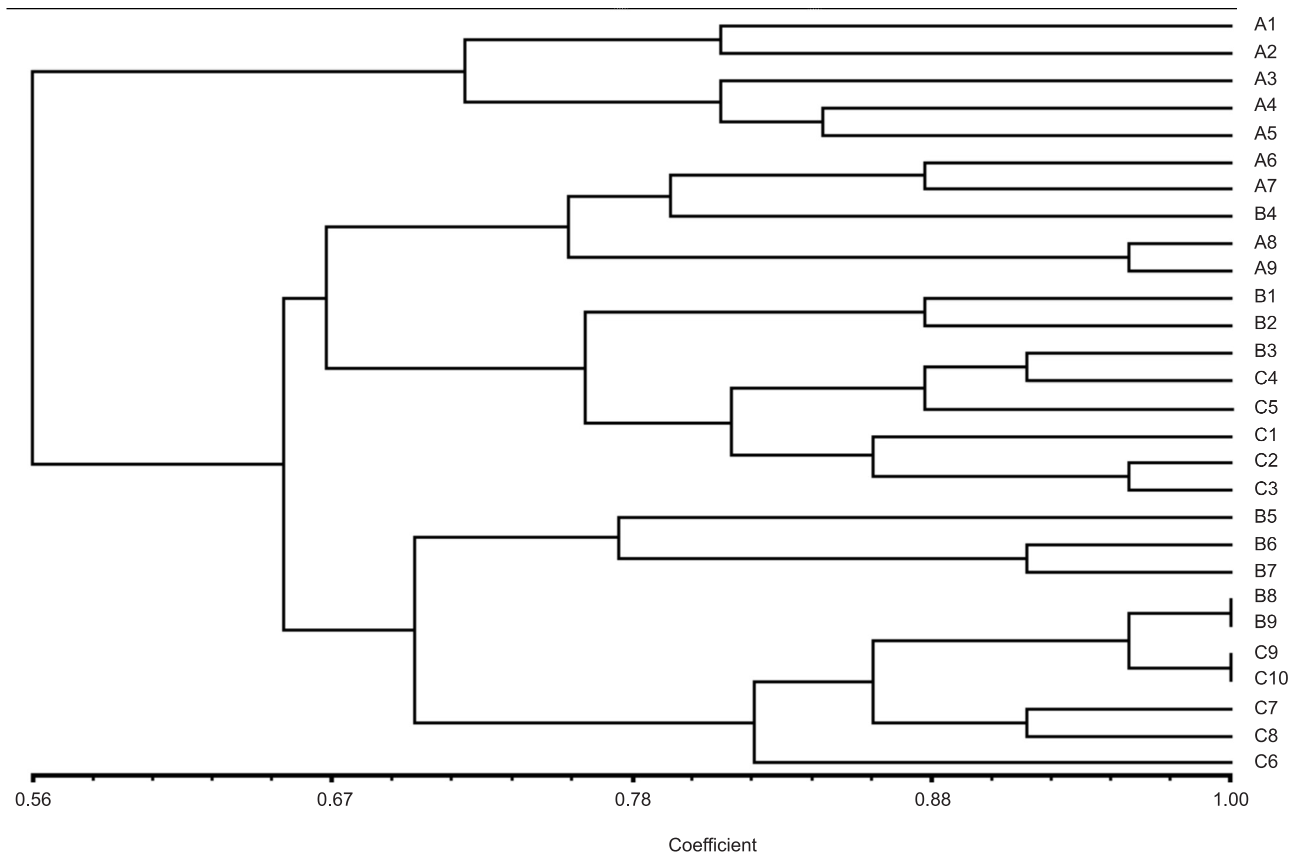

Fig. 3. Dendrogram showing the similarities of grid squares based on richness of *Quercus* species distributions

ers by forming a group of Euro-Siberian cluster with only half of its members. Remaining grids were divided into two clusters of B5-9, C6-10 and B1-4, C1-5, A6-9. Grids A6-9, part of Euro-Siberian region, were located within the same branch with grids belong to Mediterranean region. Below this node, B5-7 group was separated from the B8-9, C6-10, and also B1-2 was separated from the B3, C1-5 group.

Principal component analysis

In the results of Principal Component Analysis (Fig. 4), at first glance, three introgressive groups were identified clearly comparing to results of Cluster Analysis. According to factor 2, grids belong to Irano-Turanian region and Euro-Siberian region were presented at the upper part of the plot while grids belong to Mediterranean region were located at the lower part. Irano-Turanian and Euro-Siberian related grids were separated through vertical axis by factor 1. Grid C6 was plotted between the groups of Irano-Turanian and Mediterranean. However, A8 and A9 grids were found within the Irano-Turanian group.

Geographic analyses of sampled *Quercus* taxa

In the histogram based on longitudes (Fig. 5) the highest number of observations (35%) was found be-

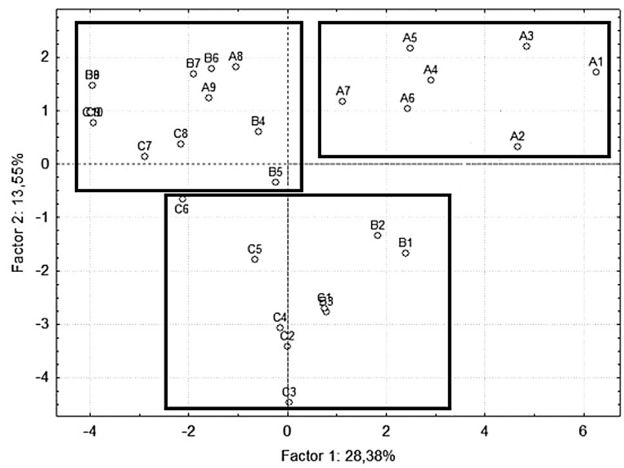

Fig. 4. Results of Principal Component Analysis of *Quercus* species distributions

tween 26°N and 30 °N longitudes and the remaining gradually reduced from 31°N to 44°N. This finding has showed a correlation with the increase in richness through the western part of the country. Histogram of observations by latitudes followed a bimodal distribution (Fig. 6). There was a similar pattern between 36°E– 39 °E and 40°E – 44 °E latitudes. Between these similar distributed peaks, less number of observations was found usually around 39 °E latitude.

Distribution of oaks was typically between 0 and 2000 m altitudes over Turkey (Fig. 7). There were

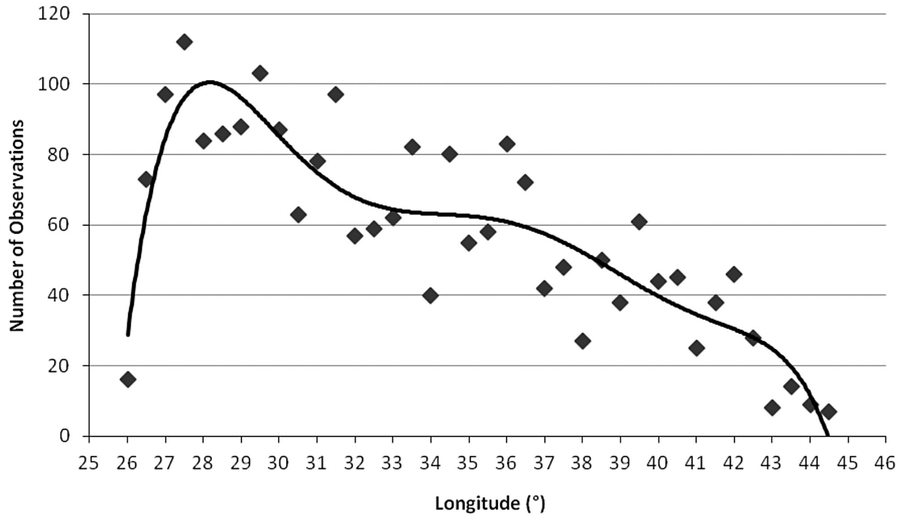

Fig. 5. Distribution of *Quercus* sampling by longitude. Each population was represented once without consideration of *Quercus* species number

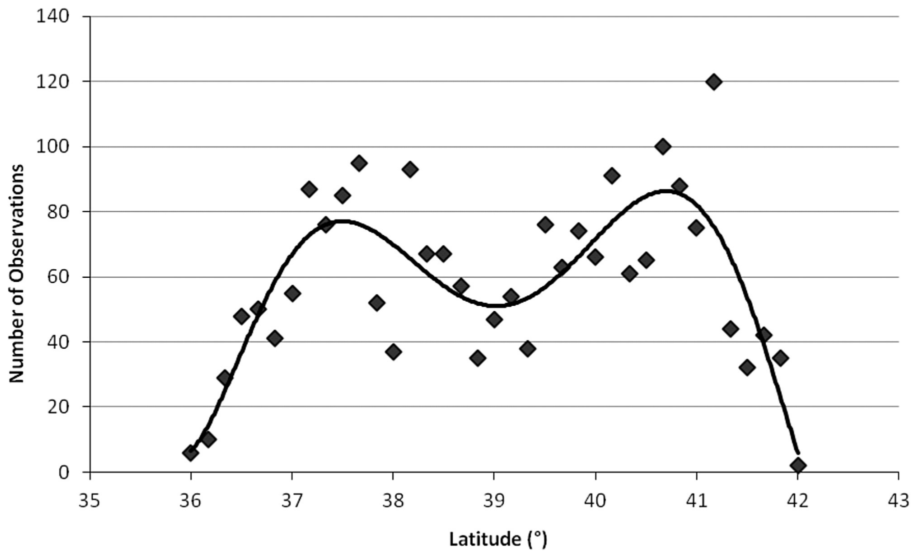

Fig. 6. Distribution of *Quercus* sampling by latitude. Each population was represented once without consideration of *Quercus* species number

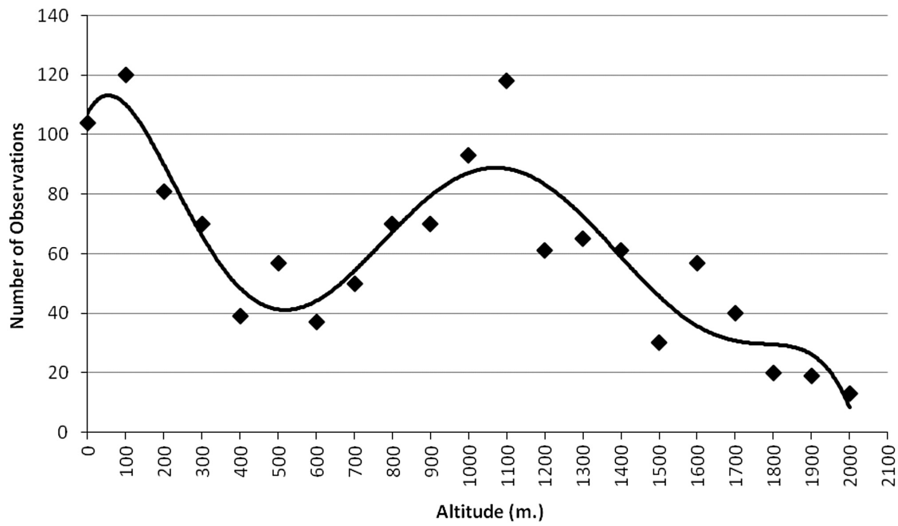

Fig. 7. Distribution of *Quercus* sampling by altitude. Each population was represented once without consideration of *Quercus* species number

two peaks within the graph; the first peak was around 200 m, and the second peak was around 1100 m altitude. However, number of observations was decreasing between elevations of 400 and 650 m. On the other hand, while the elevation increased from 650 to 1100 m, the number of observations also increased and between 1100 and 2000 m the number of observations was gradually decreased.

Discussion and conclusions

The geographical distributions of Turkish oaks with 18 species were analyzed using Geographic Information System technique based on more than three thousand georeferences. Maximum richness score was found in the three grid squares of A1-A3 (Fig. 2), which ranged between 13–15 different species. This region is located at the north-western Turkey. One of the main reasons for this region to be rich is being a transition zone between Europe and Asia. Apart from its historical importance, this region is important from a phytogeographical point of view, since the "oriental" component of the Balkan flora has reached southeast Europe via the Thracian plain while some species have only reached Thrace and not pass further through the west (Magyari et al. 2008; Kavgacı et al. 2010). Anatolia – forming a bridge between southern Europe and southwestern Asia – has apparently served as a migration route (Davis 1971) facilitating the penetration of Asiatic floral elements into south-eastern Europe. Another reason is that the A1-A3 grid squares also in a place where the two different phytogeographical regions (Mediterranean and Euro-Siberian) overlaps. The results obtained from the analysis indicate that these three squares consist of 15 oak taxa out of 18. Three species that are not found in these regions are usually either endemic, restricted to quite narrow areas, or belong to the Irano-Turanian phytogeographic origin.

The other important finding from this map is the decrease in the species richness of the *Quercus* taxa gradually from north-west through south-east of Turkey. This might be the result of geomorphologic structure of country. The eastern region is well known with its high mountains, especially the eastern part of the Anatolian Diagonal (Fig. 1). Therefore, the least number of species (1–3), would be found in grid squares A9, C7 and C8. Beside an increase in the elevation at the eastern part of the country, human impact over the vegetation might be the other reason for this region to be least diverse (Akman 1995; Çolak and Rotherham 2006). Collecting localities of *Quercus* species has supported the finding that the number of observations is decreased in the high mountain region 1100–2000 m (Fig. 7). Altitude histogram formed two peaks: one of them was around 200 m, distributed near coastal region of country; the other peak was seen around 1100 m where highland of the country covers high coastal inner mountains and plateaus. Therefore, it can be concluded that those grids A1, A2 and A3 regions are plotted in these two peaks. However, the number of observations is decreased around 400–600 m altitude (Fig. 7). Anthropogenic degradation could be a reason for this decreasing. Moreover, histogram based on longitudes also shows a decrease from 31°N to 44 °N (Fig. 5). This supports the increase in richness of *Quercus* species in the western region of country. There may be two main reasons for the high numbers of observations on the west: first, there would be more researchers studying on oaks and sampling them on the western part than the rest of the country. Second, the high mountains, heavy grazing and forest destruction were caused less sampling on the east part of Turkey. Histogram of latitude (Fig. 6) is displayed a bimodal distribution around 36° E – 39 °E and 40° E – 44° E latitudes. These areas are covered with rich and wide forest. The less number of observations was found around 39° E latitude. Most parts of these areas are the inner Anatolia where contain anthropogenic steppe.

The dendrogram (Fig. 3) and the plot (Fig. 4) are constructed based on the distribution data of the oak species with respect to the grid squares. Although both analyses are based on the same data, results are significantly different from each other. This is because only two principal components can be shown in the plot and less than half of the data was explained by this way. However, the result of Principal Component Analysis is closer to the expectations. Because, it reveals ordination of the oak distribution more clearly than those of Cluster Analysis. Since the results of PCA indicate the occurrence of three phytogeographical regions within the grid squares. On the contrary, inconvenient result of Cluster Analysis may possibly be caused by presence of an irrelevant part in the dataset since the dendrogram is constructed by analyses of all available data.

A few *Quercus* species show a distribution relevant to the phytogeography and the Anatolian Diagonal at subspecies level (Davis 1971; Güner and Ekim 1986). *Quercus robur* subsp. *robur* scattered on the western side of the diagonal whereas subsp. *pedunculiflora* Menitsky found at the eastern side. Similarly, *Q. petraea* subsp. *pinnatiloba* shows a distribution on the east of the diagonal while the two other subsp. (subsp. *iberica* Krassiln. and subsp. *petraea*) distributed western part of the diagonal. However, exclusion of the infraspecific ranks from the studied materials resulted in combination of subspecies data into single species. This causes loss of distribution information relevant to diagonal and produces some uninformative or irrelevant part within the data.

In resulting dendrogram of Cluster Analysis, a group of grid squares (A1-5) creates a separate cluster of only half of the Euro-Siberian region refers to Euxine section with one missing grid square, A6, at the east. Below this node, two clusters appear one with the members of Irano-Turanian (B5-C6) and the other with members from Mediterranean together with Euro-Siberian Colchic section (A6-C3). The first cluster seems meaningful by its constitution where all grids belong to Irano-Turanian region. This also constitutes the Eastern Irano-Turanian part which is the passage through Anatolia (Davis 1971). Mediterranean region grids located within the Euro-Siberian region Colchic section and formed the second cluster. Davis (1971) stated that there might be Mediterranean penetrations through the eastern part of Euro-Siberian region and Euro-Siberian penetrations through the Irano-Turanian region in Central Anatolian district (Fig. 1). These penetrations also explain occurrence of B4 within the A7-9 cluster. Similarly, Mediterranean region cluster composed of B1-3 and C1-5 is located next to Euro-Siberian region cluster for the same reason.

On the other hand, grid squares were scattered over the PCA plot to form three introgressive groups indicating the phytogeographical regions approximately. Euro-Siberian and Irano-Turanian groups are located on the upper part and Mediterranean group is located below. Although there is a significant range between the centers of each group, some grid squares show introgression (A8, A9, and C6). Eastern part of the Euro-Siberian region (Colchic section) shows a very narrow zone along the coast of Black sea (Fig. 1). Only half of the lands are occupied by Euro-Siberian elements. Afterwards, this region decreases through the east, the rest are occupied by Irano-Turanian elements (Davis 1971). Thus, positioning of the A8 and A9 within the Irano-Turanian group is reasonable (Fig. 4). Grid square of C6 is in the transition zone between Mediterranean region and Mesopotamian sub-region of Irano-Turanian region. Therefore, the place of C6 in the PCA plot would normally be within the two phytogeographic regions.

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References

Atalay İ. 1992. The Paleogeography of the Near East from Late Pleistocene to Early Holocene and Human Impact. Ege University Press, İzmir.

Atalay İ. 1994. Türkiye Vejetasyon Coğrafyası. Ege Coğrafya Dergisi 2: 31–47.

Atalay İ. 1995. Effects of the climatic changes on the vegetation in the Near East. Bulletin Egyptian Geography Society 68: 157–177.

Bottema S., Woldring H. 1984. Late Quaternary vegetation and climate of southwestern Turkey. Paleohistoria 26: 123–149.

Çıplak B., Demirsoy A. 1991. Arguvan (Malatya) ve çevresinde Orthoptera (*Insecta*) faunasının incelenmesi. [The study of Orthoptera fauna on Arguvan (Malatia) und its environment]. Turkish Journal of Zoology 15: 98–114.

Çıplak B., Demirsoy A., Bozcuk A. N. 1993. Distribution in Orthoptera in relation to the Anatolian Diagonal in Turkey. Articulata 8: 1–20.

Çolak H. A., Rotherham I. D. 2006. A review of the forest vegetation of Turkey: its status past and present and its future conservation. Biology & Environment: Proceedings of the Royal Irish Academy 106: 343–354.

Davis P. H. 1971. Distribution patterns in Anatolia with particular reference to endemism. In Plant life of South West Asia. Davis P. H., Harper P. C., Hedge I. C. (eds.) Botanical Society of Edinburgh, Edinburgh, pp. 15–27.

Davis P. H. 1965–1988. Flora of Turkey and the East Aegean Islands, Vol: 1–10, Edinburgh University Press, Edinburgh.

Ekim T., Güner A. 1986. The Anatolian Diagonal: fact or fiction? Proceedings of the Royal Society of Edinburgh. Section B. Biological Sciences 89: 69–77.

Gaston K. J. 1996. Species richness: measure and measurement. In: Biodiversity, a biology of numbers and difference. Gaston K. J. (ed.) Blackwell Science, London, UK, pp. 77–13.

Govaerts R., Frodin D. G. 1998. World Checklist and Bibliography of Fagales (Betulaceae, Corylaceae, Fagaceae, and Ticodendraceae). The Royal Botanic Gardens, Kew.

Hedge I. C., Yaltırık F. 1982. *Quercus* L. In: Flora of Turkey and the East Aegean Islands Vol: 7. Davis P. H (ed.). Edinburgh University Press, Edinburgh pp. 659–683.

İnal S. 1953. Palamut Meşesi Ormanları, Coğrafi Yayılışı, Ekonomik Önemi ve Amenajman Esasları.Yeni Cezaevi Matbaası, Ankara.

Kavgacı A., Carni A., Tecimen B., Özalp G. 2010. Diversity and ecological differentiation of oak forests in NW Thrace (Turkey). Archives of Biological Science Belgrade 62: 705–718.

Kayacık H. 1977. Türkiye Meşe Ormanlarına Toplu Bir Bakış ve Bunların Geleceği Hakkında Düşünceler. İstanbul Üniversitesi Orman Fakültesi Dergisi 27: 32–40.

Manos P.S., Zhou Z., Cannon C.H. 2001. Systematics of Fagaceae: Phylogenetic Tests of Reproductive Trait Evolution. International Journal of Plant Science 162: 1361–1379.

Magyari E. K., Chapman J. C., Gaydarska B., Marinova E., Deli T., Huntly J. P., Allen J. R. M., Huntley B. 2008. The ‘oriental’ component of the Balkan flora: evidence of presence of the Thracian Plain during Weichselian late-glacial. Journal of Biogeography 35: 865–883.

Yaltırık F. 1984. Türkiye Meşeleri Teşhis Kilavuzu, 3–7. Yenilik Basımevi, İstanbul.

Zeist W. V., Bottema S. 1991. Late Quarternary Vegetation of the Near East. Beiheftezum Tübinger Atlas Des Vorderen Orients Reihe (Naturwissenschaften) Nr. 18, Verlag, Wiebaden.

Zielinski J., Petrova A., Tomaszewski D. 2006. *Quercus trojana* subsp. *yaltirikii* (Fagaceae), a new subspecies from southern Turkey. Willdenowia 36: 845–849.

Zohary M. 1973. Geobotanic Foundations of the Middle East. Stuttgart Germany: Gustav Fischer Verlag, Vol: 1 pp. 110–123.