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THE RELATIONSHIP BETWEEN SPATIAL CHANGE OF AVLAN LAKE AND SURROUNDING CLIMATE

Avlan Gölü'nün Alansal Değişimi ile Çevre İklimi Arasındaki İlişki

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Abstract

This study investigates the relationship between the spatial change of Avlan Lake, which is situated around Antalya in Mediterranean Region, and climate. The lake in the study was dried up in 1980. As a result, the people living nearby as well as environmentalist organizations reported serious climatic changes in the vicinity. Also it was reported that natural and cultural plants in the local area were affected negatively. After that, the water was released into the lake in 2001 and thus it regained its status before 1980. The sample of Avlan Lake set forth a geographical perspective for the effect of lake areas on surrounding climate. In this study, in order to identify the relationships between drying up of the lake area and climate, meteorological data of three different periods were examined. Those periods were before 1980, between 1980 and 2001, and after 2001. The period before 1980 covers the time when the lake was there. The years between 1980 and 2001 covers the period when the lake was dry. Lastly, the period after 2001 follows refilling of the lake up to date. Landsat satellite images were used to reveal spatial shrinking of the lake zone. For analyzing climatic data, Mann-Kendal Test, Sen's Slope Estimate and Sezer's (1990) Continentality Indices were used. In the analysis, no direct relationship was found between drying up of Avlan Lake and the climate. Hence, balancing role played by the lake in its environment rather than the climate itself can account for the changes taking place in and around the lake. This finding suggests that water bodies in any area might cause many ecological problems though not related with climate.

Keywords: Avlan Lake, climate change, Sen's Slope Estimate, Mann-Kendal Rank Correlation Test, ekoloji, Sezer's continentality indices

Özet

Bu çalışmada Türkiye'nin Akdeniz Bölgesi içinde, Antalya il sınırları dahilinde kalan Avlan Gölü'nün alansal değişimi ile iklim arasındaki ilişkiler ele alınmıştır. Çalışmaya konu olan Avlan Gölü 1980 yılında kurutulmuş ve gölün kurutulmasına bağlı olarak yörede yaşayan halk ile birçok çevreci örgütün iklimde ciddi değişimlerin yaşandığına ve yörenin doğal ve kültürel bitkilerinin bu durumdan olumsuz etkilendiğine dair şikayetleri üzerine 2001 yılında göle tekrar su verilmiş ve göl yeniden 1980 yılı öncesindeki mevcut haline dönmüştür. Yaşanan bu örnek, göl alanlarının çevre iklime etkisini coğrafi bir perspektifle ortaya koymayı gerekli kılmıştır. Çalışmada göl alanının ortadan kalkması ile iklim arasındaki ilişkileri belirlemek amacıyla gölün mevcut olduğu 1980 yılı öncesi, gölün kurutulduğu 1980-2001 yılları arasındaki dönem ile gölün tekrar oluştuğu 2001 yılından günümüze kadar olan dönemin meteorolojik verileri üç farklı dönem halinde incelenmiştir. Göl alanının alansal daralmasını belirlemek amacıyla Landsat uydu görüntülerinden faydalanılırken, iklim verilerinin analizi için Mann-Kendal Testi, Sen'in Eğilim Tahmini Testi ile Sezer (1990)'e ait Karasallık İndisi kullanılmıştır. Yapılan analizlere göre Avlan Gölü'nün kuruması ile iklim arasında doğrudan bir ilişki belirlenememiştir. Dolayısıyla göl ve çevresinde meydana gelen değişimlerin iklimden ziyade gölün, bulunduğu çevre içindeki dengeleyici öneminden kaynaklandığı söyleyebilir. Bu durum herhangi bir alanda bulunan su kütlelerinin iklimle bağlantılı olmasa da birçok ekolojik soruna neden olabileceğini de göstermektedir.

Anahtar kelimeler: Avlan Gölü, iklim değişikliği, Sen'in eğilim testi, Mann-Kendal sıra korelasyon testi, ecology, Sezer'in karasallık testi

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INTRODUCTION

Ecological balance in any area, zone or district continues thanks to the combination and interaction of existing local facts such as geology, geomorphology, soil, flora, climate and hydrography. In case any of these circumstances disappears or is damaged, ecological balance is upset often resulting in unsolvable ecological disturbances such as climate change and aridity. Lakes are among the most important factors stabilizing the ecological balance. Lakes with varying sizes give life to all biological assets in their neighborhood. In addition to this, they play important roles such as regulating the underground water, preventing floods and overflows and controlling climatic changes. The importance of lakes even increases due to the fact that ecosystems are significantly disturbed by especially recent climate changes and aridity becomes prevalent day by day. It is expected that climate changes will affect especially functioning of ecosystems and hydrological processes of the wetlands and small lakes much more negatively in coming years (Erwin, 2009). While changes in climate vary depending on conditions such as location of lakes, geomorphologic and biological facts and height, it is known that such changes take place more slowly and at a lower extent around lake areas and close vicinity of them (Adrian ve ark., 2009). There are many studies looking at this situation closely. Those studies showed that lakes are affected from ecological changes in their surrounding so quickly while reacting to climate changes quite slowly and at low extents (Carpenter, 2007; Pham ve ark., 2008; Williamson ve ark., 2008). Especially factors such as size and level of the lake area and temperature of the lake surface can be decisive regarding climate changes (Adrian ve ark., 2009; Huryna ve ark., 2014). Most studies on dams reveal that dams have effects in varying degrees on climate elements of the region/zone where they are built (Degu ve ark., 2011; Miller ve ark., 2005; Correia ve ark., 2006; Tonbul, 1990). In those statistical studies, it was found out that artificial water bodies (dam lakes) caused particular meteorological events such as decreases in annual range of temperature, relative increase of humidity and relative increase of frost as a result.

It is crucial that lakes be preserved due to the importance they bear for ecological setting of their environment. According to the studies carried out in this area, decreasing levels of lake water and gradual shrinking and even disappearing of lake areas are explained with intense anthropogenic use and warming of climatic values (Abbaspour ve ark., 2012; Yan ve ark., 2013; Jones ve ark., 2001; Kantarcı, 2008). Observable factors of disappearing of lakes include intensive use of lakes for irrigation or drying up of lakes for agricultural activities. Moreover, increased evaporation, irregular seasonal distribution of precipitation and decrease of precipitation rates as a result of temperature rise can be contribute to narrowing down of lake areas.

In 1970s, drying activities were started in Turkey. Subsequently, many wetlands along with lakes with varying sizes were dried up for cultivation in parts of Anatolia. This in turn resulted in not only ecological problems but also aridity, desertification and salinization. In this context, Avlan Lake wetland has been selected as subject of this study since it is a sample dried up for agricultural purposes in 1970s. Drying up of Avlan Lake was started in 1976 and completed in 1980. However, the lake was filled again later in 2001 since it was reported that complete drying up of the lake brought about serious changes in local climate and other environmental problems (Çevre ve Orman Bakanlığı, 2006). In the meanwhile, the lake area remained dry nearly for 20 years. Therefore, Avlan Lake is an important example for suggesting how effective lakes and wetlands are on climate of the region they are located in. In addition, the changes in the region, discussed in detail whether caused by climate or drying of wetland. Due to these changes in its history, Avlan Lake was selected for present study as a particular example suggesting the extent at which lakes are important for climate of the region they are located in. In the study, climatic data for Avlan Lake were examined in three parts as pre-intervention, dry and rewatering periods. The climatic data were analyzed to this end. It’s also investigated with a variety of literature the possible environmental impacts of changes due to destruction of wetlands and whether there are such negative effects around the Avlan Lake. In this way, the extent at which lakes could affect surrounding climate was studied in detail in the context of Avlan Lake.

MATERIALS AND METHODS

The proposed paper analyses temporal changes of regional climate in the surroundings of Avlan Lake, Turkey, in context of the spatial changes of the lake area. Authors assessed three time periods of the area changes - before drying of the lake, during period without water body and after refilling of the lake. This analysis can be very important for our knowledge about impact of water bodies on regional climate and following relations and interactions in the territory. Authors used three different methods for the analysis - meteorological data time series analysis, remote sensing and qualitative methods (face to face interviews).

13 satellite images belonging to different years were used to identify temporal change of the spatial shrinking of Avlan Lake (Figure 1). In particular, the images displaying the period between June-August, when rainfall was minimum, were used in order to obtain accurate results concerned with the lake area. 10 of the images were for June, 1 for July and

remaining 2 were for August. During selection of the satellite images, cloudiness below 10 % was set as a criterion. Finally, change of land use/land cover was analyzed by the unsupervised classification method.

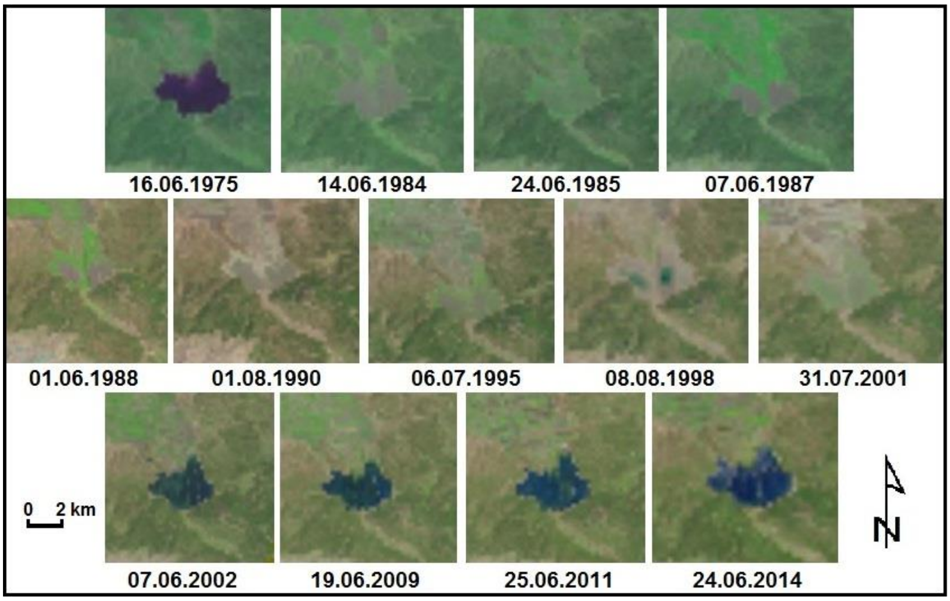

Figure 1: *Spatial and temporal changes of Avlan Lake*

Since the study aims at determining what changes were caused in environmental climate by Avlan Lake before it was dried up (1980 and earlier), when it was dry (from 1981 to 2000) after it was revived (from 2001 to 2013), the change of climate parameters was examined through mentioned periods. To this end, meteorological data were obtained from the Elmalı Meteorology Station, which is nearly 10 km far from Avlan Lake, for years between 1958 and 2013. In this scope, temporal trends in such values as average temperature, average minimum temperature, average maximum temperature, total precipitation, relative humidity, evaporation and number of frost days were shown in a curve in relation with years. For analyzing collected data, some of the nonparametric methods were used such as Sen's Slope Estimate and Mann-Kendall test analysis. As a result, trends of significant increase or decrease were found. In study findings, the term "direction of the trend" refers to increases or decreases in the change and "magnitude of the trend" is used to determine whether or not a change was found at statistical significance level (5 % or 1 %). Continentality is one of the factors determining the climate. Thus, continentality trend of the region was determined by using Sezer's continentality indices based on annual range of temperature.

The formula was discovered by (Sezer, 1990) in consideration of factors such as annual range of temperature, distance from the sea, altitude and latitude. Briefly, the index is formulized as following and preferred for our study since it is a formula applied for the context of Turkey.

$$C = \frac{1{,}614 \times A}{\csc(\emptyset + \frac{h}{125} + \frac{L}{111})}$$

Here;

''C'': The degree of continentality (%)

''A'': Mean annual temperature range (amplitude; C)

''csc'': Cosecant

''Ø'': Geographical latitude

''h'': Height (m); ''h/125''= Degree

''L'': Distance from the sea (km); ''L/111'' = Degree

In this study, qualitative research method was also employed. In this scope, *face-to-face interview* was used as it is one of the most widely used data collection techniques for obtaining important qualitative data from heads of villages in close vicinity of the lake.

STUDY AREA

The study was implemented in Avlan Lake, which is situated in the southwest of Turkey in the region of Antalya in Mediterranean Region within borders of Antalya province. Covering an approximate area of 1023 ha, the lake is located on southern end of Elmalı Polje around 1020-1050 m above sea level. In the southeast of the lake area are the Bey Mountains, in the southwest is Susuz Mountain and in the north is Elmalı Polje (Figure 2).

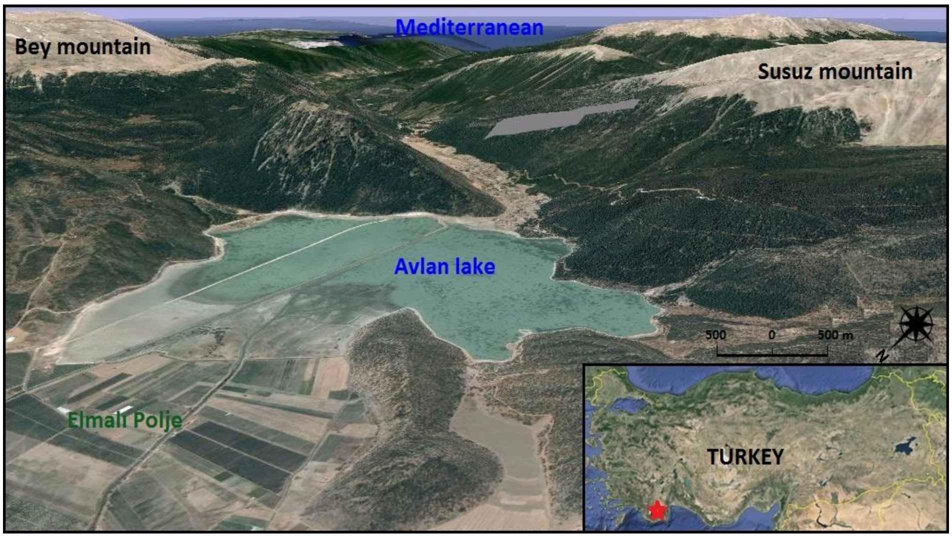

Figure 2: *Location map of the study area*

Both Avlan Lake and its close vicinity bordered within the Western Taurus Mountain System were karstificated at a great extent resulting in karstic erosion formations in varying sizes. The largest of those formations is Elmalı Polje, in which Avlan Lake is situated as well (Erinç, 2001). On the ground of the polje are Avlan Lake and Karagöl Lake, which were dried up in 1970s. There are also swallow holes on the ground and neighborhoods' of these lakes. The lakes overflow and majority of the polje area is flooded especially at times when those swallow holes become blocked.

Elmalı Basin, which Avlan Lake is enclosed in, is predominantly vegetated with both pure and mixed cedars. In ecological terms, cedars are not so drought-tolerant as junipers and black pines. In parallel, they are more vulnerable to the changes in humidity. There is a zone called *''Semi-arid continental climate''* due to its climatic feature.

Widespread karstification across the region caused the river network not to expand and to be deformed. As a consequence, there is not a well-developed river system available in the basin of Avlan Lake.

In the north side of the West Taurus Mountains is a depressed area at an altitude of nearly 1050 m. In Elmalı Polje, which also contains Avlan Lake, climate conditions are different from the coastal region. Called transition zone, this climate is characterized with continentality and altitude. In the field where the polje is located, temperature decreases below the Mediterranean coastal strip. In addition, annual temperature ranges around 13 C as a result of the altitude and continentality. Annual temperature range increases in this area and summer drought decreases in a relative amount revealing a transition of the Mediterranean and steppe climates. Also known as *Semiarid Continental Climate* (Atalay, 2010), the specific climate has an irregular precipitation regime and distribution. Climate analysis was carried out on average of the 56-year long observations between 1958 and 2013. Maximum temperatures in Elmalı were found to be in July (24,2 C) and August (24,1 C), while minimum temperatures were recorded in January (2,3 C). It was revealed that the temperature remains above annual average values from May to November and amplitude is higher than coastal parts (21,9 C). Maximum temperatures in the field reveal that the temperature is usually above 30 C in July (35,4 C) and August (35,6) due to the continentality, while it is lowest in January as 13,7 C. Throughout the polje, which look like a wide frost hollow, minimum temperatures remain above 0 C from May through November, whereas they decrease sharply in winter as much as minimum temperature average of -9,2 C in January.

Average annual rainfall in Elmalı is 496,8 mm, which is lower than the main Mediterranean climate. Again, relief conditions are consequential on decreased rainfall in this field. Not only temperature but also rainfall parameter varies due to the fact that the Taurus system block moist winds, the study area is situated in the transition zone and it is affected from polar air mass especially in interior zones during winter.

In Turkey, air mass moves towards east throughout year becoming one of the most important factors on seasonal distribution of rainfall. During movement of air masses, maximum rain also changes its place (Erinç, 1957). The field receives more than half of annual precipitation during winter (56%), 27 in spring, 10 % in summer and only 7 % of total precipitation in autumn. High rainfall during warm seasons is a sign of climatic transition from the Mediterranean to continental characteristics.

Low or high level of moisture in a certain zone plays an important role on climate. Relative humidity varies depending on water vapor existing in the air and temperature conditions. It is also crucial as a significant indicator of precipitation and evaporation and predictor of amplitude. The field has an average annual humidity of 55,4 %. It is observed that average annual humidity increases during winter as a result of decreased temperature. On the contrary, it decreases in summer since temperature gets higher then. Though maximum value is recorded during December, humidity rate remains above annual average from October through March.

Evaporation is one of the basic sources of moisture in the atmosphere. Thus, evaporation and humidity need dealing together (Koç, 2001). Evaporation anywhere is definitely bound to existence of water. The higher the temperature is, the higher the evaporation amount is. According to the longitudinal observations covering the years between 1958 and 2013, average annual evaporation is 3,3 mm across Elmalı Polje. Evaporation amount is above the average from April to November. Also annual curve of evaporation is seen to correspond to seasonal distribution of temperature. Evaporation reaches maximum levels in warm period, while it decreases down to minimum levels in cold seasons.

RESULTS

Since this study investigates the relationship between the area of Avlan Lake and climate in its neighborhood, first of all, the changes observed in the lake zone were identified. Afterwards, such changes were examined after being divided into three as the period when the lake existed (before 1980), the dry period (from 1980 to 2001) and refilling of the lake (between 2001 and 2013). Climatic data were also examined by periods given above and analyzed with Mann-Kendal Test, Sen's Slope Estimate and Continentality Indices.

In order to delineate the lake zone, Landsat MSS and Landsat TM as well as Landsat OLI/TIRS satellite images for different years were checked. It was understood from the satellite images that surface of Avlan Lake was around 910 hectares in 1975. However, the lake did not exist according to the images between 1980 and 2001 or available from years 1984, 1985, 1987, 1988, 1990, 1995 and 1999. Official sources prove that the lake was dried up in 1980 and started to be filled again in late 2001. It is also possible to spot in satellite images that the lake started to appear again and it went through a spatial change after 2001 (Figure 1). According to the satellite images, the lake area increased from 763 hectares in 2002 to 713 hectares, 981 hectares and 1023 hectares in 2009, 2011 and 2014, respectively.

Trend analysis was applied to climatic data collected from the Elmalı station for three different stages of Avlan Lake as period before drying up (A), dry period (B) and refilling period (C). The analysis yielded following results:

Average Temperatures

In relation with temporal changes in average annual and monthly temperatures, both M-K and Sen's Slope Estimate indicate an unnoticeable decrease before the drying up (A) in Elmalı. Similarly, overall trend was seen to be strongly negative in August and December (Table 1). On the other hand, mean yearly temperature shows an insignificant positive trend. Despite an overall increase in average temperatures in Elmalı throughout the dry period (B), such increase was not found significant. However, increase of average temperature was observed to be significant at 5 % in August. As for winter season, decreases were seen, albeit insignificant. On the contrary, mean yearly temperatures display a positive curve through dry period (B). As an example, strongly positive trends can be seen in summer. In addition, increases were observed following refilling of the lake (C). The increases in August and December were found significant at 5 %.

Table 1: *Average temperature trends in Elmalı*

	Pre-intervention period (1958-1980)			De-watering Period (1981-2000)			Re-watering Period (2001-2011)		
	M-K test		Sen's slope	M-K test	p	Sen's slope	M-K test	p	Sen's slope
	Test Z	p	Q	Test Z	p	Q	Test Z	p	Q
Jan	-1,88	+	-0,10	-0,19		-0,01	0,93		0,20
Feb	0,93		0,08	1,17		0,08	0,08		0,08
Marc	0,26		0,01	-1,01		-0,06	-0,16		-0,03
April	-1,32		-0,06	-0,26		-0,02	0,94		0,12
May	-0,32		-0,02	1,04		0,08	-0,55		-0,08
June	0,08		0,00	1,50		0,06	-0,55		-0,04
July	0,61		0,02	2,01	*	0,11	0,55		0,07
Aug.	-2,17	*	-0,08	1,73	+	0,04	2,18	*	0,40
Sept.	0,42		0,01	-1,24		-0,01	1,33		0,17
Oct.	0,5		0,03	0,23		0,01	-0,95		-0,09
Nov.	-1,3		-0,05	1,30		0,10	0,31		0,03
Dec.	-2,99	**	-0,12	0,68		0,05	2,26	*	0,30
Av.	-1,48		-0,02	1,72	+	0,04	0,93		0,11

** Significant increase/decrease at level 5 % (±1,96) ** Significant increase/decrease at level 1 % (±2,58)*

Average Minimum Temperatures

During the period before the drying up (A), yearly minimum temperature displayed a positive direction (Table 2). It is possible to see increases at times in a year. Such increase is as strong as 1 % in August. Still, negative trends were detected in winter such that it was 5 % in December. Though minimum temperatures have a negative tendency in autumn and spring during the dry period (B), the tendency was positive in general. However, the trend was not significant at any time throughout year. Specifically, no significant trends were found in dry period or no decreases were seen in the period following rewatering except for several months. Lastly, analysis did not yield strong trends in any particular month.

Table 2: *Minimum temperature trends in Elmalı*

	Pre-intervention period (1958-1980)			De-watering Period (1981-2000)			Re-watering Period (2001-2011)		
	M-K test		Sen's slope	M-K test	p	Sen's slope	M-K test	p	Sen's slope
	Test Z	p	Q	Test Z	p	Q	Test Z	p	Q
Jan	-1,19		-0,16	0,32		0,05	-0,79		-0,28
Feb	2,17	*	0,27	0,68		0,14	0,67		0,07
Marc	0,48		0,04	0,33		0,07	-0,79		-0,18
April	0,16		0,01	-0,88		-0,05	1,29		0,15
May	1,08		0,08	0,62		0,05	0,00		-0,01
June	-0,16		0,00	0,16		0,00	0,00		0,01
July	0,85		0,04	1,75	+	0,10	0,86		0,05
Aug.	2,88	**	0,13	0,65		0,03	0,49		0,02
Sept.	1,69	+	0,15	-0,88		-0,06	0,31		0,04
Oct.	1,06		0,08	0,52		0,05	0,00		-0,01
Nov.	-0,48		-0,06	-0,06		-0,03	1,34		0,39
Dec.	-1,99	*	-0,14	1,14		0,10	1,22		0,22
Av.	1,00		0,04	1,01		0,02	0,43		0,03

* Significant increase/decrease at level 5 % (±1,96) ** Significant increase/decrease at level 1 % (±2,58)

Average Maximum Temperatures

Maximum temperatures displayed slight increases up to June in the period before drying up (A), while the values were replaced by a decreasing trend in the second half of the year (Table 3). Although there was a negative trend in average annual temperature, Z value is meaningless and also Q value is equal to 0. To put in another way, no specific trend was found. A decrease was found in temperatures obtained from Elmalı after June during the period before the drying up (A). However, throughout the years when Avlan Lake was dry (B), an overall increase was determined in maximum temperatures. In turn, yearly maximum temperature shifted in a positive direction by 5 %. Similarly, a strong increase was seen in August by 1 %. Apart from this, while a weak negative trend was seen in March, the trend was not applicable in April due to Q value equal to 0. Lastly, in refilling period (C), direction of maximum temperatures in Elmalı changes throughout year. To note, no specific trend was seen in May (Q=0).

Table 3: *Maximum temperatures trend in Elmalı*

	Pre-intervention period (1958-1980)			De-watering Period (1981-2000)			Re-watering Period (2001-2011)		
	M-K test		**Sen's slope**	**M-K test**	**p**	**Sen's slope**	**M-K test**	**p**	**Sen's slope**
	Test Z	**p**	**Q**	**Test Z**	**p**	**Q**	**Test Z**	**p**	**Q**
Jan	0,45		0,03	1,56		0,13	-0,92		-0,15
Feb	1,43		0,14	1,43		0,11	0,79		0,08
Marc	0,40		0,02	-0,65		-0,07	-0,43		-0,19
April	1,06		0,07	-0,03		0,00	0,06		0,05
May	0,11		0,01	0,52		0,07	0,00		0,00
June	-0,21		-0,02	1,14		0,09	1,10		0,15
July	-0,45		-0,03	1,85		0,12	0,74		0,13
Aug.	-1,22		-0,06	2,76	**	0,16	-0,43		-0,07
Sept.	-1,56		-0,12	0,26		0,01	1,29		0,13
Oct.	1,43		0,10	0,20		0,01	-0,55		-0,08
Nov.	-1,72		-0,10	1,04		0,15	1,23		0,10
Dec.	-1,43		-0,09	0,26		0,02	1,34		0,19
Av.	-0,11		0,00	2,04	*	0,08	0,06		0,02

* Significant increase/decrease at level 5 % (±1,96)   ** Significant increase/decrease at level 1 % (±2,58)

Precipitation

Trend of precipitation was not fixed throughout year before the drying up (A) (Table 4). Still, the trend did not reach 5 % in any particular month. Sen's Slope Estimate yielded no particular trend in July (Q=0,0). Differences among months are not found statistically significant in spite of having a slight negative impact on average annual precipitation. Reference was made to precipitation rates between 1981 and 2000 for dry period (B) and a weak trend downwards was observed in winter. The slope value was calculated as 0 in July and September. Annual total precipitation values show a decreasing tendency in general, though not so strong. It was seen in analysis results regarding the last period (C) that precipitation rates decreased in spring still being insignificant. Different from previous periods, precipitation showed a tendency at 5 % in September and November, former being positive while the latter negative. Despite all these, such significant trends did not affect annual total precipitation rates. Rather, Z test and slope values yielded results close to 0.

Table 4: *Precipitation trends in Elmalı*

	Pre-intervention period (1958-1980)			De-watering Period (1981-2000)			Re-watering Period (2001-2011)		
	M-K test		**Sen's slope**	**M-K test**	**p**	**Sen's slope**	**M-K test**	**p**	**Sen's slope**
	Test Z	**p**	**Q**	**Test Z**	**p**	**Q**	**Test Z**	**p**	**Q**
Jan	-0,66		-0,78	-0,88		-1,70	0,31		4,56
Feb	-0,03		-0,22	-0,94		-1,22	1,87	+	4,88
Marc	0,95		0,80	0,55		0,70	-0,23		-0,77
April	1,43		0,99	0,81		0,80	-0,47		-0,63
May	-0,50		-0,34	0,81		0,65	-0,08		-0,32
June	0,69		0,40	0,26		0,36	0,47		1,30
July	0,00		0,00	-0,03		0,00	0,08		0,10
Aug.	0,90		0,13	0,39		0,12	0,00		-0,33
Sept.	-1,82	+	-0,41	0,03		0,00	2,11	*	2,34
Oct.	1,90	+	1,58	0,39		0,32	1,87	+	6,97
Nov.	0,00		-0,04	0,03		0,08	-2,34	*	-6,45
Dec.	-0,66		-1,43	-0,36		-0,56	-0,78		-7,08
Av.	-0,53		-0,19	-0,68		-0,23	0,00		-0,03

** Significant increase/decrease at level 5 % (±1,96) ** Significant increase/decrease at level 1 % (±2,58)*

Relative Humidity

Relative humidity values, despite showing a tendency to increase throughout year except for December before the drying up (A), were found significant in September only (5 %) (Table 5).

Table 5: *Humidity trends in Elmalı*

	Pre-intervention period (1958-1980)			De-watering Period (1981-2000)			Re-watering Period (2001-2011)		
	M-K test		Sen's slope	M-K test	p	Sen's slope	M-K test	p	Sen's slope
	Test Z	p	Q	Test Z	p	Q	Test Z	p	Q
Jan	1,19		0,20	-1,01		-0,32	2,01	*	0,89
Feb	1,24		0,28	-1,36		-0,32	2,87	**	1,60
Marc	1,86		0,29	-0,68		-0,18	0,06		0,11
April	1,41		0,24	0,32		0,12	0,55		0,36
May	0,34		0,10	-0,36		-0,07	0,31		0,20
June	0,00		0,00	-1,04		-0,25	-0,43		-0,25
July	0,34		0,21	-0,29		-0,08	0,18		0,04
Aug.	1,47		0,33	0,94		0,20	-1,89		-0,74
Sept.	2,14	*	0,26	0,84		0,10	-0,79		-0,56
Oct.	0,85		0,20	0,55		0,27	1,47		0,79
Nov.	1,07		0,20	-1,20		-0,41	0,06		0,18
Dec.	0,00		-0,01	0,16		0,07	0,43		0,19
Av.	1,69		0,20	-0,26		-0,04	1,40		0,38

** Significant increase/decrease at level 5 % (±1,96) ** Significant increase/decrease at level 1 % (±2,58)*

Sen's slope test revealed no slope for June being equal to 0. However, the direction of the slope shifted during drying period replacing the increase with decrease. Except for August, September, October and December, relative humidity was seen to show a negative tendency. After recollection of water in Avlan Lake (C), the humidity values started increasing again. For example, the trend became positive except for June, August and September. It was even significant in January (5 %) and February (1 %).

Evaporation

Evaporation values have a tendency to decrease in winter but increase in summer during the period prior to the drying up (Table 6). These tendencies have statistical significance in those seasons. As for the whole year, the tendency was slight but upwards. In that period (B), evaporation took place from January to September. Thus 8 months of the year were included in calculations. Though there is a positive tendency in March, April and July within this period, such tendency is not considered to be significant. In other months, no specific slope was found (Q=0). As for the period after release of water again (C), calculations were made on the basis of 8 months since evaporation findings were not available for September, October, November and December. As a result, the tendency was found positive in January and February, while it was negative in April, June, July and August. The values were not found significant in any month. For March and May, no tendency was found (Q=0).

Table 6: *Evaporation trends in Elmalı*

	Pre-intervention period (1958-1980)			De-watering Period (1981-2000)			Re-watering Period (2001-2011)		
	M-K test		Sen's slope	M-K test	p	Sen's slope	M-K test	p	Sen's slope
	Test Z	p	Q	Test Z	p	Q	Test Z	p	Q
Jan	-0,53		0,00	0,10		0,00	0,31		0,03
Feb	-0,65		0,00	0,23		0,00	0,47		0,02
Marc	-3,81	***	-0,01	0,75		0,02	0,00		0,00
April	1,46		0,06	1,54		0,03	-0,08		-0,02
May	1,51		0,10	-0,23		0,00	0,00		0,00
June	1,32		0,14	0,39		0,00	-0,31		-0,02
July	2,38	*	0,20	1,07		0,02	-1,25		-0,08
Aug.	2,33	*	0,10	0,84		0,00	-0,16		-0,01
Sept.	3,07	**	0,11						
Oct.	1,78		0,04						
Nov.	-1,67		-0,03						
Dec.	-2,96	**	-0,01						

** Significant increase/decrease at level 5 % (±1,96) ** Significant increase/decrease at level 1 % (±2,58)*

Frost Days

The number of frost days in the period before the drying up (A) showed a tendency downwards in spring; whereas it increased in October, December and January (Table 7). Such tendencies were found significant only in December (5%).

Afterwards, in dry period (B), number of frost days increased in January, March and April; however, such increase was not statistically significant. As for the last period (C), the values were positive only in March and December. This was reflected to mean values and shifted to the direction opposite previous periods. In other words, the number of frost days seems to decrease in the last period regarding the study area. Since the study area resembles a frost hole, the analysis did not show a clear relationship between water mass and number of frost days in that regard.

Table 7: *Number of frost days*

	Pre-intervention period (1958-1980)			De-watering Period (1981-2000)			Re-watering Period (2001-2011)		
	M-K test		Sen's slope	M-K test		Sen's slope	M-K test		Sen's slope
	Test Z	p	Q	Test Z	p	Q	Test Z	p	Q
Jan.	1,12		0,23	0,59		0,14	-0,06		-0,08
Feb.	-0,39		-0,14	-0,23		-0,04	-1,12		-0,41
Mar.	-0,73		-0,15	0,85		0,31	0,37		0,24
Ap.	-0,26		0,00	0,23		0,00	-0,71		0,00
Oct.	0,36		0,00	-0,90		0,00	0,61		0,00
Nov.	0,79		0,11	-1,27		-0,27	-1,16		-0,31
Dec.	2,25	*	0,46	-0,29		-0,09	0,00		0,00
Av.	1,00		0,11	0,06		0,01	-0,25		-0,03

** Significant increase/decrease at level 5 % (±1,96) ** Significant increase/decrease at level 1 % (±2,58)*

Continentality/Maritime

Continentality is associated with distance from the sea, altitude and geomorphologic factors blocking the sea effect. The shift/change of continentality across study area was analyzed by using Sezer's continentality indices based on annual range of temperature. According to Sezer's indices, Elmalı is covered by "maritime-transitional continental climate". Climatic class values applicable for the Elmalı Station were found to be 25,2 %. Tendencies of continentality indices were calculated separately for periods before the drying up (A), during dry period (B) and after dry period (C). There was a positive slope in the period both before the drying up (A) and during the drying up (B), while the slope was negative in the last period (C) (Table 8). It can be inferred from these findings that temporal tendency of continentality indices of Elmalı is contradictory to drying up of Avlan Lake. To exemplify, the slope was seen to be positive during the period when the lake zone was shrunk and the lake was dried up; however, it showed a negative tendency after the dry period, when the lake area started to expand upon release of water again.

Table 8: *Continentality trends in Elmalı*

Period			M-K test		Sen's slope
		n	Test Z	p	Q
1958	**1980**	23	1,53		0,12
1981	**2000**	20	0,84		0,11
2001	**2011**	13	-0,62		-0,17

** Significant increase/decrease at level 5 % (±1,96) ** Significant increase/decrease at level 1 % (±2,58)*

Land Use

The area of the water body was analyzed using remote sensing techniques, Landsat data were used. The area of water body can have impact on the regional climate; however, land use is also very important for climate forming in local extent. Changes of land use can be one of the most important factors influencing local/regional climate. One of the most important factors which influence climate elements is land usage and the changes which occur on land cover. These changes should be well considered in order to approach to the subject from a wider perspective. Significant periodical alterations can be seen on the land cover between 1975 and 2011.

Table 9: *Changes in land use around Avlan Lake (1975-2011)*

Year	Grassland	Avlan Lake	Irrigated agriculture	Dry farming
1975	11034	910	3354	3436
1987	8309	824	6315	3286
2001	8066	0	7970	2698
2011	8541	981	3916	5296

The most important climate element which changes periodically on a certain level in the study is humidity. When we look at the relationship between the changes in land usage and the level of humidity it is seen that especially lands with irrigated farming are enlarging on the other hand forage, lands with dry farming and lakes are diminishing. Moreover, during the drying period, it is also seen that the level of humidity is also in a downward trend and in return lands with irrigated farming is decreasing and forage, lands with dry farming and lake lands are expanding. It is also seen that the level of humidity is increasing during the pre-drying and post-drying periods. As a result of these observations it is obvious that there is a strict correlation between changes in land usage and humidity. Hence in addition to decreasing of lake lands, changes in land usage are also an important factor which affects the alterations in climate elements (Table 9)

Qualitative Method (Face to Face Interviews)

Face-to-face interviews were held with heads of Göltarla, Karamık and Yakaçiftlik Villages as it is a widely used qualitative technique. The interviews included clear open-ended questions to describe what changes have been seen in local people's life as a result of temporal change of the lake zone. The interviewees were above 50 years. While data obtained from the interviewees were found partially inconsistent, significant changes were reported to result from drying up of Avlan Lake. Those changes include dying trees in forests, decreased population of birds, and increased frost. Some indirect changes were referred such as decreasing yield value of most crops mainly apples and worsening of the flora in close neighborhood of the lake because of the drying up. Furthermore, it was argued that agricultural production first increased due to allocation of dried lands to three villages nearby. However, drought emerged later as a result of drying up of the lake and irrigation was scarce in the area. So, yield rates decreased. As far as this study is concerned, there can be two reasons for dying of forests and decrease of yield rates. First, it can be due to the climate since there was found a decrease in humidity at the Elmalı station during the period when the lake was dried up albeit insignificant. Also frost increased at insignificant level during spring months, which is the growing period. The change in climate elements probable had a negative effect on cedar trees spread on a large area and particularly sensitive to the climate along with growing phase of the agricultural products in the region. As an example, a study carried out in Western Mediterranean Region showed that cedar forests around Avlan Lake are much more closely related with climate than all other species across the region (Erkan ve ark., 2004). Especially frost can affect cedars negatively as they shoot forth during summer. Moreover, cedars are susceptible to early forest during autumn (Oğurlu ve Avcı, 1999). Nevertheless, no relationship was found between temporal change of the lake area and number of frost days in the study.

DISCUSSION AND CONCLUSION

This study addresses probable changes which took place in the climate around Avlan Lake as a result of drying up of the lake. To this end, the values such as temperature, precipitation, humidity and evaporation were subjected to trend analysis by time. As a conclusion, apparently no significant climatic changes were seen as a result of drying up of Avlan Lake, and current changes can be interpreted as individual fluctuations across certain years. The existing climatic oscillation tendencies recorded in Elmalı can be due to the effect of general atmosphere circulation on the land rather than the result from drying up of Avlan Lake. Shrinking or removing of water surface inevitably has some environmental impacts. Specifically, such impact seems to have taken place at ecological level rather than climatic level in and around Avlan Lake. Hence, it can be suggested that drying up of Avlan Lake has disrupted the ecosystem instead of climate and such consequences can be put forward in future research. The reason is, as mentioned above, physical and chemical changes in the ecosystem disturb communication of the environments and flow and interaction of energy, cause environmental changes and undermine the cycle of matter. Killing of the buffer zone between the Lake Zone and forests upsets the cycle in ecosystem deeply. The reason is that such buffer zones function as a corridor between the lake and forests and agricultural lands and ensure proper continuation of flow of the wild life, energy cycle and the whole ecosystem (Macdonald ve ark., 2006). Bearing this in mind, forests adjacent to lakes and other buffer zones need to be preserved**.**

More importantly, the ecosystem could have gone through a change as a result of drying up of the lake. It is known that existence of water areas in a particular region not only contributes to the population of birds and other mammalian in that region but also controls the flow of food and energy in their location (Macdonald ve ark., 2006). Furthermore, birds and other mammalian play an important role for ecosystems. In particular, birds are crucial for opening of closed seeds of trees and spreading of these seeds (Cordeiro ve Howe, 2003; Şekercioğlu ve ark., 2004). In addition, birds eat harmful pests thus help trees be much more robust and produce fruit much better. Unfortunately, upon drying up of Avlan Lake, water bird population decreased in both study area and its close vicinity and wild life was affected negatively

(Başaran ve ark., 2008). Departing from these findings, study area together with its close vicinity might have faced negative changes in relation with germination, disease risk and yield rate of crops because of drying up of the lake. Furthermore, killing of the buffer zone between the Lake Zone and forests upsets the cycle in ecosystem deeply. The reason is that such buffer zones function as a corridor between the lake and forests and agricultural lands and ensure proper continuation of flow of the wild life, energy cycle and the whole ecosystem (Macdonald ve ark., 2006). Bearing this in mind, forests adjacent to lakes and other buffer zones need to be preserved. Also, the wetlands like Avlan Lake which has a big water reservoir play an important role in using nutrients to keep agricultural, industrial and domestic waste and to purify the organic and inorganic matter of waste water (Huryna ve ark., 2014). These features have vital importance in ecosystems around the lake and wetlands.

Avlan Lake also contributes to underground water in its region since there is a close relationship between underground water level and geological structure and surface waters in that latter feeds the former (Winter, 1999). Especially in areas like Elmalı Polje encompassing Avlan Lake where carbonated rock are prevalent, drainage is distorted and river network has an irregular regime, underground water flow is well developed (Ekmekçi, 1993). Therefore, it seems that drying up of that area had its consequences on the underground water level and thus ecological conditions.

Besides all these, Avlan Lake is subject to areal expansion/shrinking on a seasonal basis. No matter how much summer aridity causes areal shrinking of the lake, areal change is also affected by irrigation around the lake and building of irrigation ponds and dams on rivers running into the lake. For example, Çayboğaz Dam is built on the Akçay River, which is the main source of the lake. Built for the purpose of irrigation, the dam was started to be constructed in 1986 and completed in 2002 (Devlet Su İşleri Genel Müdürlüğü, 2014). At the same time, the waters of Akçay on the ground of the polje are used for irrigation instead of being let to flow into the lake via ducts.

As a conclusion, apparently no significant climatic changes were seen as a result of drying up of Avlan Lake, and current changes can be interpreted as individual fluctuations across certain years. The existing climatic oscillation tendencies recorded in Elmalı can be due to the effect of general atmosphere circulation on the land rather than the result from drying up of Avlan Lake. Shrinking or removing of water surface inevitably has some environmental impacts. Specifically, such impact seems to have taken place at ecological level rather than climatic level in and around Avlan Lake. Hence, it can be suggested that drying up of Avlan Lake has disrupted the ecosystem instead of climate and such consequences can be put forward in future research. The reason is, as mentioned above, physical and chemical changes in the ecosystem disturb communication of the environments and flow and interaction of energy, cause environmental changes and undermine the cycle of matter.

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