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Vegetation Cover and Climatic Conditions of Southwest Anatolia according to the Pollen Records during Early to Mid-Holocene

Çetin Şenkul[1], Mehmet Ali Özdemir[1], Warren J. Eastwood[2]

[1]Afyon Kocatepe University, Faculty of Sciences and Arts, Department of Geography, 03200, Afyonkarahisar, Turkey
[2]School of Geography, Earth and Environmental Sciences, University of Birmingham, Edgbaston. Birmingham. B15 2TT. UK.
e-posta: cetinsenkul@gmail.com

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Pollen; Vegetation; Climate Change; Early Holocene; Southwest Anatolia.

Abstract

In this study, pollen records collected from Southwest Anatolia belonging to early to mid-Holocene Period (10000 / 6000 ^{14}C years BP) reinterpretation was carried out with the biomization based on plant functional type. It was discovered that the climate conditions of ~9000 ^{14}C yr BP were colder and dryer than today's conditions while the forest vegetation in the mountainous area interior region of the Mediterranean coastal belt 50-60% of the total area. In the earlier of the Holocene (~ 9000 ^{14}C yr BP), the interior Mediterranean the climate conditions were milder, that is colder and more semi humid/arid in comparison with the Younger Dryas period (~ 11000/10000 ^{14}C yr BP) while steppe vegetation prevailed. In the final stages at the ends of early Holocene (~ 7000 to 6000 ^{14}C yr BP) forest prevailed in a major part of Southwest Anatolia due to the impact of changing climate conditions. These results show that, unlike the other regions of Turkey, the change of the flora of Southwest Anatolia paralleled the climatic changes during the early Holocene time interval and that the steppe flora transposed into the forest pattern without delay.

Polen Kayıtlarına Göre Güneybatı Anadolu'nun Erken Holosen Dönemi Bitki Örtüsü ve İklim Koşulları

Anahtar kelimeler
Polen; Bitki Örtüsü; İklim Değişimi; Erken Holosen; Güneybatı Anadolu.

Özet

Güneybatı Anadolu, Avrupa ve Ortadoğu ölçeğinde bitki sığınma alanları içerisinde en önemli bölgelerden biridir. Bölgenin Erken Holosen'e ait palinolojik kayıtlarının dağılışı ve yeterliliği bu veriler üzerinden vejetasyon örtüsü ve iklim koşullarına ilişkin genel bir değerlendirme yapılmasına olanak sağlamaktadır. Bu nedenle Erken Holosen'deki (GÖ. 10000 / 6000 ^{14}C yılları) bitki örtüsü ve iklim koşulları, fonksiyonel bitki tipine dayalı biomizasyon metoduyla yeniden yorumlanmıştır. GÖ. ~9000 ^{14}C yılında'da iklim koşullarının günümüzden daha soğuk ve kurak olduğu, orman vejetasyonunun ise Akdeniz kıyı kuşağında ve kıyı gerisindeki dağlık alanda %50-60'ı bulduğu saptanmıştır. Akdeniz ardında ve iç kesimlerde ise Holosen'in ilk bölümünde (GÖ. ~9000 ^{14}C yılı) Genç Dryas dönemine (GÖ. ~ 11000/10000 ^{14}C yılı) kıyasla daha zayıf olmak kaydıyla soğuk ve yarı nemli/yarı kurak iklim koşulları ile step vejetasyonu egemen olmuştur. Erken Holosen'in son bölümünde ise (GÖ. ~ 6000 ^{14}C yılı) Güneybatı Anadolu genelinde değişen iklim koşulları ile ilişkili olarak büyük ölçüde orman örtüsü hakimdir. Elde edilen sonuçlar, Güneybatı Anadolu'nun bitki örtüsü ve ikliminin tüm lokasyonlar için genellenecek kadar tekdüze olmadığını göstermiştir. Bu sonuçlar; Türkiye'nin diğer bölgelerinden farklı olarak Güneybatı Anadolu'da, Erken Holosen boyunca vejetasyon örtüsünün değişen iklime paralel olarak ve bir gecikme göstermeden step türü bitkilerden orman örtüsüne geçtiğini göstermektedir.

1. Introduction

The most important determinant of the ambient changes, which took place during the glacial and interglacial periods in the Quaternary, is undoubtedly the climate. In addition, climate change has been the fundamental reason for changes in vegetation patterns and biological diversity (Medail and Diadema, 2009; Allen et al., 2010). During the end of the last cold period of the intermediate period (Younger Dryas 11000-10000 ^{14}C yr BP), climate and vegetation pattern changes

started and continued throughout the 4000 year in the early Holocene period, major ambient changes such as soil formation and faunal migrations had taken place (Kutzbach et al., 1998; Prentice et al., 2000; Roberts, 2002; Kotthoff et al., 2008; Turvey, 2009). This period had a major impact on the proliferation of plants in refuge areas, in the formation and development of present day vegetation (Brewer et al., 2002; Taberlet and Cheddadi, 2002; Cheddadi et al., 2006). Thus the period (10000 – 6000 ^{14}C yr BP) revealed the domination of tree species in the vegetation pattern which is one of the major changes in world's natural history.

Among European and Middle Eastern plant refuge areas, Southwest Anatolia is one of the most important locations. Because well documented pollen diagrams taken from different points in this region (van Zeist et al., 1975; Bottema and Woldring, 1984; Yaşar, 1994; Eastwood, 1997; Rossignol-Strict, 1999) in which hold a light to the changes in the early Holocene vegetation pattern. Vegetation reconstruction carried out through the utilization of pollen data explains the climate conditions as well as enables mapping the direction of the mobility ratio between biomes and the taxonomy of individual plants in Europe and the Middle East (Brewer et al., 2002; Taberlet and Cheddadi, 2002; Cheddadi et al., 2006).

Although there is sufficient research material for early Holocene period flora within Southwest Anatolia boundaries on a local scale, there are no regional assessments for the reconstruction of paleo-environmental conditions. Since the relationship between the establishment of the vegetation pattern for this period and its development phase and climate conditions are unknown, it was deemed necessary to choose the objective of this paper.

2. Study Area - Material and Method

The research work was started by separating the accessible early Holocene pollen registrations for 8 locations in Southwest Anatolia according to their locations and assessing them into 2 vegetation regions in accordance with contemporary climate conditions (Table 1; Figure 1). Later, *Pinus, Artemisia,* Chenopodiaceae*, Juniperus, Cedrus, Quercus* and *Olea* pollen records were selected as foreseen by the biomization method based on plant functional type (PFT) (Prentice et al., 1992; Prentice and Webb, 1998; Prentice et al., 2000; Cramer, 2002) by taking into consideration both the fact that the species had common features and were widespread and characterized by different temperature and precipitation conditions (Olson et al., 1983; Prentice and Sykes, 1995; de Noblet et al., 1996; Haxeltine et al., 1996; Kutzbach et al., 1998; Cheddadi et al., 2001; Otto et al., 2002; Sitch et al., 2003). Finally, the model study was interpreted accordingly.

Pinus, *Artemisia* and Chenopodiaceae are cosmopolitan species growing naturally in Southwest Anatolia. Thus, they appear in all vegetation regions. Although these three taxa/pollen types have a similar hardness in greater abundance summer draughts, because of their need for moisture, *Pinus* and *Artemisia* are more profuse in areas with more winter precipitation than Chenopodiaceae (Singh et al., 1973; Moslimany, 1990). *Juniperus* and *Cedrus,* which are characterized by cool and humid environments, are coniferous tree plants (Günal, 1997). Both species have Mediterranean phytogeographical characteristics. For this reason, while *Cedrus* is capable of growing in Southwest Anatolia, especially in the humid areas, *Juniperus* prefers to grow in more arid areas. At the same time, tree species such as *Quercus* and *Olea*, which prefer a hot climate, also have a high tolerance for winter temperatures (Prentice et al., 1996). These two species are the leading hot environment indicators used in vegetation and climate reconstruction (Rossignol-Strick, 1993; 1995; 1999).

Table 1. Locations of pollen records selected from Southwest Anatolia.

No	Location	Elevation (m a.s.l.)	Vegetation regions	References
1	Aegean Sea	0 m	Mediterranean	Yaşar, 1994
2	Mediterranean Sea	0 m	Mediterranean	Rossignol-Strict, 1999.
3	Avlan Lake	1043 m	Mediterranean Mountain Region	Bottema and Woldring, 1984
4	Söğüt Lake	1400 m	Mediterranean Mountain Region	Van Zeist et al. 1975
5	Gölhisar Lake	1000 m	Mediterranean Interior Region	Eastwood, 1997.
6	Pınarbaşı Lake	980 m	Mediterranean Interior Region	Bottema and Woldring, 1984
7	Beyşehir Lake	1120 m	Mediterranean Interior Region	Van Zeist et al. 1975
8	Karamık Marsh	1000 m	Mediterranean Interior Region	Van Zeist et al. 1975

Figure 1. Digital elevation model and selected pollen record locations in Southwest Anatolia.

3. RESULTS

3.1. Mediterranean-Mediterranean Mountain Region

Pollen data pertaining to the Aegean Sea (Yaşar, 1994), show that the early Holocene (9000 ^{14}C yr BP) vegetation pattern was consistent with 40% Arboreal Pollen (AP), while the dominant tree species were *Quercus* (20%) and *Pinus* (10%) (Figure 2). Other species which reflect cool and hot environmental conditions (*Cedrus, Juniperus* and *Olea*) are virtually nonexistent. Herbaceous vegetation consisting of 40% Chenopodiaceae (Non-Arboreal Pollen; NAP, ~ % 60) is dominant (Figure 3). These correlations show that cold and arid environmental conditions were moreprevailing in the western part of Southwest Anatolia during the early Holocene period than they are today.

After the 3000 year period within early Holocene Age between 9000 and 6000 ^{14}C yr BP together with changing ambient conditions, decreasing NAP ratios in the Aegean Sea perimeter were substituted with 60% AP (Figure 2). The fact that a major part of the vegetation pattern consisted of *Pinus* (45%) and *Quercus* (15%) had declined during this period shows that a major climax forest cover had developed in the region. Pollen records for the Mediterranean (Rossignol-Strict, 1999), ~9000 ^{14}C yr BP show that AP was 60 %. The dominant species within AP were *Quercus* (30%) followed by *Pinus* (5%) and other tree

species (25%) (Figure 2). The major part of NAP consists of species such as Chenopodiaceae (7%), *Plantago lanceolata,* Cistaceae and Cichoriaceae (Figure 3).

While *Quercus* values increase to 48% within AP values which increase to 80% in 6000 BP in the Mediterranean, *Pinus* (10%) is an increasing AP value. This situation in the vegetation pattern reveals that even during the period when human impact was not reflected in the pollen records, approximately 20% of the vegetation pattern on the Mediterranean coast region consisted of an herbaceous and brush cover.

Pollen data for Söğüt Lake in the Southwest Anatolian mountain zone (van Zeist et al., 1975), 9000^{14}C yr BP NAP ratio ~80%, the ratio of *Artemisia* and Chenopodiaceae reached ~ 50% (Figure 3). AP, on the other hand, consists of *Pinus* (~7%), *Quercus* (6%) and *Juniperus* (3%). These data show that in the early part of the early Holocene period, the forest cover of the mountain zone had not yet fully developed.

The AP values of 6000 ^{14}C yr BP in the vicinity of Söğüt have increased in a major way in comparison with 9000 ^{14}C yr BP and reached 85%. The dominant tree species during this period were *Quercus* (35%), *Juniperus* (25%) and *Pinus* (20%). On the other hand, the ratio of *Artemisia* and Chenopodiaceae within the NAP was 15%. These data show that at the end of the early Holocene period, the vegetation pattern of the region consisted mostly of a forest cover and climate changes had occurred which had resulted in a major increase in precipitation values.

The pollen data for Avlan Lake (Bottema and Woldring, 1984); within ~9000^{14}C yr BP 70% AP was mainly represented by *Cedrus* (37%) and *Pinus* 30% which had the highest ratios (Figure 2). Also, even though the representation was at minimal level during this time period, *Quercus* (1%) and *Juniperus* (1%) were among the observed species. The NAP ratio which was 30 % included *Artemisia* and Chenopodiaceae at a rate of ~7% (Figure 3).

AP existence was observed at the high ratio of 6000 ^{14}C yr BP 85%. During this period, the dominant species within the AP was *Pinus* (65%) followed by *Cedrus* (25%) and *Quercus* (2%). Chenopodiaceae (4%) and *Artemisia* (1%) formed a major part of NAP. This situation in the vegetation pattern with a ~6000 ^{14}C yr BP value for the region in general, shows that the climate conditions were similar to the current Mediterranean climate.

3.2. Mediterranean Interior Region

Pollen data for Gölhisar Lake in the Mediterranean interior vegetation area, within an AP of (Eastwood, 1997) ~9000 ^{14}C yr BP 50%, *Pinus* with a ratio of 40% had the major share. In addition, *Quercus* (8%) and *Juniperus* (2%) were among other species observed within this time interval (Figure 4). The NAP ratio which was 40 % included a minimal ratio of *Artemisia* and Chenopodiaceae, while species such as Poaceae, Lactuceae had a more prolific ratio (Figure 5).

The ratio of AP for the Gölhisar pollen data, ~6000 ^{14}C yr BP, went as high as 90%. With 65 % *Pinus* had the largest share within the AP, while *Quercus* (20%), *Cedrus* (3%) and *Juniperus* (% 2) were among other observed species. During this period, *Artemisia* together with Chenopodiaceae, Cerealia, Gramineae, Lactuceae were among observed species within the NAP species. Similarly to the other locations, ~6000 ^{14}C yr BP reveals that the temperature and humidity conditions of this vegetation area were suitable values for forest vegetation.

Pınarbaşı, which is another location in the Mediterranean interior area, (Bottema and Woldring, 1984) within a 60 % AP value of ~9000 ^{14}C yr BP and a ratio of 50% of *Pinus* and 5% *Cedrus* ratio had a similar vegetation pattern to the one in Gölhisar (Figure 4). *Artemisia* and Chenopodiaceae formed a major part of the 40 % NAP.

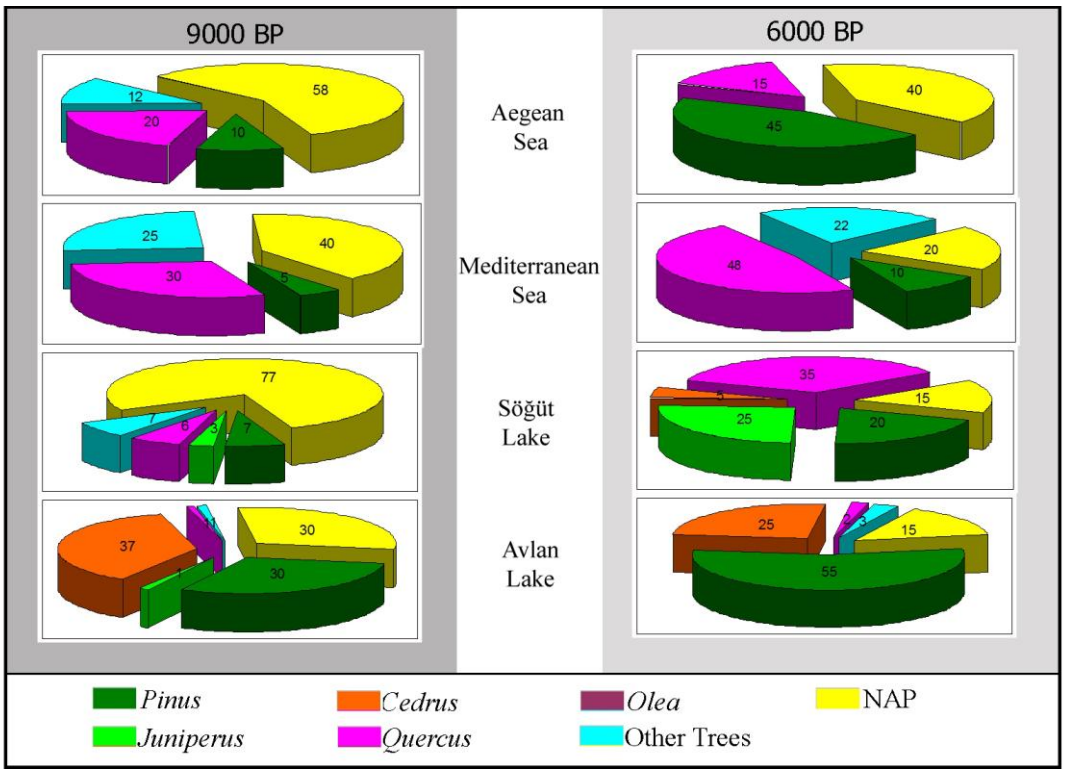

Figure 2. The vegetation pattern distribution of the Mediterranean and Mediterranean mountain vegetation zones 9000 and 6000 ^{14}C yr BP in Southwest Anatolia.

The AP values for Pınarbaşı, ~6000 ^{14}C yr BP increased in a major rate and reached 95%. During this period, the dominant tree species was *Pinus* (80%) followed by *Cedrus* (13%). On the other hand, *Artemisia* and Chenopodiaceae were species observed within the receding NAP. The pollen data for both locations situated in the Mediterranean interior area show that the climate conditions in the region had reached optimum level.

The pollen data for Karamık Marsh (van Zeist et al., 1975), 9000 ^{14}C yr BP, show that 55% of the surrounding vegetation consisted of NAP and that the ratios of *Artemisia* and Chenopodiaceae were around 20% (Figure 4). During this period the AP ratio was 45% while the dominant species were *Pinus* (20%), *Cedrus* (20%), *and Quercus* (3%). This distribution of the vegetation pattern shows that cold and semi-arid conditions prevailed during early Holocene environment.

A major increase occurred in Karamık between 9000-6000 ^{14}C yr BP the ratios and AP reaching 95%. The dominant tree species within the vegetation pattern were *Cedrus* with 60 %, while the *Pinus* ratio reached to 25 % (Figure 4). In addition, *Abies* and *Betula* were among other species to be found in the environment (van Zeist et al., 1975). The increase of AP ratios in a similar way in other locations in Southwest Anatolia is a reflection of the climatic improvements. During this period, the NAP ratio decreased to 5%. This change in the vegetation cover shows that the cold semi-arid conditions had been replaced by cool-humid conditions at around 6000 ^{14}C yr BP.

The pollen data for Beyşehir Lake, which is another location in the interior region of Southwest Anatolia (van Zeist et al., 1975) consists of 25% AP values for 9000 ^{14}C yr BP ^{14}C and *Pinus* (10%) *Cedrus* (8% *)* and *Quercus* (5%) (Figure 4). The dominant species within the 75% NAP consist of *Artemisia,* Chenopodiaceae, *Polygonum,* Gramineae and *Matricari*.

AP values at ~6000 ^{14}C yr BP increased in a major way and reached 80%. The highest ratio within the AP consisted of *Pinus* (50 %) followed by *Cedrus* (30%). The ratios of Artemisia and Chenopodiaceae in the vegetation pattern receded in line with the decrease of the NAP ratio.

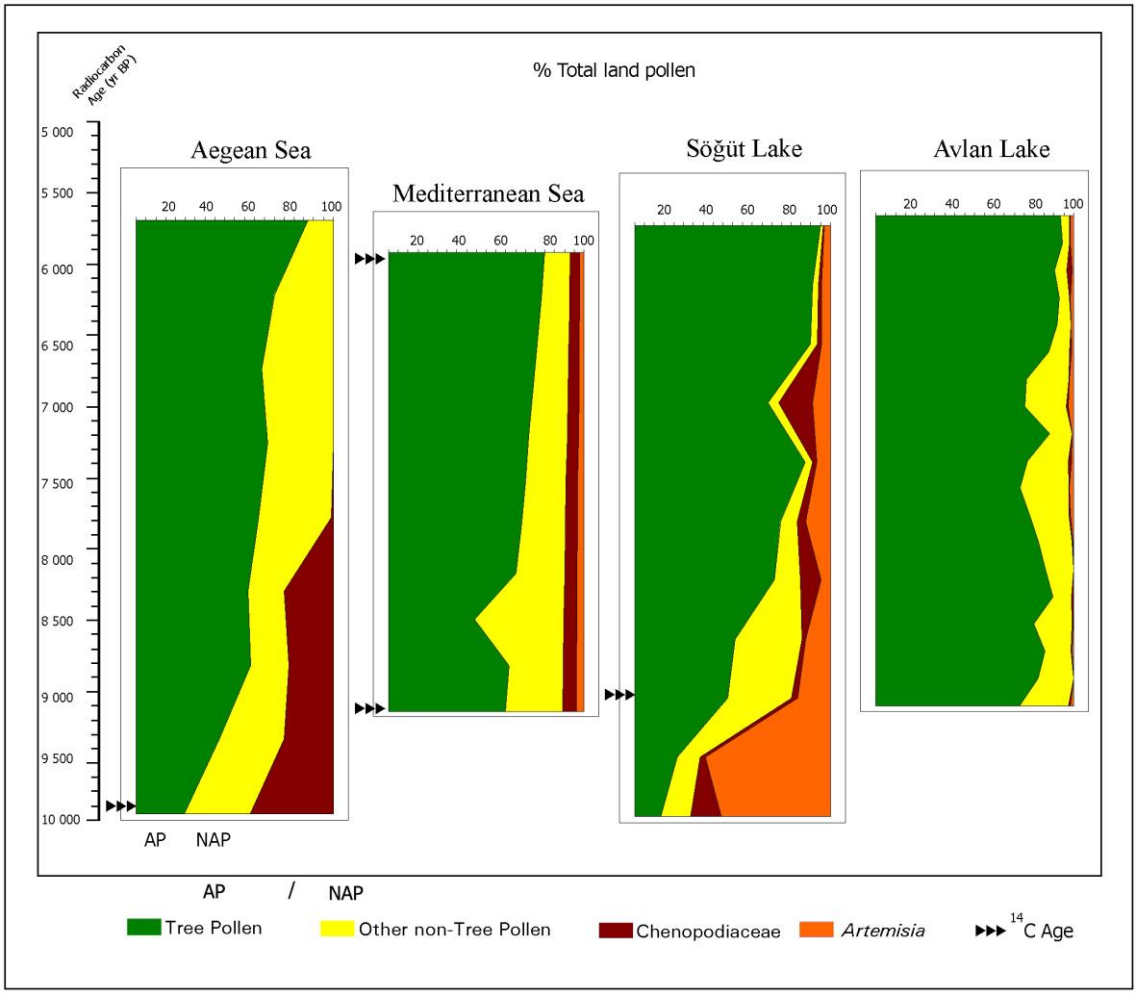

Figure 3. The pollen diagrams of the Mediterranean and Mediterranean mountain vegetation zones 9000 to 6000 ^{14}C yr BP in Southwest Anatolia.

4. DISCUSSION

4.1. 10000 to 7000 ^{14}C yr BP

Some pollen records (Söğüt, Beyşehir and Karamık) pertaining to the period 11000-10000 ^{14}C yr BP was characterized by cold and arid climate conditions of the Younger Dryas period, and have been discovered (van Zeist et al., 1975; Bottema, 1995). During this period the forest areas had not only prolapsed further south but had been confined to refuge areas. The pollen data pertaining to Southwest Anatolia reveal that during the Younger Drayas period the AP ratio had formed only 10% of the total pollen ratio and the remaining vegetation pattern consisted of herbaceous plants which reflected the arid and cold climate conditions (van Zeist et al., 1975; Bottema, 1995).

When the Younger Dryas period (~10000 ^{14}C yr BP) ended abruptly, major changes occurred in the climate of the Mediterranean Watershed. The climate of the region from cold and arid conditions into warm and humid climate conditions in an interval of less than a thousand years (Peyron et al., 1998; Robinson et al., 2006; Eastwood et al., 2007). 2The summer temperatures in present day Southwest Anatolia ensued at the same time in the Mediterranean Watershed, Europe and many parts of the world during the first 1000 year period of the Holocene (Yaşar, 1994; Rossignol-Strict, 1995;Kallel et al., 2004; Magri et al., 2004).

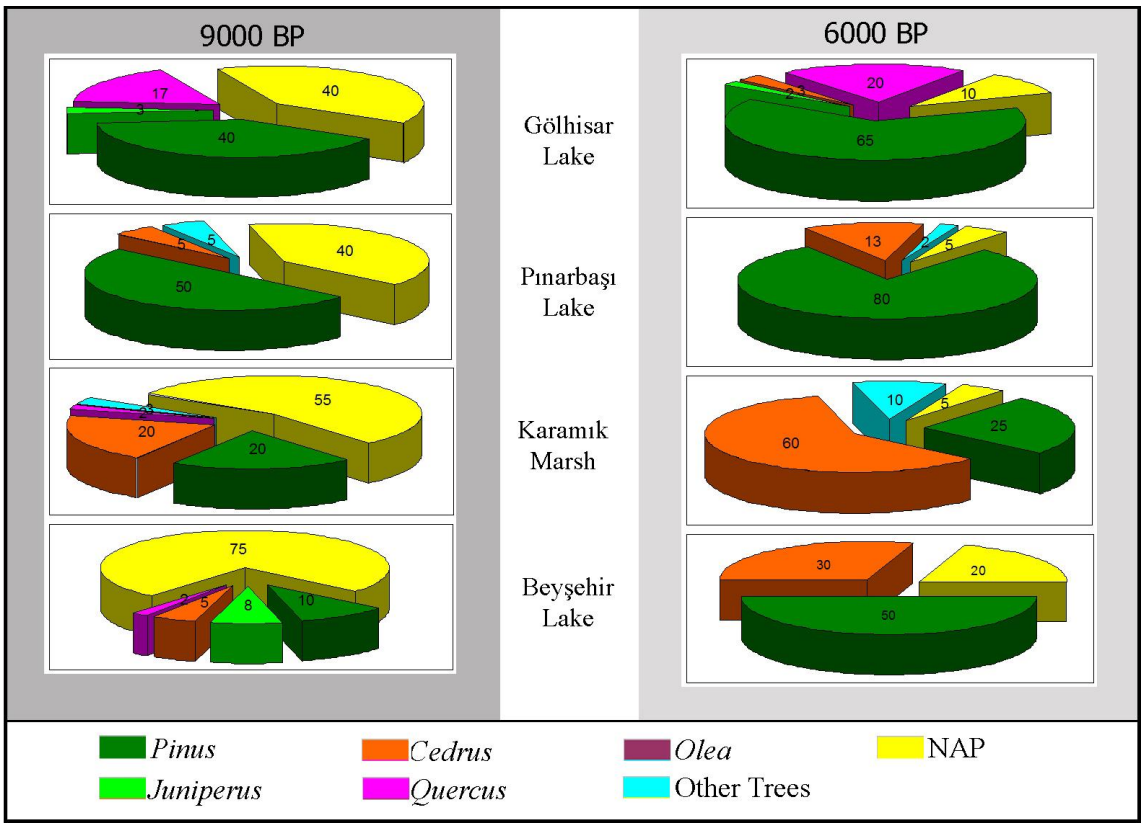

Figure 4. The vegetation pattern distribution of the Mediterranean and Mediterranean mountain vegetation zones 9000 and 6000 ^{14}C yr BP in Southwest Anatolia.

The other proxy data with pollen records (Bar-Matthews et al., 1997; Rossignol-Strick, 1999; Emeis et al., 2000; Robinson et al., 2006; Eastwood et al., 2007; Roberts et al., 2008) indicate environmental conditions of Southwest Anatolia of early Holocene period. One of them is made by Eastwood et al., (2007). This study focuses on environmental conditions of southwest Anatolia; low (depleted) isotope values which are derived from Gölhisar indicate that climate conditions of earliest Holocene (10000–8200 ^{14}C yr BP), were drier conditions than at present. During the early to mid-Holocene (8200–5000 ^{14}C yr BP) more humidity conditions with arid and humid oscillations in isotop values have been determined. Roberts et al. (2008) has obtained that the humidity in early Holocene was more than present by modeling stable isotope data from the lakes in Mediterranean. Highest moisture and mildest winters in early Holocene have been determined by using sapropels records in Mediterranean near the cost of Southwest Anatolia (Rossignol-Strick, 1999). Emeis et al., (2000) determined that average sea surface temperatures (SSTs) increased between 3 and 6 ^{o}C in early Holocene (9500 and 6600 ^{14}C yr BP) with respect to former period. In addition, they have determined that SSTs were lower as 2 and 3 ^{o}C with respect to the present.

As is the case for overall Southwest Anatolia, the vegetation and climatic conditions were not uniform in the early Holocene either. During this period climatic factors had a much stronger impact on the proliferation of plant species than other control mechanisms. For this reason during the first 1000-2000 years of the Holocene period, the expansion of the forest vegetation adapted itself to the climate. During the climatic change period both plant species increased and the vegetation structure expanded. Tree species expanded from refugial areas and occupied a larger share of the vegetation pattern. The changes that have occurred in line with this period had been on a species basis and pioneered the establishment of a forest vegetation cover inclusive of *Pinus, Cedrus, Juniperus* and *Quercus*.

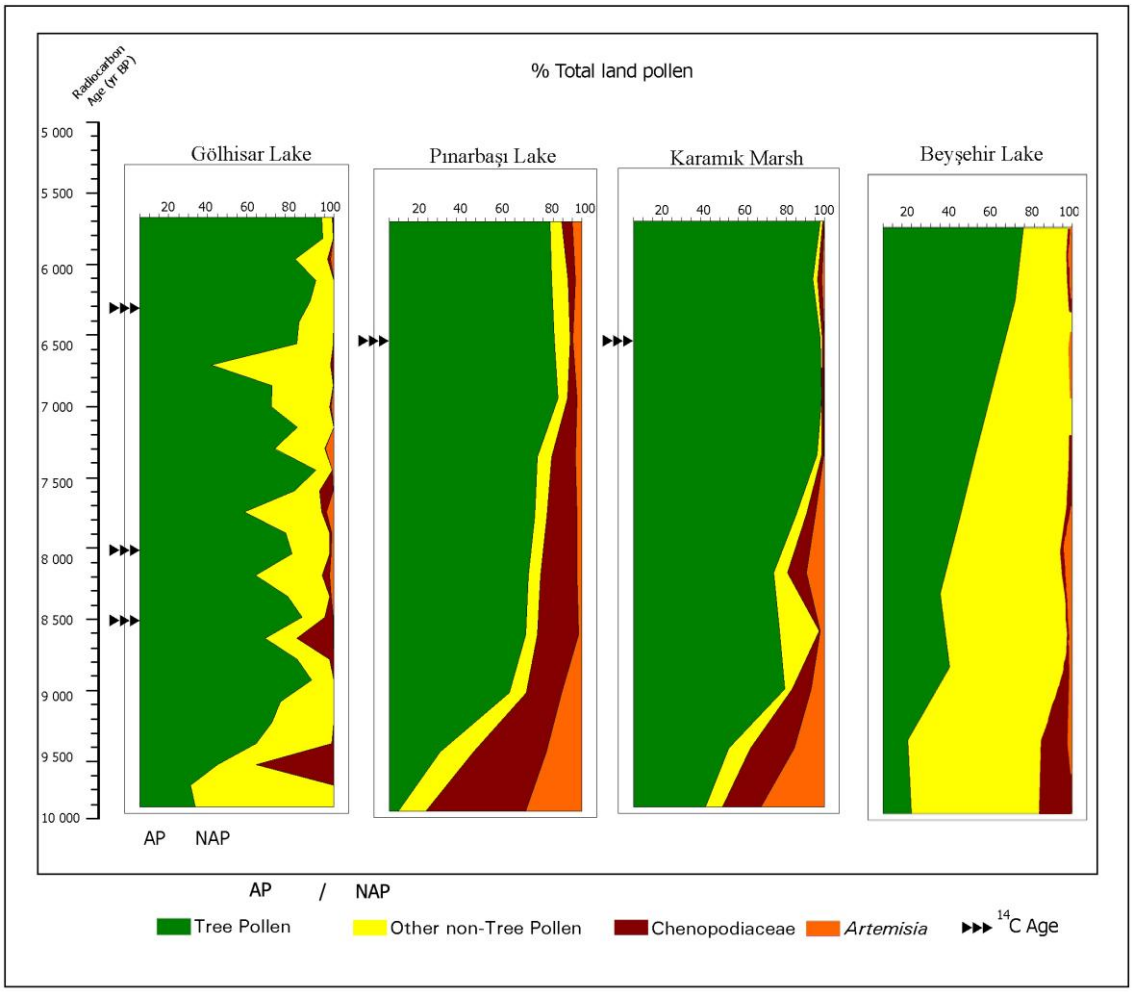

Figure 5. The pollen diagrams of the Mediterranean interior vegetation zones 9000 to 6000 ^{14}C yr BP in Southwest Anatolia.

Since the physiographical barriers in Southwest Anatolia prevented the free movement of forests, the emergence of individual species was not dependent only upon the migration rate, it also had an impact on their renewed progress in their inception positions. As a result, the early Holocene period was characterized by the success in expanding of individual plant species rather than migrations and adaptation of all vegetation formations; from the species point of view, a more complicated environment than envisaged had existed.

The presence of an AP entity formed by species totaling approximately 40-60% which characterize the cool and humid environment of Southwest Anatolia in 9000 ^{14}C yr BP, shows that the development of a forest cover had begun. The point of interest here is that the increase in AP humidity amount was paralleled by a proportional increase. During the early Holocene period AP revealed a different development especially in the central and eastern parts of Turkey; it took 3000 years to reach maximum values (Landmann et al., 1996; Woldring, 2001). For this reason, from the flora development point of view in the early Holocene period, the difference is the response of the vegetation pattern of Southwest Anatolia to the climate change without delay.

4.2. 7000 to 6000 ^{14}C yr BP

At large, the climate conditions 6000 years ago in the world are assumed to be the same as they are today (Wanner et al., 2008; Prentice et al., 2000; Gachet et al., 2003). On the other hand, climatic stability did not exist in different parts of

the world during the Holocene period; different proxy data determined the Holocene sub-periods to be either cooler and more humid or warmer and more arid (Eastwood et al., 2007; Roberts et al., 2008). The vegetation pattern starting from 9000 ^{14}C yr BP in Southwest Anatolia in general reached a far more different structure after the 3000 year period. With the pollen diagrams AP values of 6000 ^{14}C yr BP revealed a remarkable increase; this change was characterized by the invasion of trees concept.

The climatic conditions of Southwest Anatolia around 6000 ^{14}C yr BP bear a resemblance with today's conditions. During this period the conditions on the Aegean Sea and Mediterranean coasts were humid/semi-humid and hot. On the other hand, more interior region of the Mediterranean semi-humid climate conditions prevailed. Under these climate conditions AP species became dominant within the vegetation pattern.

The palaeo-climate reconstructions are supported by pollen data pertaining to around 6000 ^{14}C yr BP of Southwest Anatolia which reflect the increase of species under humid/semi-humid and hot climate conditions (COHMAP Members, 1988; Cheddadi et al., 1997; Prentice and Webb, 1998; Davis et al., 2003). In addition, changes in atmospheric circulation during early-middle Holocene period did not bring increased precipitation to any of the mid latitude countries; these areas remaining outside the subtropical region appeared to be more arid than they are today (COHMAP Members, 1988). Because the renewed progress of forest area vegetation in the other regions of Anatolia started later than in Southwest Anatolia, the development of climax forest vegetation was also completed later (Roberts and Wright, 1993).

5. Conclusion

Although interglacial conditions abruptly appeared 10000 ^{14}C yr BP it would be a mistake to assume that the early Holocene climate, ecosystem, and land features were no different than they are today. It has been shown by pollen data that during the early Holocene, the vegetation cover and climate conditions of Southwest Anatolia were not uniform enough to warrant generalizations. The main reason for this is that although the distances may be short between the different regions/areas of Southwest Anatolia, the differences are still quite remarkable.

At ~9000 ^{14}C yr BP in Southwest Anatolia, especially in interior areas, there is minimal forest covers which characterize cold climates. Similarly, a 50-60% forest ratio in total vegetation was determined in coastal areas with cool climates. During this period cold/arid climate conditions observed throughout Anatolia had also been partially influential in Southwest Anatolia and these climate conditions were accompanied by a vegetation cover in which NAP species were dominant.

During the final part of early Holocene, the vegetation pattern and climate conditions of Southwest Anatolia presented a more variable profile in comparison to other regions. Additionally, around 6000 ^{14}C yr BP, pollen data from a large section of Southwest Anatolia show that a sudden increase in the AP ratio, which is reflected by humid/semi-humid and partly hot climate conditions took place while a corresponding major decrease in NAP was observed. Especially at locations where the Mediterranean climate conditions are influential, the AP ratios have started to become dominated by species which are characterized by hot and humid environments. On the other hand, interior Mediterranean regions have been covered by semi-humid forest vegetation. Semi-humid forests sometimes consist of conifers and sometimes of deciduous trees. It is plausible to state that during the final part of the early Holocene period most of Southwest Anatolia had suitable climate conditions for forest vegetation.

The results achieved through this study deny the presumption that a majority of the early Holocene Southwest Anatolian vegetation cover consisted of steppe and desert-like steppes. The distinctive changes in the regional vegetation

pattern for early Holocene show that this was realized concurrently with climate change.

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