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Investigation of Aksehir and Eber Lakes (SW Turkey) Coastline Change with Multitemporal Satellite Images

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Abstract Detection and analyses of coastline changes are an important task in environmental monitoring. Several factors such as geology, hydrology, climate impact, environmental problems etc. play an important role in this change. The main objective of this study is to determine coastline change in the Aksehir and Eber lakes (SW, Turkey) by using different remote sensing methods on the multitemporal satellite images. In present study, Landsat MSS (1975), Landsat TM (1987), Landsat ETM+ (2000) and ASTER (2006–2008) satellite images were used. In order to explain reasons of coastline change, geological, hydrogeological and hydrological investigations were carried out. Also, surface area and volume calculations were performed with the aid of bathymetric map which was digitized by using the Arc GIS 9 version software program. The obtained data show that precipitation, evaporation and surface flow are effective in the Aksehir and Eber coastline change. The Eber Lake was evaluated with level measurements due to aquatic plants covered surface of the lake. The coastline change of the Eber Lake is related to hydraulic factors. The Aksehir Lake volume and surface area have decreased 1.11 km^3 and 257.95 km^2, respectively from 1975 to 2006 years. Furthermore, the Lake Akşehir was dried up completely in 2008.

Keywords Aksehir Lake · Coastline change · Hydrology · Remote sensing

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1 Introduction

The coastline is defined as the line of contact between land and a body of water (Pajak and Leatherman 2002; Alesheikh et al. 2004). It is the most dynamic part of coast zone since its shape is affected by many factors, such as hydrography, geology, climate, and vegetation (Guariglia et al. 2006; Zhao et al. 2007). Coastal zone monitoring is an important task in sustainable development and environmental protection. In recent years, coastal zones, probably more than any other parts of the earth have been exposed to pressure and processes of change (Sesli et al. 2008). These changes are urbanization, acute nature and environmental problems, retreat of coastal occupations, climate impact etc. (Anker et al. 2004).

Determination of coastline changes of water bodies by satellite images and remote sensing methods became increasingly important over the recent decades because of both the problem of global climate change and worsening ecology (Alemayehu et al. 2006; Alesheikh et al. 2007; Ekercin 2007; Durduran 2009). Satellite optical images are simple to interpret and easily obtainable (Van and Binh 2008). On the other hand, remote sensing data can be integrated with Geographic Information Systems (GIS) which are an essential tool for analyzing and extracting more reliable and consistent information by using satellite image as a base data (Bausmith and Leinhardth 1997; Goodchild 2001; Jaiswal et al. 2002; Durduran 2009). In case these techniques are supported with geological, hydrogeological and hydrology data, more reliable results can be obtained.

In recent years, water levels of the lakes in Turkey are characterized by considerable decreases due to aridity and less rainfall. Many of these lakes are located within the Lake District in the southwest of Turkey. The Aksehir and Eber lakes which are the subject of this study are also important lakes in the Akarcay basin in the Lake District (Fig. 1). Akarcay basin is a closed basin and covers an area of 7.300 km^2 in the western Anatolia. The basin is occupied largely by the Akarcay plain that extends roughly in an east–west direction and comprises an almost flat-lying bottom of a Pleistocene lake. The plain slopes gently towards the Aksehir Lake in the east. Internal drainage is maintained by the perennial Akarcay Stream flowing from west to east. This drainage system feeds the Eber Lake which is connected with the Aksehir Lake in the east (Merter et al. 1986; Dogdu and Bayarı 2005).

Remote sensing technology and GIS were applied in this study to detect and analyze the coastline changes in the Aksehir and Eber lakes. In order to support obtained results, geological, hydrogeological and hydrological data were used as different from previous researches.

2 Data Set

To determine coastline change in studied lakes, Landsat Multispectral Scanner (MSS), Landsat Thematic Mapper (TM), Landsat Enhanced Thematic Mapper (ETM+), and ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) satellite images were used in present study. Each image was acquired in different dates: Landsat MSS in 1975, Landsat TM in 1987, Landsat ETM+ in 2000, ASTER in 2006 and 2008. Landsat MSS image has four band and 79 m spatial resolution of pixel. Landsat TM image has pixel resolution of band 1, 2, 3, 4, 5, 7

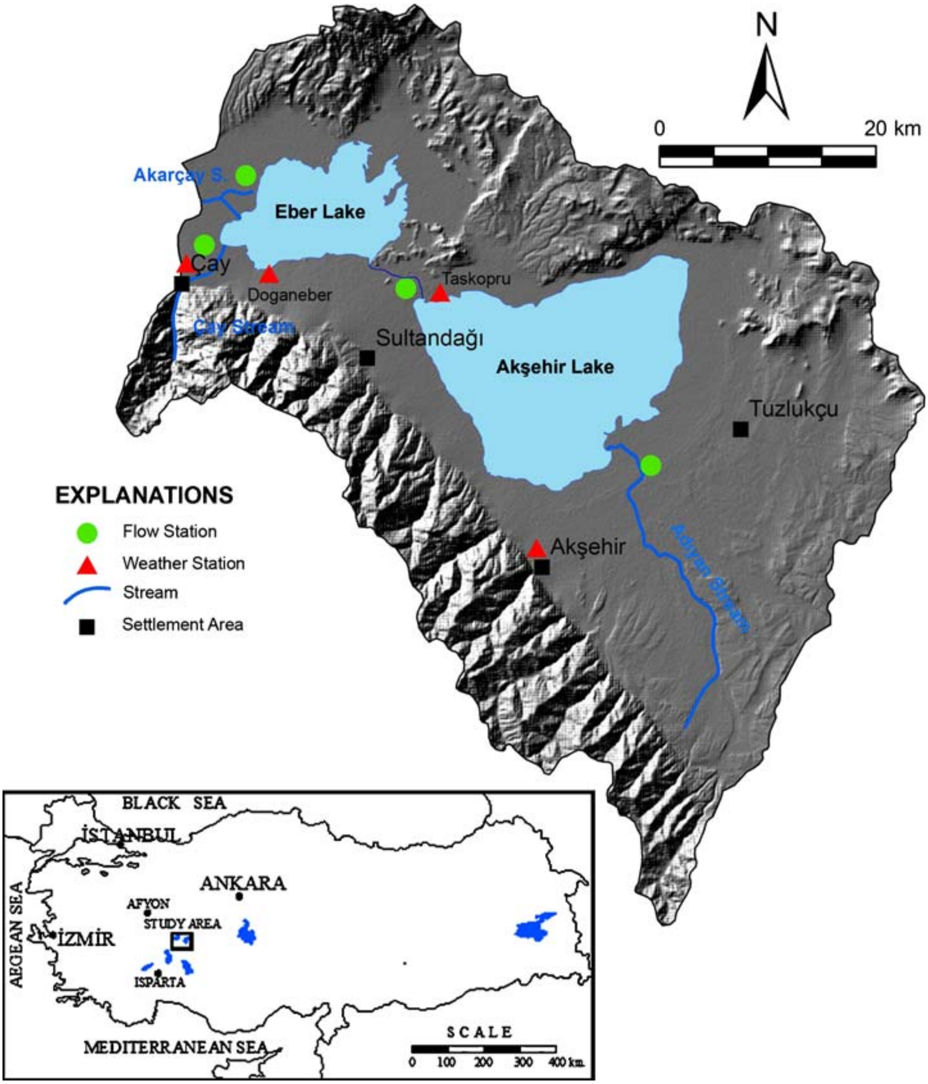


Fig. 1 The location map

in 30 m, ETM+ band 8 particularly in 15 m which were archived on the Global Land Cover Facility server (http://glcf.umiacs.umd.edu/). ASTER image has three groups of bands with different pixel resolutions: VNIR bands in 15 m, SWIR bands in 30 m and TIR bands in 90 m (Van and Binh 2008). The properties of images are given in Table 1. In order to evaluate hydrologic impact onto the coastline change, precipitation and evaporation data were used which are measured in the Dogan-Eber, Taskopru, Aksehir and Cay meteorological stations. Bathymetric map of the Aksehir Lake prepared by State Hydraulic Works (SHW) (1998) were used for calculation of the lake volume. Topographical and bathymetric maps were digitized

Table 1 Properties of satellite images

Acquisition date	Satellite/sensor	Resolution			
		Spatial (m)	Temporal (day)	Radiometric (bit)	Spectral (band)
28.05.1975	Landsat MSS	80	18	7	4
11.09.1987	Landsat TM	30	16	8	7
04.07.2000	Landsat ETM+	30	16	8	8
06.08.2006	Terra\ASTER	15	48	8	14
11.08.2008	Terra\ASTER	15	48	8	14

by ArcGIS 9.0 software program. The geological map was used for hydrogeological evaluation of the research area which was prepared by Tezcan et al. (2002).

3 Methodology

Remote sensing and GIS techniques were used to extract coastline change in the lakes. These techniques are digital image processing and geographic overlay (Alesheikh et al. 2007; Li et al. 2001; Frohn et al. 2005; Alexandridis et al. 2006; Moore 2000). Various methods for coastline extraction from optical imagery have been developed. Coastline can even be extracted from a single band image, since the reflectance of water is nearly equal to zero in reflective infrared bands, and reflectance of absolute majority of land covers is greater than water (Kelley et al. 1998; Alesheikh et al. 2007; Maiti and Bhattacharya 2009).

3.1 Geometric Correction

In this study, we collected five multitemporal and multisensor satellite images from 1975 to 2008 (Table 1). Each image was geometrically corrected and rectified to the European Datum 1950 (ED 50) and the Universal Transverse Mercator (UTM-Zone 36) coordinate system using the second-order polynomial geocoding model and the nearest neighbour resampling method. To improve the positional accuracy, 25 ground-control points (GCPs) were used for rectification, with root mean square (RMSE) error of less than 0.5 pixel. The required GCPs were obtained from Topcon Hyper+ DGPS using Real Time Kinematic (RTK) data collected method. The geometric correction was performed using Erdas Imagine 8.7 image processing software (ERDAS, Inc., Atlanta, Georgia, USA).

3.2 Atmospheric Correction

Atmospheric correction of images is necessary to obtain correct results because electromagnetic energy radiated by objects exhibits different properties under different atmospheric conditions depending upon the illumination and the geometrical shape of the object, mist, fog and haze in the air. The objective of atmospheric correction is to retrieve the actual 'clear sky' surface reflectance from remotely sensed imagery by removing the specific meteorological related atmospheric noise from a specific scene (Alparslan et al. 2007). In this study, the atmospheric correction was done using Erdas Imagine 8.7 image processing software with haze reduction method.

3.3 Coastline Detection

The near infrared bands (NIR) are quite suitable for separating water bodies from lands in the coastline detection studies (Van and Binh 2008). Therefore, lake water body was extracted from NIR band combinations of each image using supervised classification method. Then, final coastline extraction is converted into vector format and exported into ArcGIS software for analyzing changes in 1975–2008. Figure 2 illustrates the steps of the using method.

The lake surface area was calculated using ArcGIS 9.0 software program after the determination of coastline of the lake. Also, with the aid of digitized bathymetric map the volume calculation was performed by the same software program for 1975, 1987, 2000, 2006 and 2008 years. Thus, lake surface area and volume changes were examined in this study.

4 Results and Discussion

In this study, 178/033 scenes of Landsat MSS (1975), Landsat TM (1987), Landsat ETM+ (2000) and ASTER (2006–2008) images were used for the analyses (Fig. 3).

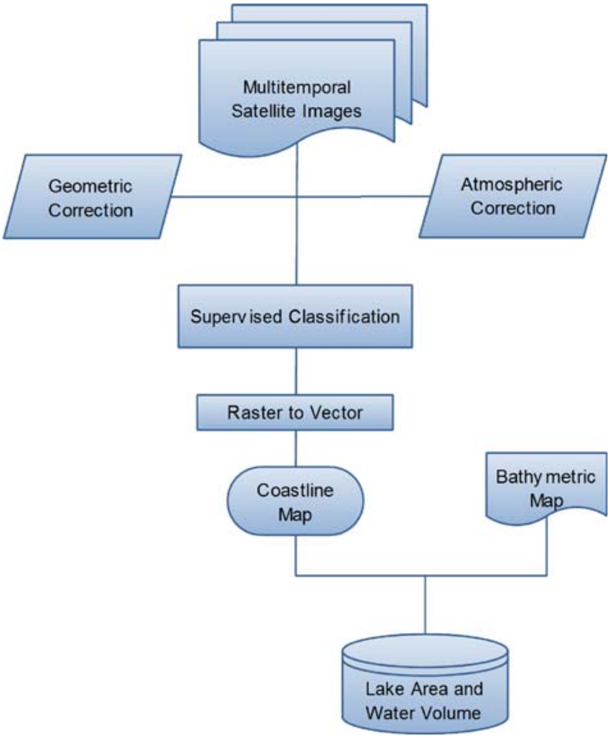
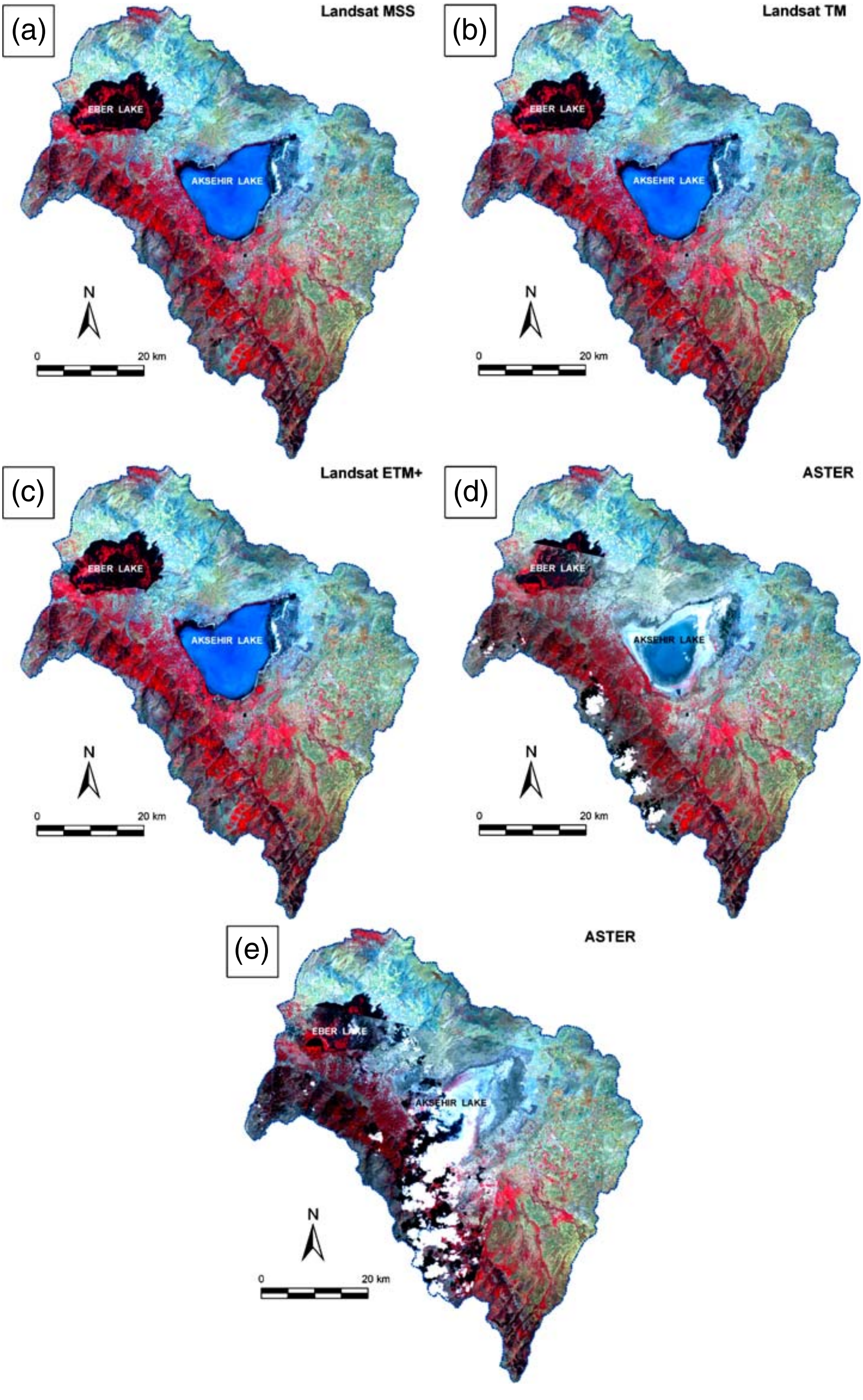


Fig. 2 Flowchart of extracting coastlines from multitemporal satellite images


(a)
Landsat MSS
EBER LAKE
AKSEHIR LAKE
N
0
20 km
(b)
Landsat TM
EBER LAKE
AKSEHIR LAKE
N
0
20 km
(c)
Landsat ETM+
EBER LAKE
AKSEHIR LAKE
N
0
20 km
(d)
ASTER
EBER LAKE
AKSEHIR LAKE
N
0
20 km
(e)
ASTER
EBER LAKE
AKSEHIR LAKE
N
0
20 km

◀ **Fig. 3** Satellite images: **a** Landsat MSS (1975), **b** Landsat TM (1987), **c** Landsat ETM+ (2000), **d** ASTER (2006) and **e** ASTER (2008) images

Aksehir Lake coastline changes were determined using Landsat–ASTER NIR band combinations (Fig. 4). Surface area in the Aksehir Lake was determined using the ArcGIS 9.0 version software program in different dates. While the lake surface area was 342.89 km^2 in 1975, it was decreased to 84.94 km^2 in 2006. The lake surface area decreased at a ratio of 75.23% (257.95 km^2) in this period (Table 2). The level changing of the Aksehir Lake is directly proportional to rainfall. Table 3 shows that the decreases of water level are not related with evaporation in the lake. While the Aksehir Lake level was 957 m in 1975, it decreased to 953.5 m in 2004 (Fig. 5). In addition, the bathymetric map of the Aksehir Lake was digitized which was prepared by SHW. The Digital Elevation Model (DEM) of the Aksehir Lake topography was created with the aid of the ArcGIS 3D Analyst software program and lake volumes were calculated in different dates. While the lake volume was 1.215 km^3 in 1975, it decreased to 0.104 km^3 in 2006 (Table 2; Fig. 6). Furthermore, the Lake Akşehir dried up completely in 2008.

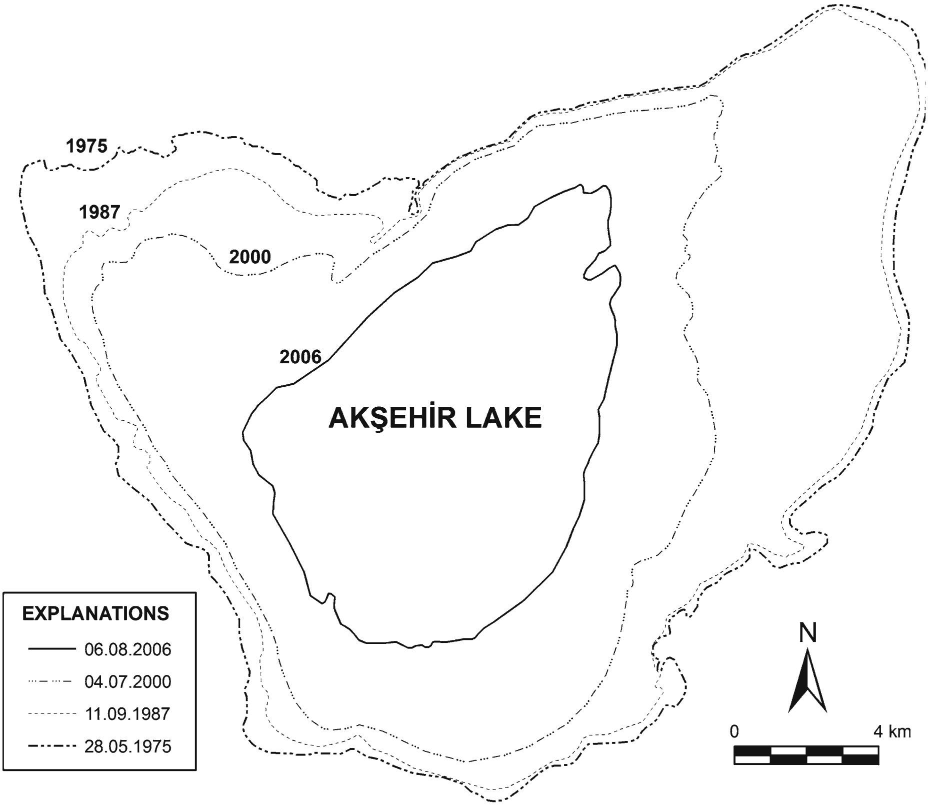


Fig. 4 Aksehir Lake coastline change

Table 2 Mean annual values of the major components of the hydrological budget and morphometric parameters of the Akşehir lake

Period	Annual evaporation (km^3–mm)	Annual precipitation (km^3–mm)	Annual river inflow (km^3)	Morphometry at end of period	
				Area (km^2)	Volume (km^3)
1971–1975	46.77–1295.7	13.96–386.76	0.0721	342.89	1.215
1975–1987	40.28–1115.9	15.94–441.5	0.1568	309.59	1.013
1987–2000	39.25–1087.4	14.23–394.3	0.06596	202.72	0.241
2000–2006	37.32–1033.8	9.91–274.6	0.00257	84.94	0.104

Eber Lake surface are covered with aquatic plants. Therefore, coastal change of the lake can't be determined using satellite images. So, the coastline change was evaluated with the lake level measurements which are performed by SHW. The water level was decreased from 1985 to 1995. In the Eber Lake while the level was 966.9 m in 1985, it decreased to the lowest level, 964.75 m in resent years. A rise was observed from 1996 to 1999 and it again decreased 965.40 m in 2006 (Fig. 5). Sudden changes were observed in the Eber Lake level after stopping discharge to the Aksehir Lake in 1990. According to obtained data, the lake level change is directly proportional with rainfall and surface flow.

In order to analyses the reasons of these coastline changes geologic–hydrogeologic and hydrologic properties of region were examined. River discharge, precipitation, condensation and evaporation are the predominant components of the water balance. Eber and Aksehir lakes are closed basin within the Akarcay basin. The Eber Lake is recharged by rainfall and surface flow. Discharges of the lake were evaporation and flow to the Aksehir Lake until 1990. The flow to the Aksehir Lake is stop because of establishing Eber regulator. Discharging of the Aksehir Lake is only evaporation. It is recharged by surface flows with seasonal and permanent streams of the Aksehir basin and Eber flow until 1990. Infiltration doesn't occur towards the Eber and Aksehir lakes from alluvium due to its having widespread impervious clay levels. Based on hydrogeology and isotopic investigations, Tezcan et al. (2002) interpreted that groundwater doesn't play an important role on the discharge or recharge of the Eber and Aksehir lakes. Therefore, precipitation, evaporation and surface flow data were used to investigate reasons of coastline changes of the lakes.

4.1 Precipitation

Rainfall data were measured in Taskopru meteorological station for Aksehir Lake and Doganeber meteorological station for Eber Lake. The cumulative deviation from annual precipitation curve was plotted using the average annual rainfall data for Doganeber and Taskopru meteorological stations (Fig. 7). The annual average rainfall was determined as 389.06 mm for a period of 36 years of Taskopru meteorological station. The maximum rainfall was 574.7 mm in 1976. The rainfall decreased importantly from 1991 to 2006 in dry period. The annual average rainfall is 341.99 mm for Doganeber meteorological station and the maximum rainfall was 513.9 mm in 1996. The dry period was observed between 1981 and 1995. The uniform period was also observed after 1998 (Fig. 7).

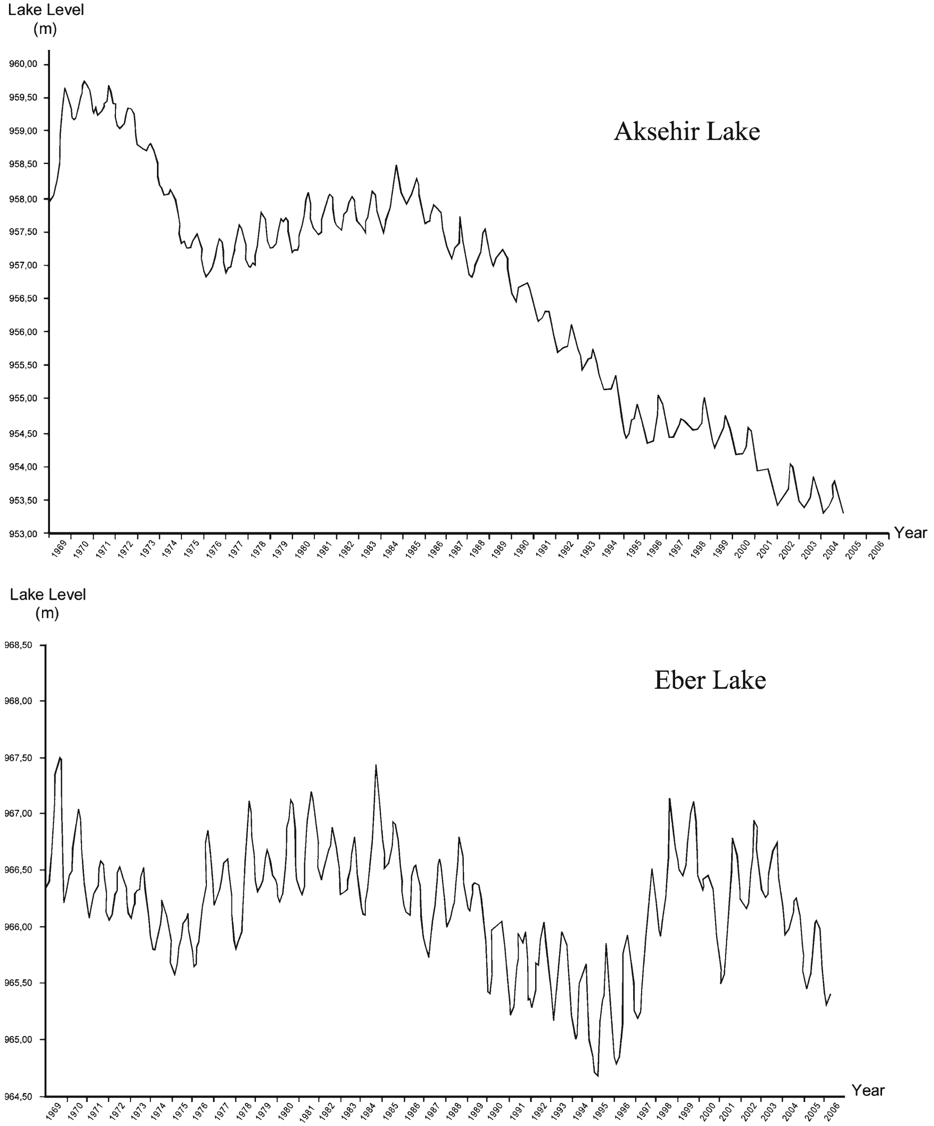


Fig. 5 Akşehir and Eber lakes water level graph

4.2 Evaporation

Evaporation is nowadays the most important water flux. However, it is difficult to determine by direct measurements or calculations. In the research area, evaporation is the most important discharge component of the lakes and measured on the basis of United States Class A pan values. Evaporation pan values are measured for 7 months except for winter months. The absent evaporation data were completed

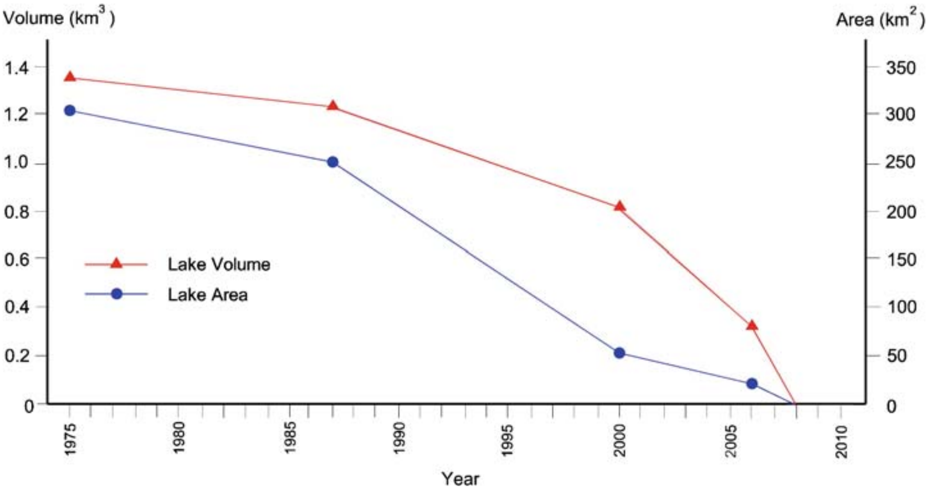


Fig. 6 Exchange of area and volume of the Aksehir Lake according to years

with calculated values using Penman–Monteith method 1 in near meteorological station. The Penman–Monteith formula was given below as:

$$\mathrm{ET_o} = \frac{0.408\Delta\,(R_\mathrm{n} - G) + \gamma\,\frac{900}{T+273}u_2\,(e_\mathrm{s} - e_\mathrm{a})}{\Delta + \gamma\,(1 + 0.34u_2)} \tag{1}$$

where:

$\mathrm{ET_o}$	reference evapotranspiration (mm day^{-1}),
R_n	net radiation at the crop surface (MJ m^{-2} day^{-1}),
G	soil heat flux density (MJ m^{-2} day^{-1}),
T	air temperature at 2 m height (°C),
u_2	wind speed at 2 m height (m s^{-1}),
e_s	saturation vapour pressure (kPa),
e_a	actual vapour pressure (kPa),
$e_\mathrm{s} - e_\mathrm{a}$	saturation vapour pressure deficit (kPa),
Δ	slope vapour pressure curve (kPa °C^{-1}),
γ	psychrometric constant (kPa °C^{-1}).

Nowadays, Penman–Monteith method is accepted as the most widespread and the most valid method due to calculation with energy balance approach taking into consideration whole meteorological factors (Allen et al. 1998). The Aksehir and Cay meteorological stations data were used for evaporation calculations in this method due to their locations close to the lakes. The data calculated until 1998 were taken from Tezcan et al. (2002) and other data were also calculated using meteorological station measurements (Table 3).

Surface of the Eber Lake are covered by aquatic plants. The water loss has been observed from both evaporation from surface lake and transpiration from aquatic plants in the Eber Lake. In wetland, coefficient of plant water consumption value was ordered by Tezcan et al. (2002) according to wind speed and humidity for the Eber Lake. The coefficient is 1.155, 1.165, 1.160 for July, August and September,

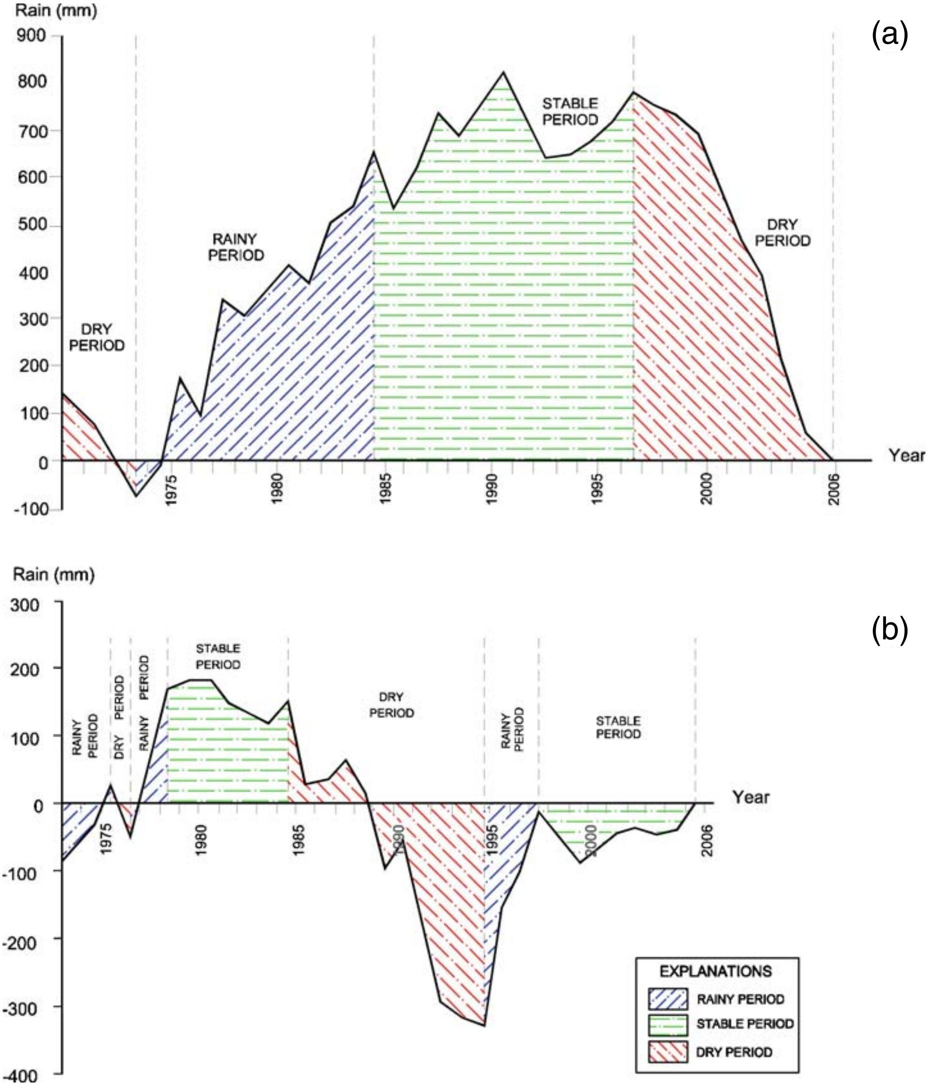


Fig. 7 The cumulative deviation from annual precipitation curves: **a** Taşköprü weather station, **b** Doganeber weather station

respectively, and 1 for June–October months. It was used 0.6 for the other months (Tezcan et al. 2002). The important differences were not observed in the evaporation values (Table 4).

4.3 Flow

Eber Lake is recharged with overland flow from Akarcay and Cay streams. The average flow of Akarcay stream is 5.15 m^3/s. Cay Stream recharges to the Eber Lake with the average flow 0.65 m^3/s. The long-term maximum and minimum flow

Table 3 Evaporation data of the Aksehir Lake

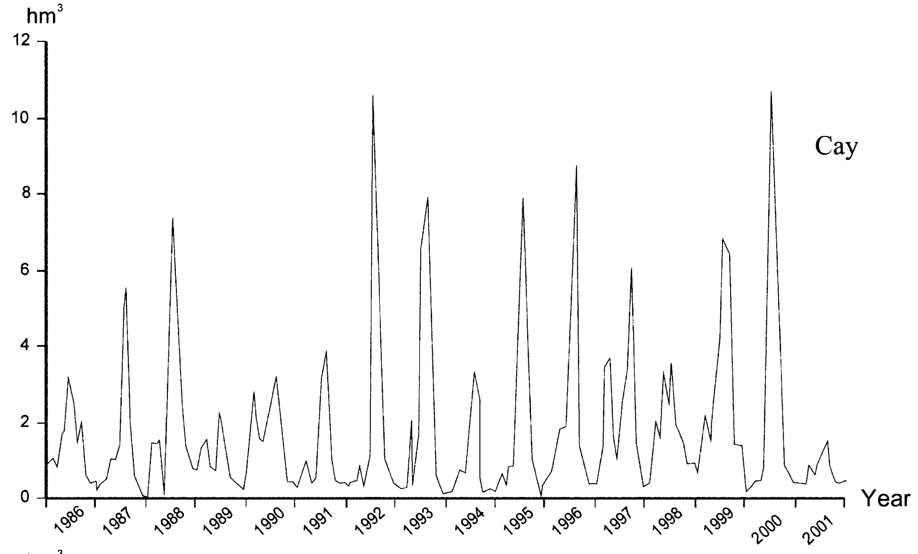
Year	January	February	March	April	May	June	July	August	September	October	November	December	Total
1965	38.3	42.7	67.4	81.5	112.5	147.2	191.4	178.9	120.9	57.4	44.7	38.7	1,121.7
1966	42.1	51.6	70.2	93.5	134.6	153.9	188.8	197.5	132.1	91.9	53.5	40.6	1,250.2
1967	37.8	39.0	59.8	74.3	105.7	148.1	196.8	181.9	118.3	75.1	43.2	36.2	1,116.2
1968	39.4	44.8	63.7	70.4	125.4	162.0	209.3	188.4	12.2	44.8	44.9	37.9	1,043.4
1969	39.3	46.1	68.2	14.6	39.5	121.0	170.3	167.0	119.2	65.0	44.4	38.5	933.1
1970	44.5	51.5	72.2	70.4	125.4	145.8	241.1	227.7	155.6	73.7	44.5	34.9	1,287.5
1971	42.4	46.9	67.5	62.7	121.7	173.2	227.9	225.0	159.8	71.8	43.8	34.3	1,277.1
1972	30.4	34.6	62.5	77.5	148.7	171.1	241.9	198.9	138.7	86.9	44.4	32.7	1,268.4
1973	35.3	47.3	64.2	58.7	186.8	182.3	241.1	196.6	181.7	87.9	43.7	34.9	1,360.5
1974	32.9	41.9	68.7	70.4	131.8	187.6	270.0	195.7	134.8	101.6	49.0	34.4	1,318.7
1975	36.0	41.7	68.6	104.8	112.3	153.4	225.9	203.9	150.2	80.4	44.7	32.1	1,253.9
1976	34.3	38.2	63.4	42.1	112.6	170.8	204.3	200.6	135.5	77.8	47.8	37.0	1,164.3
1977	39.0	51.5	68.2	74.9	162.5	195.8	271.0	269.6	146.2	55.5	46.1	35.9	1,416.4
1978	38.6	50.5	70.0	70.4	182.0	189.4	257.2	242.4	160.8	96.2	43.3	34.9	1,435.8
1979	41.3	49.1	72.3	70.4	139.7	182.6	224.8	250.3	169.9	71.1	46.5	36.7	1,354.9
1980	36.7	41.8	63.2	108.1	106.7	134.8	181.3	142.7	92.3	56.8	47.7	36.8	1,048.9
1981	40.6	44.3	69.0	80.2	94.4	131.0	145.3	136.4	98.6	77.1	45.6	38.3	1,001.0
1982	44.0	42.9	63.0	59.3	102.7	128.6	155.3	131.4	92.5	45.0	42.4	34.7	941.8
1983	33.7	40.2	64.9	91.9	123.5	116.5	138.5	114.7	87.5	51.0	44.4	37.3	944.1
1984	42.1	48.8	67.6	74.6	116.2	149.0	153.3	112.0	110.8	66.4	45.4	31.3	1,017.4
1985	39.1	39.1	58.9	85.7	117.9	144.9	159.0	146.9	105.9	53.8	44.7	36.8	1,032.6
1986	42.3	48.8	70.0	89.4	88.7	125.6	156.5	144.1	89.8	65.0	41.9	32.5	994.7
1987	40.9	48.7	56.4	75.4	117.7	139.6	159.5	155.9	110.4	56.6	43.2	34.9	1,039.0
1988	40.1	45.0	62.9	67.3	105.8	129.8	161.1	149.0	119.8	54.5	41.6	34.6	1,011.4
1989	34.9	40.4	69.8	111.9	121.8	151.0	161.9	158.6	128.6	62.8	43.5	34.5	1,119.7
1990	32.8	39.8	65.1	82.8	101.9	158.8	195.5	164.5	143.9	61.1	47.8	38.2	1,132.1
1991	36.6	39.0	67.2	72.8	106.3	152.6	166.7	158.6	116.8	79.6	45.2	30.9	1,072.2
1992	29.1	32.2	56.3	79.4	96.8	127.0	149.5	163.1	114.5	79.7	46.3	31.2	1,005.2

1993	29.8	37.0	63.1	107.9	105.5	159.0	187.2	161.2	130.3	79.4	44.5	35.9	1,140.7
1994	43.5	46.6	66.3	113.7	138.8	211.8	239.6	195.7	174.7	76.0	45.5	32.7	1,385.0
1995	39.4	49.0	73.6	56.7	123.7	170.5	148.1	175.7	125.6	36.4	39.2	31.8	1,069.8
1996	38.2	47.0	62.5	58.5	144.8	139.1	174.0	150.3	104.9	46.1	45.8	40.1	1,051.4
1997	43.1	43.0	59.3	35.8	122.0	135.3	198.7	136.7	90.8	47.8	46.0	37.4	996.1
1998	39.1	43.9	65.0	67.9	96.7	134.3	215.8	199.0	130.0	67.0	45.8	36.2	1,140.8
1999	21.5	28.14	44.4	77.2	134.4	132.5	179.7	169.7	103.1	65.8	32.2	21.6	1,010.2
2000	20.1	22.8	51.9	71.3	102.1	124.38	213.0	183.4	107.5	50.3	33.9	20.7	1,001.38
2001	23.7	29.6	61.6	46.2	106.5	222.6	249.0	207.7	142.8	71.1	30.7	19.4	1,010.9
2002	18.2	31.1	56.3	35.5	110.7	171.3	178.0	180.3	74.7	50.3	29.6	16.2	952.2
2003	23.5	27.8	40.3	26.1	115.8	168.5	225.3	160.8	87.6	53.2	34.2	18.05	981.1
2004	17.7	31.2	57.05	74.82	112.6	146.1	222.6	185.2	123.9	54.4	34.1	20.1	1,079.7
2005	21.1	27.8	47.3	56.6	117.3	159.6	243.0	194.4	108.0	46.2	30.3	25.6	1,077.2
2006	14.8	31.8	47.03	82.4	83.6	175.1	212.7	257.5	109.6	32.3	32.2	22.9	1,101.9

Table 4 Evaporation data of the Eber Lake

Year	January	February	March	April	May	June	July	August	September	October	November	December	Total
1965	22.7	25.1	40.4	48.2	63.9	135.7	199.9	189.3	131.8	60.0	30.1	24.8	971.7
1966	24.6	31.6	42.3	52.6	75.2	143.2	202.4	213.3	142.8	86.3	36.0	25.6	1,075.8
1967	22.3	24.1	36.9	42.1	59.3	137.8	210.8	196.8	128.2	70.9	29.6	23.9	982.6
1968	22.5	27.2	38.5	58.2	79.8	123.9	225.4	195.0	120.1	59.7	31.4	24.7	1,006.2
1969	22.2	28.3	41.3	49.0	68.8	148.9	192.9	207.1	167.2	80.0	31.2	25.6	1,062.5
1970	25.7	31.3	43.7	58.2	77.3	142.7	216.0	215.4	151.8	78.9	31.0	22.7	1,094.8
1971	25.5	28.8	40.8	44.4	62.3	139.8	203.4	190.6	131.8	74.5	30.4	22.5	994.8
1972	18.7	21.6	38.7	62.0	69.9	116.0	194.4	209.2	154.7	80.3	30.4	21.7	1,017.7
1973	21.4	29.5	38.8	48.1	71.9	143.2	220.0	220.9	185.7	105.7	29.5	23.2	1,138.0
1974	19.2	25.3	42.2	48.5	75.1	61.4	202.0	174.6	138.5	86.4	32.6	21.1	926.9
1975	20.8	25.5	42.4	47.0	47.4	120.8	202.7	177.0	137.9	73.1	30.1	19.3	944.0
1976	19.1	22.9	38.5	38.3	60.4	122.7	183.4	172.1	123.3	56.3	32.7	23.9	893.7
1977	22.6	31.5	41.7	47.9	73.5	149.7	200.9	206.9	122.5	54.8	32.0	23.2	1,007.3
1978	22.8	30.6	42.6	42.4	77.1	150.8	223.1	176.1	134.6	64.8	28.9	22.9	1,016.7
1979	24.3	30.5	44.3	49.9	58.0	128.9	199.4	195.0	138.1	55.5	31.6	23.6	979.2
1980	21.4	25.7	38.3	42.6	63.3	139.6	211.1	194.0	122.5	59.7	32.6	24.1	974.9
1981	23.8	27.2	43.0	47.8	57.4	131.8	191.5	166.4	94.3	82.9	30.6	25.6	922.4
1982	25.5	25.5	37.6	46.3	57.8	122.5	184.1	180.2	124.2	46.7	29.1	22.8	902.2
1983	19.4	24.2	39.4	51.0	71.3	125.7	170.5	150.9	126.3	51.4	30.6	24.2	884.8
1984	24.6	29.9	40.8	29.7	79.2	158.3	184.1	159.8	152.8	74.5	31.2	20.6	985.5
1985	23.6	23.9	36.1	51.5	65.7	141.5	213.2	193.3	127.2	47.3	31.3	24.0	978.6
1986	24.9	30.0	43.0	58.9	57.6	139.3	207.6	227.0	119.7	36.2	27.3	21.0	992.4
1987	24.3	29.7	39.7	41.8	66.2	135.3	246.7	178.1	150.6	53.0	29.4	22.9	1,017.8
1988	23.6	27.7	38.4	37.2	86.2	147.4	207.1	149.7	107.5	50.5	27.8	22.8	925.8
1989	19.7	23.8	42.5	66.2	64.8	146.5	224.4	203.1	138.9	58.7	29.5	22.4	1,040.4
1990	20.3	26.1	41.3	44.1	59.1	129.4	226.3	191.7	122.6	74.8	33.0	24.8	993.2
1991	21.5	24.1	42.1	38.6	51.1	124.2	197.6	180.3	129.1	68.6	30.9	20.4	928.7
1992	17.2	19.9	35.0	57.4	65.5	131.0	164.6	213.5	144.1	80.1	31.5	20.7	980.6

1993	18.5	23.7	39.2	60.2	57.1	133.9	206.7	240.2	144.6	72.4	30.3	23.8	1,050.7
1994	26.0	29.0	41.6	53.5	78.3	177.1	223.4	228.4	180.4	77.2	30.7	21.4	1,166.8
1995	23.9	30.7	42.0	49.9	78.6	139.9	170.1	195.0	162.2	86.8	26.9	21.8	1,027.7
1996	22.0	28.9	37.3	46.8	77.0	144.7	190.4	182.3	103.9	44.5	31.5	26.5	935.8
1997	25.3	26.6	35.8	21.1	57.4	115.7	184.8	156.9	130.4	61.2	31.0	24.4	870.7
1998	23.2	27.1	39.8	47.7	51.2	114.7	194.2	232.6	126.7	59.5	31.3	23.5	971.5
1999	21.6	28.1	44.4	40.5	70.3	111.6	199.4	181.4	138.9	46.1	32.2	21.6	936.1
2000	20.1	22.7	51.8	48.7	52.1	115.4	218.6	186.1	98.9	46.9	33.9	20.7	915.9
2001	23.7	29.6	63.0	46.9	58.9	160.2	214.6	176.3	133.6	56.2	30.7	19.4	1,013.1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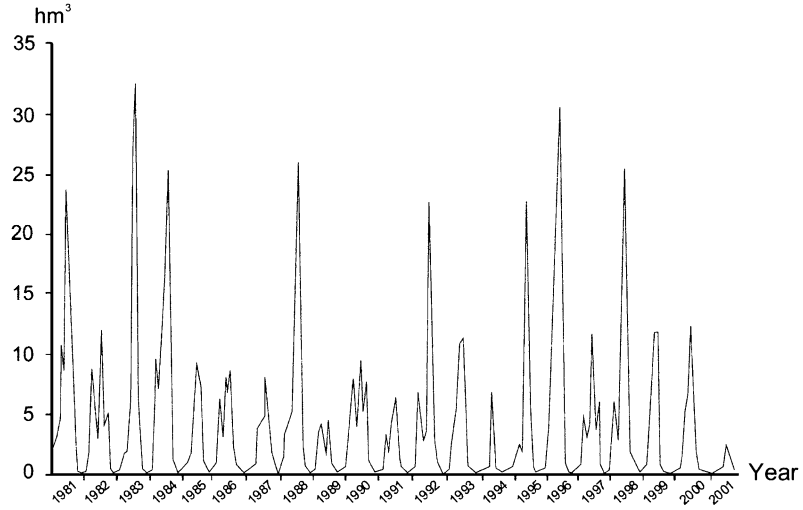
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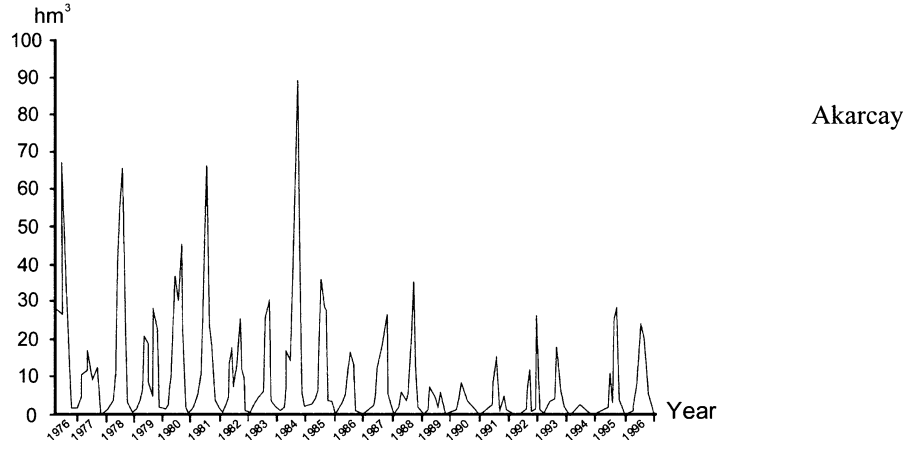
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◀ **Fig. 8** Flow graph of Akarcay, Adıyan and Cay streams

rates were 0.97 m^3/s in 1999 and 0.26 m^3/s in 2001, respectively. Adıyan stream recharges to Aksehir Lake with the average 1.80 m^3/s flow. The maximum flow rate was 4.03 m^3/s in 1977 and minimum flow rate was 0.081 m^3/s in 2001. The long-term flow observations of these streams have been shown in Fig. 8. The flow observations change as directly proportional with precipitation.

5 Conclusions

Several methods were devised to detect the coastline changes of water bodies. The integration of remote sensing and GIS is a powerful tool in coastline change detection particularly in large areas. Also, in these type of studies, get previous images obtained in different times is one of the most important problems. Nowadays, water level decreasing has been observed in significant rates related to climate change. Generally, the coastline change studies are performed using remote sensing techniques in literature. However, the reasons of this change are not examined in detail. Several factors can affect water bodies negatively or positively. In this stage, after the determination coastline change of the water body, the reasons of this change should be examined. In order to sustainable lake management, negative and positive effects which are determined with hydraulic and hydrogeologic investigations should be defined in detail. Hence, manmade negative effects can be removed due to identification its reasons. Especially, this is the most important task for protection of drinking water reservoir.

The primary objective of the study was to determine coastline changes in the Aksehir and Eber lakes and to discuss their reasons. The lakes are located within the Akarcay basin in Lake District. In order to determine coastline change of the lakes, multitemporal satellite images and remote sensing techniques were used. Each image was acquired in different dates: Landsat MSS in 1975, Landsat TM in 1987, Landsat ETM+ in 2000, ASTER in 2006 and 2008. After the required geometric and atmospheric corrections of images were made, lake water body was extracted using supervised classification method. Thus, probable errors were minimized. For this process authors benefit from NIR band combinations. Finally, coastline change of the lake was detected for analyzing changes in 1975–2008. The obtained results were supported with geological, hydrogeological and hydrological data. Tezcan et al. (2002) reported that there is not any groundwater effect on the water level change of the lakes. Therefore, precipitation, evaporation and surface flow data were used to evaluate reasons of coastline changes. Precipitation and surface flow are the most important recharge components and evaporation is the discharge component of lakes.

Besides coastline change detection, the change of the lake surface area and volume were determined using shore-edge line of the Aksehir Lake and lake topography of three dimensions for 1975–2006 periods. While the lake surface area was 342.89 km^2 in 1975, it decreased to 84.94 km^2 in 2006. The lake volume has also decreased to 1.11 km^3. In this period, the Aksehir Lake surface area decreased in the ratio of 75.23%. Finally, the Lake Akşehir dried up completely in 2008. The reliable data for the Eber Lake was not obtained due to aquatic plants covering surface of the lake. Therefore, the Eber Lake was evaluated with level measures performed by SHW. The Eber Lake water level changed with rainfall and surface flow as directly proportional. Excessive decreases of lake water levels and surface areas have been mainly resulted from dry period. We concluded that, the lakes have been affected seriously from climatic changes in recent decades.

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References

Alexandridis TK, Takavakoglou V, Crisman TL, Zalidis GC (2006) Remote sensing and GIS techniques for selecting a sustainable scenario for Lake Koronia, Greece. Environ Manage. doi:10.1007/s00267-005-0364-2

Allen RG, Pereira LS, Raes D, Smith M (1998) FAO-56: crop evapotranspiration, guidelines for computing crop water requirements. FAO Irrigation and Drainage Paper No 56, Rome, p 326

Alemayehu T, Ayenew T, Kebede S (2006) Hydrogeochemical and lake level changes in the Ethiopian Rift. J Hydrol (Amst) 316:290–300. doi:10.1016/j.jhydrol.2005.04.024

Alesheikh AA, Ghorbanali A, Talebzadeh A (2004) Generation the coastline change map for Urmia Lake by TM and ETM+ imagery. Map Asia Conference, Beijing, China

Alesheikh AA, Ghorbanali A, Nouri N (2007) Coastline change detection using remote sensing. Int J Environ Sci Tech 4(1):61–66

Alparslan E, Aydöner C, Tufekci V, Tufekci H (2007) Water quality assessment at Ömerli Dam using remote sensing techniques. Environ Monit Assess 135:391–398. doi:10.1007/s10661-007-9658-6

Anker HT, Nellemann V, Sverdrup-Jensen S (2004) Coastal zone management in Denmark: ways and means for further integration. Ocean Coast Manag 47:495–513. doi:10.1016/j.ocecoaman.2004.09.003

Bausmith JM, Leinhardth G (1997) Middle school students' map construction: understanding complex spatial displays. J Geogr 97:93–107. doi:10.1080/00221349808978834

Dogdu MS, Bayarı CS (2005) Environmental impact of geothermal fluids on surface water, groundwater and streambed sediments in the Akarcay Basin, Turkey. Environ Geol 47:325–340. doi:10.1007/s00254-004-1154-5

Durduran SS (2009) Coastline change assessment on water reservoirs located in the Konya Basin Area, Turkey, using multitemporal landsat imagery. Environ Monit Assess. doi:10.1007/s10661-009-0906-9

Ekercin S (2007) Water quality retrievals from high resolution ikonos multispectral imagery: a case study in Istanbul, Turkey. Water Air Soil Pollut 183:239–251. doi:10.1007/s11270-007-9373-5

Frohn RC, Hinkel KM, Eisner WR (2005) Satellite remote sensing classification of thaw lakes and drained thaw lake basins on the North Slope of Alaska. Remote Sens Environ 97:116–126. doi:10.1016/j.rse.2005.04.022

Goodchild MF (2001) Metrics of scale in remote sensing and GIS. International Journal of Applied Earth Observation and Geoinformation 3:114–120. doi:10.1016/S0303-2434(01)85002-9

Guariglia A, Buonamassa A, Losurdo A, Saladino R, Trivigno ML, Zaccagnino A, Colangelo A (2006) A multisource approach for coastline mapping and identification of shoreline changes. Ann Geophys 49:295e304

Jaiswal RK, Mukherjee S, Raju KD, Saxena R (2002) Forest fire risk zone mapping from satellite imagery and GIS. International Journal of Applied Earth Observation and Geoinformation 4:1–10. doi:10.1016/S0303-2434(02)00006-5

Kelley GW, Hobgood JS, Bedford KW, Schwab DJ (1998) Generation of three-dimensional lake model forecasts for Lake Erie. Weather Forecast 13:305–315

Li R, Di K, Ma R (2001) A comparative study of shoreline mapping techniques. The 4th international symposium on computer mapping and GIS for coastal zone management, Halifax, Nova Scotia, Canada, June 18–20

Maiti S, Bhattacharya AK (2009) Shoreline change analysis and its application to prediction: a remote sensing and statistics based approach. Mar Geol 257:11–23. doi:10.1016/j.margeo.2008.10.006

Merter U, Genc S, Goksu L, Tunalı S (1986) Water quality of lakes in Isparta and surrounding: physical, chemical and biological parameters. Scientific and Technique Research Society of Turkey, Sea Units and Group of Environment Research, Ankara, Project number CAG-45/6

Moore LJ (2000) Shoreline mapping techniques. J Coast Res 16(1):111–124

Pajak MJ, Leatherman S (2002) The high water line as shoreline indicator. J Coast Res 18(2):329–337

Sesli FA, Karsli F, Colkesen I, Akyol N (2008) Monitoring the changing position of coastlines using aerial and satellite image data: an example from the eastern coast of Trabzon, Turkey. Environ Monit Assess. doi:10.1007/s10661-008-0366-7

State Hydraulic Works (SHW) (1998) Hydrology revise report of Eber-Aksehir Project. SHW XVIII. Region Directorate, Isparta/Turkey, p 150

Tezcan L, Meric T, Dogdu N, Akan B, Atilla O, Kurttas T (2002) Hydrogeology of Akarcay Basin and groundwater flow model, final report. Hacettepe University International Research and Applicatıon Center for Karst Water Resources (UKAM)–General Directorate of State Hydraulic Works, p 339 (unpublished)

Van TT, Binh TT (2008) Shoreline change detection to serve sustainable management of coastal zone in Cuu Long Estuary. International Symposium on Geoinformatics for Spatial Infrastructure Development in Earth and Allied Sciences

Zhao B, Guo H, Yan Y, Wang Q, Li B (2007) A simple waterline approach for tidelands using multitemporal satellite images: a case study in the Yangtze Delta. Estuar Coast Shelf Sci 77(2008): 134–142