PRELIMINARY ASSESSMENT ON ENVIRONMENTAL CHANGES IN THE LAKE VAN REGION (TURKEY): PALYNOLOGICAL IMPLICATIONS DERIVED FROM SEDIMENTS OF KADIM DAM LAKE

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Abstract

Kadim dam constructed in a natural bowl or ancient lake is one of the old water reservoirs in the Lake Van region (Turkey). For pollen and dating analysis, four samples in different depth of lake sediment layer from lowest to surface have been taken by drilling. The samples were subsequently analyzed using sedimentological and palynological methods and dated with the 14C dating methodology. The all new data of this study were compared with previous studies in the area. The results have indicated both changes of the regional climate regime and changes of the vegetation in study area. The analysis results of two samples, at 19,230 yr Befor Present (BP) and at 15,070 yr BP, show cold and dry climate, with steppe vegetation in eastern Lake Van. The third sample records has been indicated the climate changing to more moisture and steppe-forests at 6,700 14C yr BP in study area. Records of last sample, at 4,000 14C yr BP show that steppe-forests and dominated human activity on region vegetation.

Özet

Doğal bir çukurluk veya eski bir göl çanağı içinde inşaa edilen Kadim barajı Van Gölü (Türkiye) bölgesindeki en eski su rezervaurlarından biridir. Polen ve tarihleme analizi için, göl sedimentlerinin en altından üste doğru, farklı derinliklerden, karotlu sondaj ile dört örnek alınmıştır. Örnekler; sedimantolojik, palinolojik analizleri yapılarak, 14C yöntemi ile tarihlendirilmiştir. Ayrıca bu çalışma ile elde edilen yeni veriler bölgede yapılmış önceki çalışmaların sonuçları ile karşılaştırılmıştır. Sonuçlar, çalışma sahasında bölgesel iklim rejimi ve bitki örtüsündeki değişiklikleri göstermektedir. Analizleri yapılan iki örnek, Van Gölü doğusunda (Günümüz Öncesi) GÖ 19,230 14C yıl ve GÖ 15,070 14C yıl dönemlerinde soğuk ve kurak iklim koşullarındaki step bitki örtüsünü göstermektedir. GÖ 6,700 14C yıl olarak tarihlenen üçüncü örnek analiz sonuçları, çalışma sahasında nemli iklim koşulları altındaki step-ormanlarını, iklim değişikliğini işaret etmektedir. GÖ 4,000 14C yılına tarihlenen son örneğe ait analiz sonuçları step ormanlarını ve bölgenin bitki örtüsü özellikleri üzerindeki insan etkisini göstermektedir.

1. Introduction

Lake Van (38°36′N, 42°54′E) situated in Eastern Anatolian is the biggest lake in eastern Turkey. In addition to Lake Van there are many small natural, as well as artificial water reservoirs that have existed since at least the last glacial maximum (Belli 1994; Belli 1999; Kempe and Degens 1978; Litt et al. 2009). One of these water reservoirs is the Kadim Dam/Lake (38°26′18″N, 43°26′06″E), located 12 km east from the Van city center (Fig. 1) (Belli 1994; Belli 1999). Lake sediments are very useful in obtaining data about the paleo-geographic environment (Landmann et al. 1996; Jones & Roberts 2007; Litt et al. 2007; Roberts 1983). As a case study, this report both presents the preliminary assessments and findings of the palynologic analysis and compare the result of this study with the former records belonging to the vicinity of Lake Van region (Landmann et al. 1996; Lemcke et al. 1997; Wick et al. 2003).

The Kadim Dam/Lake, still used as a water reservoir by the local inhabitants, was selected for investigation because at the end of the summer season the Kadim Dam dries out and can be boreholed to extract sediments (Fig. 2). A single borehole was drilled and used to extract 4 samples from different depths of same core. These samples were analyzed to provide palynologic, sedimentologic and chronological data.

2. Material and methods

The thickness of the lake sediment was determined by drilling with the help of a 10 cm diameter corer, using a rotary drilling technique. The results of the drilling and stratigraphic continuousness were tested by geophysics surveys such as Geo-Electric, Seismic and Geo-radar. Grain Size Analysis, palynologic and dating analyses were applied to all core samples (Turoğlu et al. 2007). Grain size analysis have been made by Galehouse (1971) and McManus (1991) methods. For sample dating, ^{14}C determinations techniques have been used by NSF Arizona AMS Facility, The University of Arizona.

Palynological studies were performed on 1 cm^3 size sediment samples using standard methods such as treatment with HCl, HF and KOH (Erdtman 1954; Moore et al.1991).

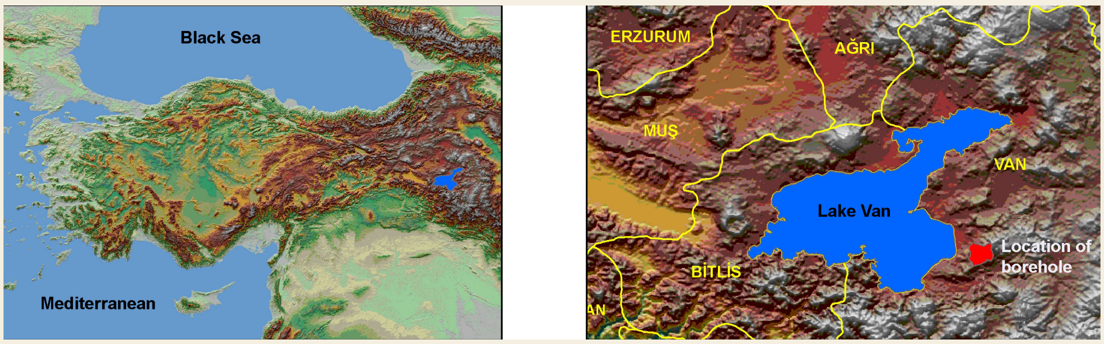

Fig. 1- Location map of the study area and site location of core.

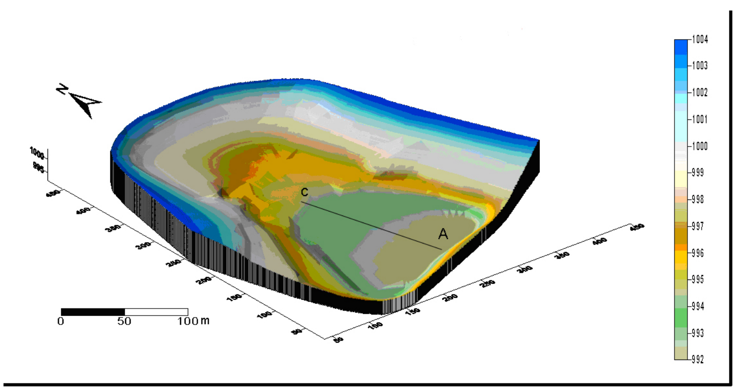

Fig. 2 - Digital Elevation Model of Kadim Dam. Sediment samples have been taken floor of this old dam by drilling. "A" is location of the borehole. "A-C" line is the Seismic refraction profile line.

Lycopodium spore tablets were used for the calculation of pollen concentrations (Stockmarr 1971). The identification of pollen types was based on the reference collection of the Institute of Marine Sciences and Management of Turkey. Past climates in the Near East were reconstructed based on pollen data. Changes in quantities of ***Quercus, Pistacia, Artemisia, Chenopodiaceae, Gramineae*** and other taxa were used as indicators for changes in humidity and temperature (Bottema & Zeist 1991; Roberts & Wright 1993; Rossignol-Strick & Cheddadi 1995).

3. Environmental setting

Kadim Dam is 1700m above sea level and surrounded by steep peaks up to 3000 m. The water sources of the Kadim Dam/Lake are melting snow from the surrounding area, spring water and precipitation (Erinç 1953; Erinç 1980). The Lake Van region has a continental climate with long, cold winters and warm summers. Prevailing southwesterly winds from the eastern Mediterranean cause precipitation during autumn, winter and spring, whereas the dry summers are due to continental air masses. Precipitation shows a strong gradient with 600-800 mm in the southwest to only 300-400 mm annual precipitation to the north and east of the lake (DMIGM 2005).

The distribution of precipitation suggests that Lake Van is located in the transitional zone between two vegetation types (Erinç 1953; Erinç 1980; Valeton 1978).

Based on the above facts one would expect the vegetation to range from Oak forest belts including several deciduous oak species, ***Pistacia atlantica, Acer cinarescans, Juniperus oxycedrus, Pyrus syriaca, Crataegus spp*** in the southwest to steppe type vegetation dominated by ***Artemisia fragrans*** with sub-Euxinian oak-forest remnants in the north and east. The natural upper forest limit, most likely to be formed by ***Betula verrucosa***, is located at 2500-2700 m (Erinç 1953). Nevertheless after thousands of years of human impact, hardly anything is left of the natural vegetation that one would have expected in the Lake Van region. (Peşmen 1980; Sevin 2003)

4. Analysis and results

4.1. Stratigraphic records

Stratigraphic features of lake sediments were determined by using core samples, a maximum depth of 440cm below the lake floor. From the lake floor to surface of the main rock, the core section was composed of very fine sediments as clay, silt and mud (Table 1).

Table 1- Summarized core sediments obtained from 10 cm diameter core in Kadim Dam.

Deep (From surface to main rock)	**Features of sediments**
0- 10 cm	• Fine grained (fine sand, clay, silt, mud). • Many cracks originating from drying. • Upper part of layer is yellow, brown, green colors. • Abundant organic cavities.
10 – 30 cm	• Very fine sediments, grain size 0.064-0.002 mm. • Yellow, brown, green color sequences. • Poor organic cavities. • High moisture density
30 – 150 cm **150 – 350 cm** **350 – 440 cm**	• Moist, fine sediments, brown, color, without cavity. • Green and dark green, with moisture, grain size between 0.02-0.002 mm. • Very fine grained, strong, blue or green-blue color,
440–450 cm	• Clay Stone with limestone fragment (bed rock), • without moisture, • without cavity, • Very hard

The visual check of the core sediments showed clear color differences. As expected the general character of the lake sediments conform to standing water environment. The continuity of the core sediment features was further confirmed by means of a geophysics survey. The results of Vertical Electric Drill, Seismic refraction (Fig. 3) and GPR survey show similar texture and structure within core sediments. A sediment thickness map of the Kadim Dam is provided in (Fig. 4; Fig. 5) and indicates the consistency of the data with the expectations of a standing water lake (Turoğlu et al. 2007).

AB/2	R
1	18,97956
1,5	16,69106
2	19,52557
2,5	20,03582
3	20
9124	
4	23,19064
	23,4
6	25,64595
	27,4 657

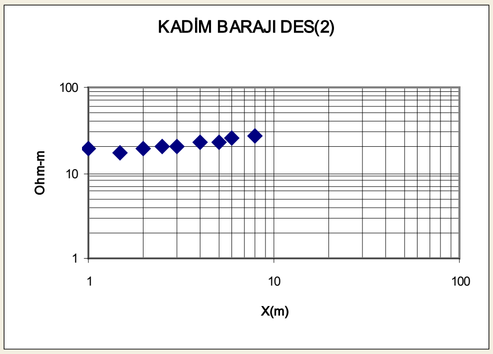

Fig. 3- Vertical Electric Drill results and curve of Kadim Dam (Turoğlu et al. 2007).

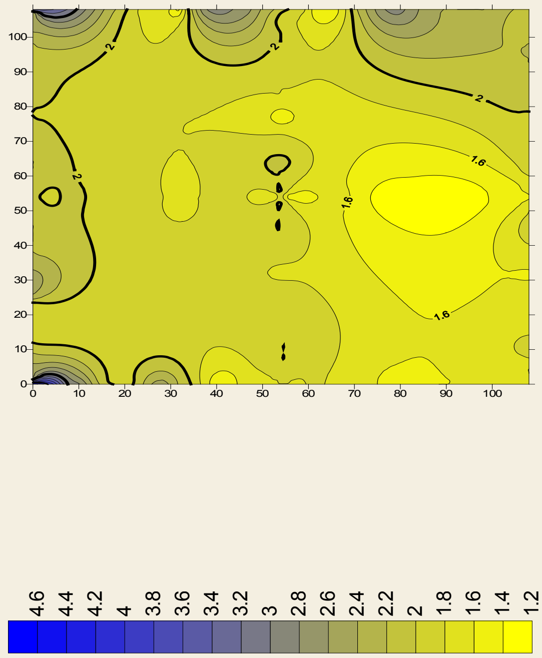

Fig. 4- Sediment thickness map of the Kadim Dam (Turoğlu et al. 2007).

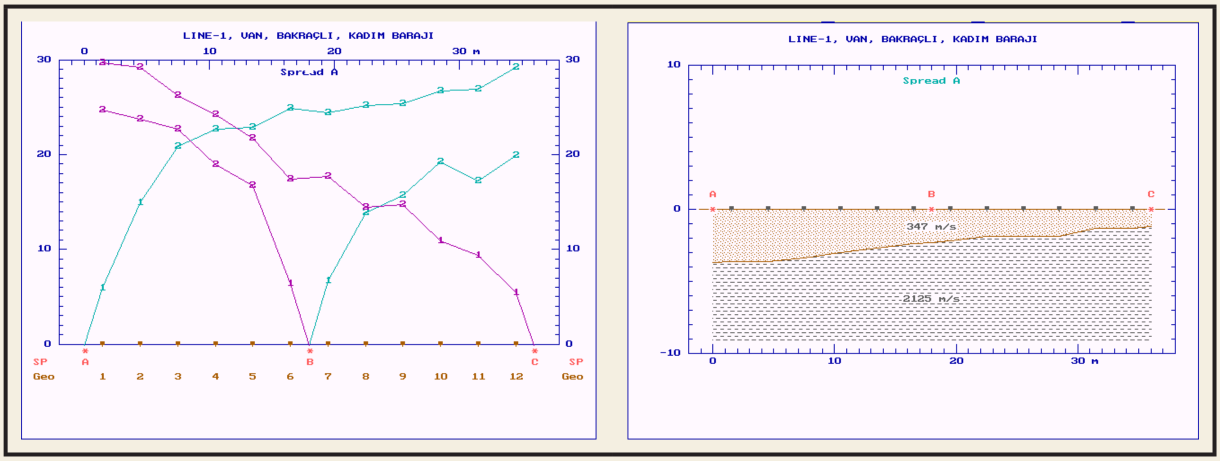

Fig. 5- Seismic refraction P wave, time-distance diagram and seismic ground cross section in bottom of the Kadim Dam/Lake throughout the A-C profile (Fig. 2) (Turoğlu et al. 2007).

Table 2- Grain size distributions of Kadim Dam core sediments.

Sample No	**Depth (cm)**	**Sand (%)**	**Silt (%)**	**Clay (%)**
K-3	-100	1.76	14.22	84.02
Y-1	-150	0.38	12.28	87.34
K-2	-340	1.88	21.17	76.95
K-1	- 440	-	10.80	89.20

Table 3- Comparison of pollen assemblage zones and dating.

Samples	**Age**	**Environment**	**Taxa**
K-3 -1.00 m	BP 4,000 to present	Steppe-Forest	Dominated by human activity indicators such as *Plantago, Polygonum, Rumex* and *Vitis*. *Pistacia* and *Juniperus* are dominated in AP.
Y-1 -1.50 m	BP 7,584 ±97	Steppe-Forest	Deciduous oak dominate (*Quercus*), Pistacia is also. Decreasing *Artemisia* and *Chenopodiaceae*.
K-2 -3.40 m	BP 18,347 ±170	Cold-Steppe and dry climatic condition	Dominated by *Artemisia* and *Chenopodiaseae*.
K-1 -4.40 m	BP 22,928 ±310	Cold-Steppe and semi- dessert climatic condition	Dominated by *Artemisia, Chenopodiaseae* and *Poaceae*.

4.2.Grain Size Analysis

Grain size and grain size ratios of the four core samples (Table 2) were analyzed. According to the result of sedimentologic analysis, the whole of samples are fine material as sand, silt and clay (Table 2) and very high proportion of fine materials is constituted by clay. This feature indicates that analyzed samples are from in quiet hydrodynamic conditions such as a lake environment.

4.3. Pollen records

Reconstructions of past climate in the Eastern Mediterranean region are generally based on both pollen data and Oxygen isotope records (Fauqette et al 1999; Jones & Roberts 2007; J-Moreno et al 2007; Landmann et al 1996; Lemcke et al 1997; Stevens etc. 2001; Wick et al. 2003; Litt et al 2009).

In palynologic analysis, high quantities of *Quercus, Pistacia, Artemisia, Chenopodiaceae, Gramineae* and other taxa were used as indicators for changes in humidity and temperature (Fauqette et al 1999; J-Moreno et al 2007; van Zeist & Bottema 1991; Roberts & Wright 1993; Rossignol-Strick & Cheddadi 1995). Human impact indicators are *Plantago*, *Rumex* and *Vitis* (van Zeist & Bottema 1991; Roberts & Wright 1993). The four sample analyzed in this study, have been named “Kadim Dam Samples” K1, K2, Y1 and K3 respectively. The palynologic analysis of the respective Kadim Dam samples is summarized as follows.

K1 is characterized by a high concentration of nonarboreal pollen (NAP). *Artemisia* (45%) is the most prominent of nonarboreal pollen followed by *Chenopodiaceae* (20%),

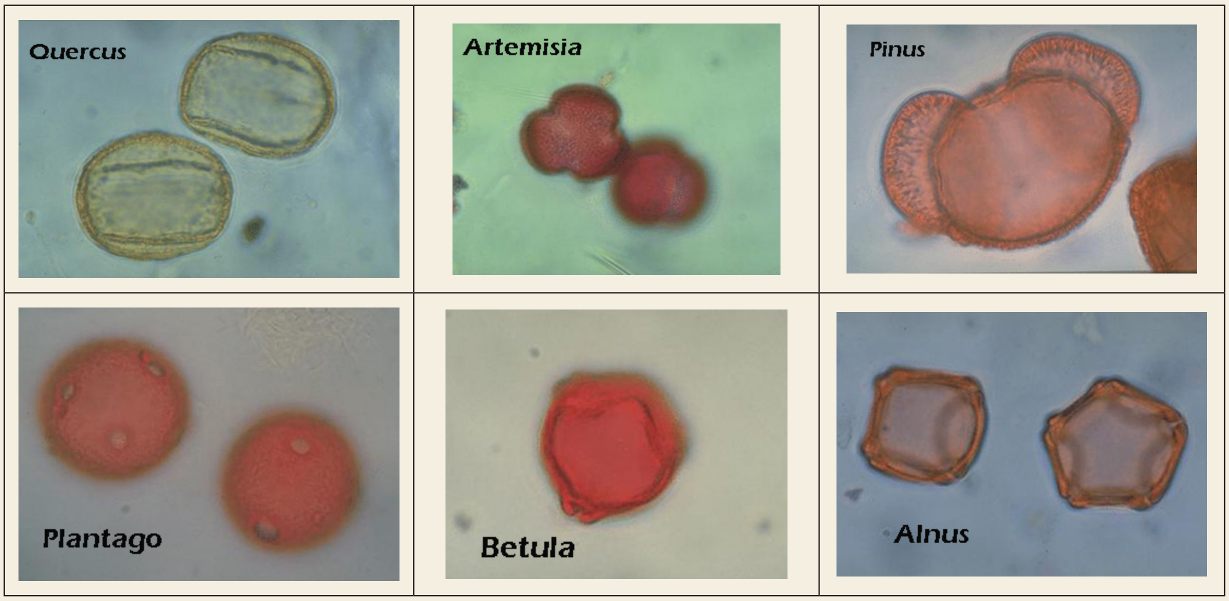

Fig. 6- Photos of plant pollen from Kadim dam sediment samples (magnification 500x).

Poaceae (20%) and Umbelifereae (15%). The ratio of arboreal pollen grains is of a lower value than nonarboreal pollen grains (NAP 85% and AP 15%). ***Betula*** is the common species amongst the arboreal pollen grains. ***Pinus*** percentages high values in AP (Table 3)(Fig. 6). The last glacial maximum (18,000 years BP) is marked by a large influx of steppe pollen indicators such as *Artemisia* (Landmann et al. 1996; Lemcke et al. 1997; Stevens et al. 2001; Wick et al. 2003). During the Late Glacial period steppe vegetation rich in ***Artemisia, Chenopodiaceae,*** ***Poaceae*** and Umbeliferae prevailed in the Lake Van area, indicating very arid climatic conditions. K1 is correlated with upper pleniglacial peiod (23 kyr BP).This is characterized by cold and semi- dessert climatic condition (Table 3)(Fig. 6, 7).

In the K2 sample, the ratio of nonarboreal pollen grains is still high (80%) in this sample. The most common among the NAP grains are ***Artemisia*** (50%), ***Chenopodiacea*** (30%) and Umbeliferae (20%). ***Pinus*** (35%) and Betula (16%) are the most common species of arboreal pollen grains in the K2 sample. An increase in percent ***Pinus***, common ***Artemisia*** pollen

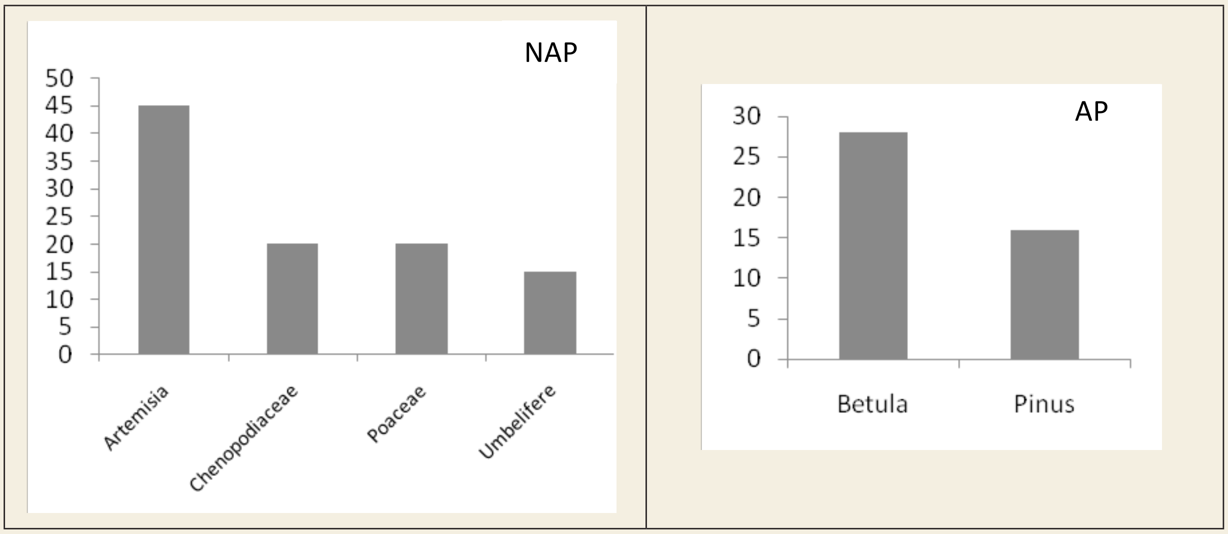

Fig. 7- Distribution of NAP in K1, percentage abundance of the dominant non arboreal pollen types and main indicator taxa.

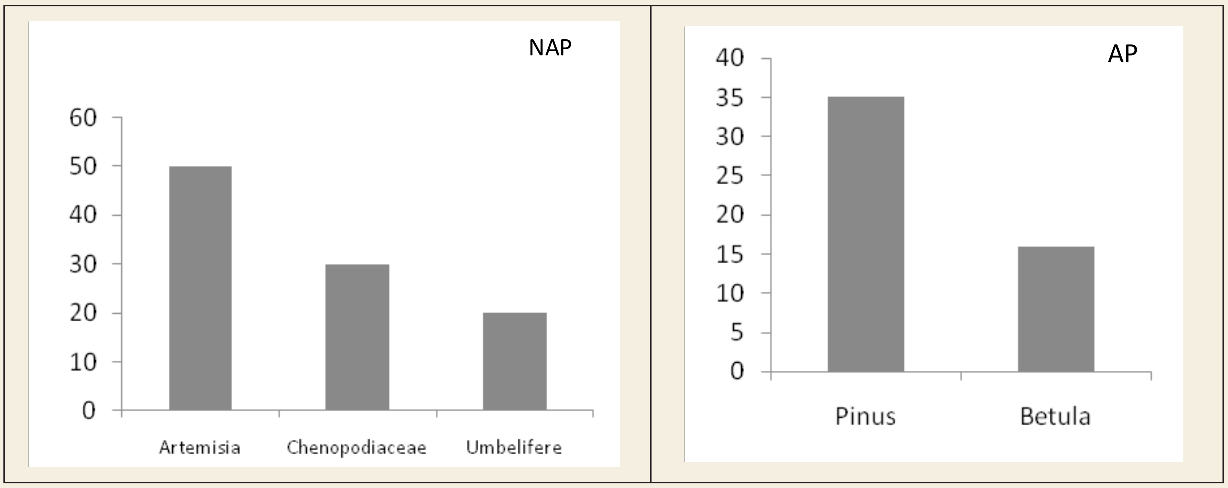

Fig. 8- Distribution of NAP and AP in K2, percentage abundance of the dominant pollen types and main indicator taxa.

grains which has ages of 18.347 yr BP. These assemblages indicate cold and dry climatic condition (Last Glacial Maximum) (Table 3) (Fig. 6, 8).

The Y1 sample shows a significant change of the NAP to AP pollen ratio. Now the arboreal pollen makes up 68% of the count. In the time period of the sample deciduous oak and pistachio have become the dominant species of AP with 55% and 27% respectively. The increase in *Quercus* and *Pistacia* pollen indicates a change to climatic conditions favoring a forest-steppe vegetation type. *Vitis* (30%) and *Gramineae* (35%) are common among the nonarboreal pollen whereas the ratios of *Artemisia* (15%) and *Chenopodiaceae* (20%) have decreased in this sample (Table 3) (Fig. 6, 9).

Indicators of human impact, such as ***Plantago*** (20%), ***Polygonum*** (17%) and ***Rumex*** (16%) are prevalent in the K3 sample. ***Chenopodiaceae, Vitis*** and ***Artemisia*** show lower values than within the other samples. The percentage of arboreal pollen is 68% whereas nonarboreal pollen is only 32%. ***Quercus*** is the common species among the AP with 22%. ***Alnus*** and ***Tilia*** pollen also exist in the K3 (Table 3) (Fig. 6, 10).

4.4. Radiocarbon dating data

^{14}C dating analysis realized in NSF-Arizona AMS (Accelerator Mass Spectrometry) laboratory was performed on three core samples named K-1, K-2 and Y-1 (Table 4) (Fig. 11). K-1 is from the lowest sediment layer and falls in late Pleistocene, at 22,928 ± 310 yr BP. K-2 is 1.50 m above the K1 sample

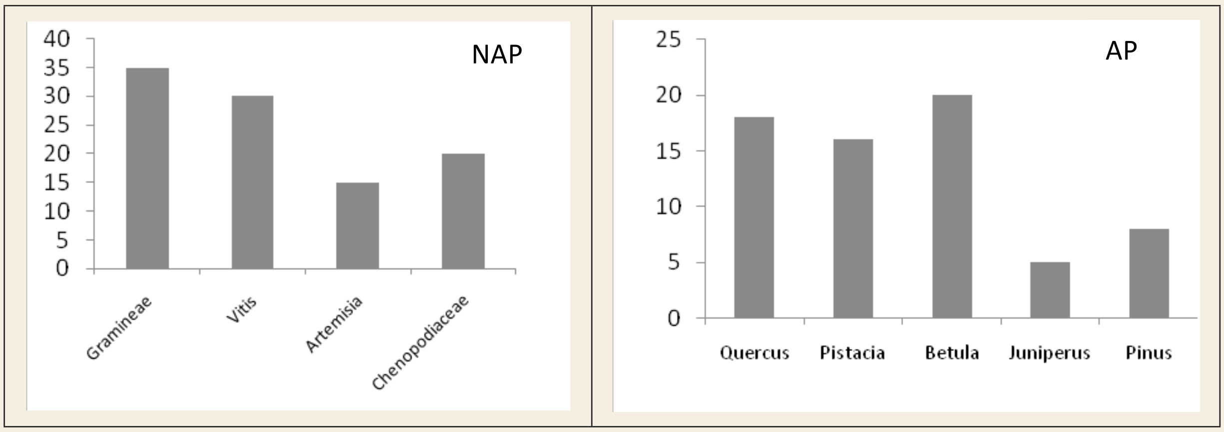

Fig. 9-Distribution of NAP and AP in Y1, percentage abundance of the dominant pollen types and main indicator taxa.

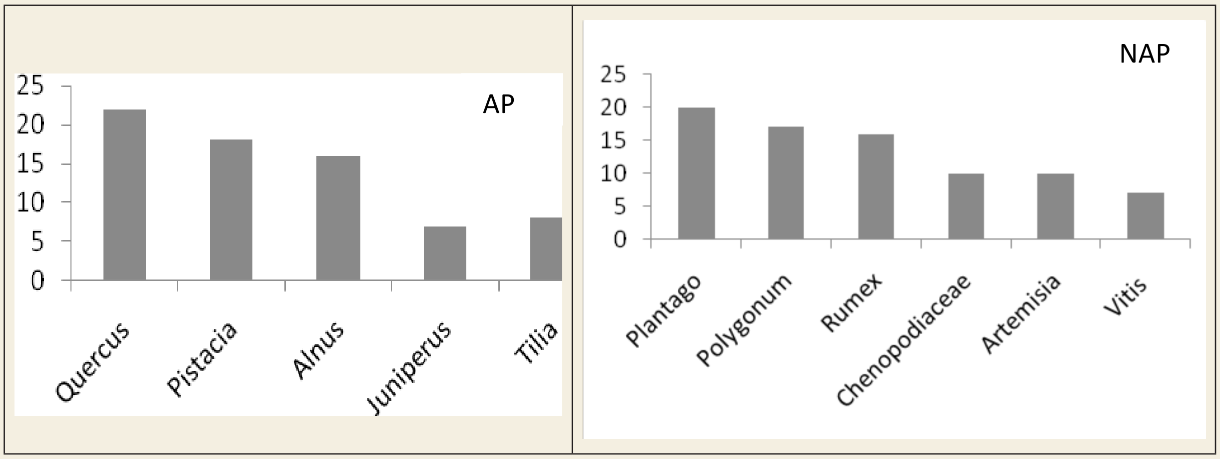

Fig. 10: Distribution of NAP and AP in K3, percentage abundance of the dominant pollen types and main indicator taxa.

Table 4- ^{14}C dating results of Kadim Dam/Lake samples.

Sample	Lab number	δ^{13}C VALUE	FMODERN	+- dFMODERN	^{14}C AGE BP	AGE ERROR	Calibrated age BP
K-1	AA71648	-3.8	0.0912	0.0035	19,230	± 310	22,928
K-2	AA71649	-4	0.1532	0.0032	15,070	± 170	18,347
Y-1	AA71650	-11	0.4333	0.0052	6,717	± 97	7,584

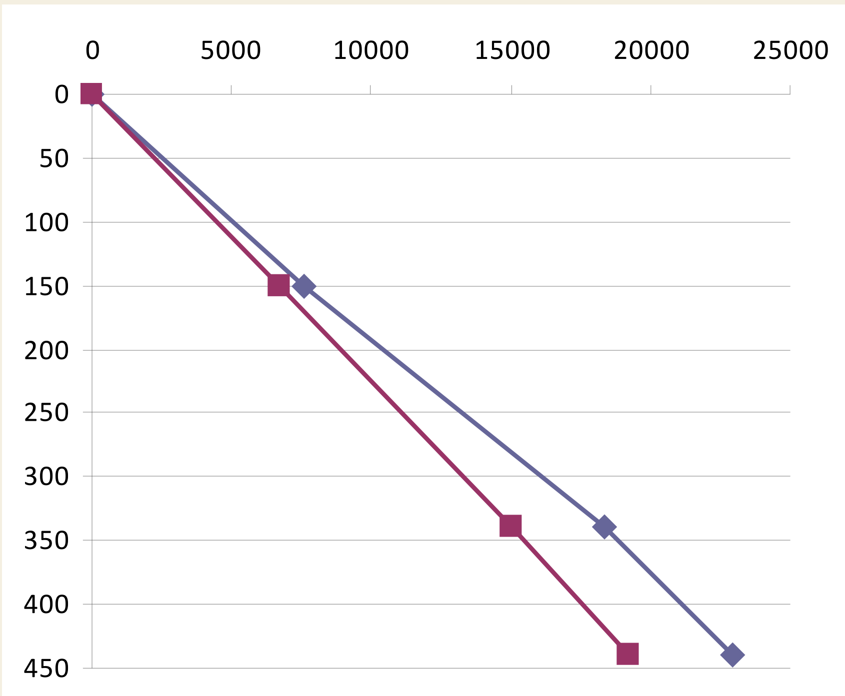

Figure 11- Calibration of ^{14}C dates using CALIB 5.0. Right hand plot shows calibrated ages.

Table 5- Arboreal and non-arboreal plant distribution ratios in eastern Lake Van region.

Samples	Arboreal pollen (%)	Nonarboreal pollen (%)	Calibrated age (BP)
K 1	15	85	22,928 ±310
K 2	20	80	18,347 ±170
Y 1	68	32	7,584 ±97

and is dated as latest Pleistocene, at 18,347 ±170 yr BP. The last dated lake sediment Y1 extracted 1,50 m below ground is from the middle Holocene period dated at 7,584 ±97 yr BP.

5. Correlation of results with former data

A number of palynological studies have previously been conducted in the Lake Van region (van Zeist & Woldring 1978; Bottema et al. 1990; Bottema & Van Zeist 1991; Landmann et al. 1996; Lemcke et al. 1997; Wick et al. 2007; Turoğlu et al. 2007). Results of the prior studies align with the current findings based on characteristic climatic indicators such as *Quercus, Chenopodiaceae, Artemisia*. A comparison of relevant data points is presented in Table 5. It is generally believed that the last glacial-interglacial transition period spans at 15,000-9,000 ^{14}C yr BP including the Younger Dryas Chronozone (van Zeist & Woldring 1978; Roberts 1983; Williams et al. 1996; Lowe & Walker 1997; Roberts et al. 1999; Kashima 2002; Preusser & Schluchter 2005). The climates of the K1-K2 samples indicate a cold and dry period in late Pleistocene before this transition period (Table 3-4-5).

6. Conclusions and discussion

This research has been prepared as a case study and preliminary assessment of its results summarized as below.

Stratigraphic and sedimentologic records show that the Kadim Dam region has been a lake sedimentation environment since at least at 19,230 ±310 ^{14}C yr BP (Calibrated age 22,928 ±310 BP) (Table 1-2-4, Fig 3).

Palynologic and dating analysis results of the Kadim Dam samples are clear indicators of past vegetation and climate changes in the study area. The change from Cold-Steppe to Steppe-Forest taxa shows that there were clear variations in climate between the last glaciation and the present (Table 3). The change in ratios of arboreal and nonboreal pollen is another proof of the climatic changes in the Lake Van region (Table 5).

Based on pollen analysis and ^{14}C dating results it can be indicate that the east of the Lake Van region has been dominated by cold steppe taxa such as *Artemisia, Chenopodiaseae* and nonarboreal vegetation around 19,230 ±310 ^{14}C yr BP (Table 3-4). This period named the Lateglacial period for Lake Van region was determined as cold and dry, with steppe vegetation in former publications (Jones & Roberts 2007; Wick et al. 2003; Litt et al. 2009).

According to dating and pollen analysis of sample K2, we inform that Lake Van region was under the cold and dry weather conditions around 15,070 ±170 ^{14}C yr BP (Calibrated age 18,347 ±170 BP). But, this period is almost consistent with the Pleistocene – Holocene boundary characterizing a climatic change from cooler and wetter to warmer and dryer environment.

At 6,700 ^{14}C yr BP (Calibrated age 7,584 ±170 BP). the increase of *Quercus* and *Pistacia* vegetation has attracted attention (Table 3-4). Until that time the Eastern Lake Van region had been dominated by forest-steppe vegetation type. One can infer from pollen variety and densities, that the Lake Van region, especially the highlands, probably had richer vegetation in the earlier Holocene than in the present.

The last period, marked by *Plantago, Polygonum, Rumex* and *Vitis* pollen indicates human activity in study area. Common species such *Quercus, Alnus* and *Tilia* species show the effects of arid conditions in the eastern Lake Van region.
These results have been confirmed by seed of Vitis, barley, etc. finding archaeologic excavating in Lake Van region (Turoğlu et al. 2007). These vegetational markers indicate that

the climatic condition were probably similar to the present. Large scale forest damage caused by war, fire, cutting etc have caused major deforestration of the region since starting 4,000 yr BP.

Environmental changes have been attempted to verify both dates obtained from Radiocarbon dating and pollen analysis using palynologic analysis. Unfortunately these methods have been applied by insufficient samples due to conditions of research. Few available pollen spectra recovered from the core do not allow for interpretations in terms of vegetation evolution, but can only provide punctual images of the landscape during 3 time intervals. In adittion, the analysis results of this study have been useful for comparing with former or further research and interpretations.

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