# THE ANALYSIS OF DESTRUCTION IN FLAMINGO HABITAT OF ACIGOL WETLAND

M. Karaman*, Z. D. Uca Avci, I. Papila, E. Ozelkan

Istanbul Technical University, Center for Satellite Communications and Remote Sensing, Maslak, Istanbul,Turkey
(muhittin, damla, emre, papila)@cscrs.itu.edu.tr

**Abstract: Industrial developments improve human life whereas it can destroy, pollute and decrease the available feeding and breeding area for the animals. Acigol Lake, being a saline shallow wetland, offers a suitable feeding and breeding area on the migration way of flamingos'. Acigol Lake is the main sodium sulfate production area in Turkey. Sodium sulfate production is carried out by industrial firms and high amounts of water are pumped from lake to salt pans. In this study, spatial and temporal variation of flamingos' feeding sites due to water pumping is investigated by using remote sensing. Dry and water covered areas were determined by using modified normalized difference water index (MNDWI). Then, the MNDWI images were classified to 'feeding by wading' and 'feeding by swimming' areas by using the in-situ depth measurements. The decreases in the lake water level during salt production period, showed the direct effect of industry on flamingos' feeding areas.**

**Keywords: flamingo, Lake Acigol, MNDWI, salt lake, salt pans, remote sensing**

## 1. INTRODUCTION

Lake Acigol is located on the migration route of flamingos and it is a suitable living and feeding area because of its shallow and salty characteristic. It is determined by Yarar and Magnin (1997) that, 150 nests of colony breed in Acigol by 1993, which indicates that Acigol, Turkey can be accepted as one of the important breeder area of flamingos (Kahraman, 2007). 178 bird species are observed between 2001-2007 in this region. The dominant flamingo species here is the "Greater Flamingo" and "phoenicopterus ruber" (Urhan and et al., 2010) (Figure 4. And Figure 5.). Phoenicopterus Ruber, which is one of the endangered animals, overwinter on a regular basis in Turkey. In Acigol 105 individuals in 2003, 356 individuals in 2004, 200 individuals in 2005 and 22 individuals in 2007 are observed. (Özesmi and et al., 2008: Balkız, 2005).

Flamingos live in colonies and they breed in a few numbers of extreme environments on earth. Changes in water levels are the main problem for breeding of flamingos (Birdlife International, 2004: Özesmi and et al. 2008: Nager and et al., 1996) Urhan et al. (2004) concluded in their researches related to this region that most common problems in flamingo living areas are uncontrolled production of salt, wastes of salt industry and residential areas, agricultural irrigation activities. (Figure 1).

In this study, the changes in the flamingos living and breeding areas in Acigol were examined with remote sensing methods. Besides, the effects of salt production activities at the living areas of flamingos were examined, which had been suspected as destructive by many zoologists. The spatial and temporal analyses of water covered areas in the basin area were distinguished by considering the feeding type of flamingos as wading. For the same time period, salt production activities were compared and their effects were evaluated.

**Figure 1.** The picture of a dead flamingo in Tuz Lake (photo credit: Murat Ataol ) (Balkız et al.,2009)
**Figure 2**. The artemia salina deaths in salt pans (Karaman, 2011)

## 2. STUDY AREA

Lake Acigol located between 37°55'27.98"-37°45'7.41"N and 30° 0'17.24"-29°41'11.72"E. Acigol is geographically located on the border of Denizli and Afyon province of the Turkey (Figure 3).

**Figure 3.** Study area (Lake Acigol-Denizli)

Lake Acigol is a saline lake with a brine composition of Na-Cl-$SO_4$ (Mutlu,1995). Acigol is a shallow, alkaline (pH 8.0-8.6) lake, containing dissolved sulfate at around 258.68 meq/l. Total estimated water budget of the lake is 99,054,305.16 $m^3$ and maximum lake depth value is 2.1m by May 29$^{th}$, 2010. (Tasdelen at al., 2010)

Lake Acigol has an important economic value, since major amount of sodium sulfate production of Turkey is supplied here. Salt production activities have been continuing with increasing production potential and areal extend, since 1953 (URL-ALKIM). Salt is produced by applying two kinds of production methods, which are natural production from salt pan and industrial production at factories. (Gündogan et al., 1995; Karaman et al., 2010).

The areas of salt pans cover 33.4 km$^2$. Industrial activity includes sodium chloride production since 2004, in addition to the present sodium sulphate production.

## 3. GREATER FLAMINGO

**Figure 4.** Greater Flamingo in Lake Acigol (URL-4)
**Figure 5.** Feeding in shallow water (URL-5)

The Greater flamingos inhabit at saline shallow water environments like salt pans, salt lagoons and alkaline lakes. The food of Greater flamingos is brine shrimp, larvae, blue-green and red algae, artemia etc. (Oglive, 1986). Greater Flamingos are the tallest flamingo species and their height is between 120 and 150 cm. The legs of adult flamingos can vary between 80 and 125cm (URL-3). Having long legs, they can wade into deep waters. They swim at water surface while feeding, where the depth of water is higher than their legs (URL-1). Salt pans can also be considered as a feeding area where microorganisms (artemia salina) live although their life cycle is effected by the activities on salt pans (Figure 2).

## 4. DATA USED

In order to determine spatial-temporal changes in lake during dry season, Landsat5-TM images acquired on three different dates (28 May 2010, 16 August 2010, 01 September 2010) taken from USGS were used. All images have same path row (179/34). Cloud coverage of Landsat5-TM image of September 1 was %19.98, other images were cloudless. The images were cropped to cover Lake Acigol basin. All images were already geometrically corrected by USGS. The image May 28$^{th}$ was used as a base for the registration of other images. Registration was performed with first order polynomial by ±0.375726 RMS error. Registered images were resampled by the nearest neighbor method.

### 4.1. Bathymetry Map

Lake Acigol Bathymetry Map published by Tasdelen et al. (2010) was used as a base map to locate shallow and deep areas in lake (Figure 6).

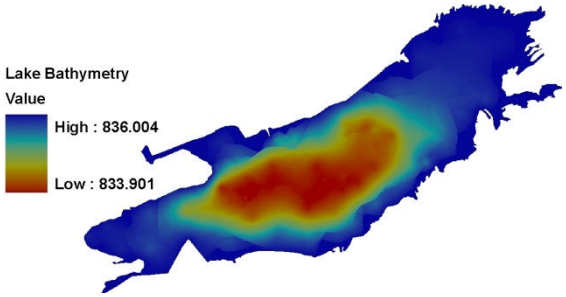


**Figure 6.** Lake bathymetry (Tasdelen et al., 2010)

## 5. APPLICATION

### 5.1. Mapping Water Covered Area (WCA)

The flamingos tend to live in water covered areas in Acigol salt Lake. Therefore, MNDWI (Modified Normalized Difference Water Index) was used to delineate these regions from Landsat TM images. MNDWI uses Landsat green (Band2) and middle infrared band (Band5) to figure out water features as equation (1) (Xu, 2006).

MNDWI = (Green - Mir / Green + Mir) (1)
MNDWI = (p0.56- p1.65)/(p0.56+p1.65) (p:wavelength)

Water index images derived from MNDWI contains zero, negative and positive values indicating waterless, water covered areas (Table A).

**Table A** MNDWI classification (Xu, 2006)

| Value | Type |
|---|---|
| MNDWI > 0 | Water |
| MNDWI <= 0 | Soil, vegetation |

Waterless areas which have negative values or zero in water index image were blocked out by masking (Figure 7).

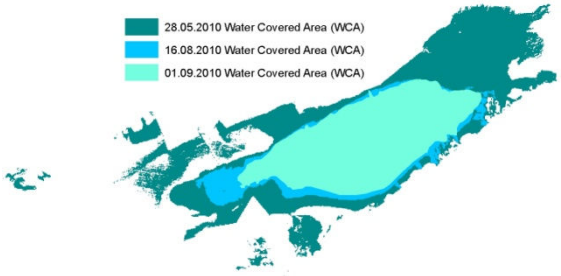


**Figure 7.** Spatial and multitemporal variation of lake area

Additionally, lake boundary was derived by raster-to-vector conversion method from water index image (Figure 8).

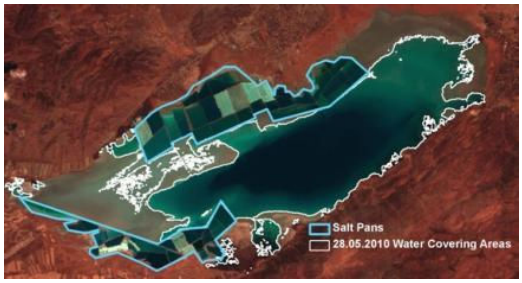


**Figure 8.** Lake boundary and salt pans in Lake Acigol (Landsat5-TM RGB:532)

### 5.2. Determining Feeding Area

Flamingo's feeding areas were evaluated in ArcGIS. Water covered areas were classified in two classes as Flamingo's wading and swimming area by using their leg length for classification criteria. Since the legs of an adult flamingo can vary between 80 and 125 cm, the depth of the water about 80 cm was used as a limit for maximum

wading depth. Shallow (depth < 80 cm) and deep areas (depth >= 80cm) were regarded as feeding by wading area (FWA) and feeding by swimming areas (FSA) for flamingos, respectively.

Bathymetry map contours were filtered to display only baseline depth and result contours were exported to "baseline" polyline shape to form polygon shape. Finally, this baseline polygon shape shows FSA. The FWA was determined by cutting out the swimming areas from water covered area to produce FWA bands (Figure 9).

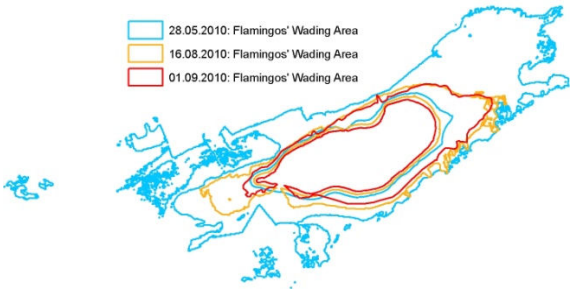


**Figure 9.** Spatial and multitemporal change of flamingo wading area

### 5.3. Spatial and Multitemporal Analysis

WCA areas and flamingos' feeding areas were determined for May, August and September period. The lake boundary in May 28 Landsat5-TM image was used as a baseline to compare the decrease of the lake area for each period.

**Figure 10.** 19 Decreasing of lake boundary On July, 2010 ( Karaman, 2011)

Comparison results show that FSA was close to the center and its mean covering value is 21.16 km$^2$ during dry season (Figure 11). When WCA in September 1 was compared with the one on May 28, it was seen that WCA and FSA had decreased by 51 km$^2$ and 5.8 km$^2$, respectively (Table B). At the same period of this areal decrease about 61.4 %, the areas in the lake that FWA were reduced from 59.158 km$^2$ to 14.005 km$^2$, and the FSA were reduced from 23.762 km$^2$ to 17.995 km$^2$.

**Table B.** Water area and flamingos' feeding area

| Date | WCA (km$^2$) | FWA (km$^2$) | FSA (km$^2$) |
|---|---|---|---|
| 28.05.2010 | 82.920 | 59.158 | 23.762 |
| 16.08.2010 | 38.956 | 18.183 | 20.773 |
| 01.09.2010 | 32.000 | 14.005 | 17.995 |

### 5.4. Salt Pans

Salt (Sodium Sulfate – Sodium Chloride) pan areas determined from Landsat 5-TM images is 33.4 km$^2$ in Lake Acigol. The effects of the salt production on shrinkage of the lake were investigated by multi-temporal MNDWI images. The MNDWI images of each date were combined as RGB colored image (R:May 28, G: August 16 B:September 1) (Figure 11).

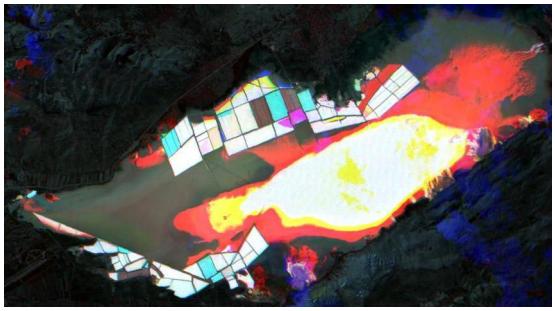

**Figure 11.** RGB colored MNDWI image

It have to be mentioned that the clouds in September image cause yellow colored parts at the center of water covered area. The colors referring to dates for the produced MNDWI image set were given in Table C.

White colored areas in RGB image are water covered areas during dry season whereas dark colored areas are waterless. The areal size of salt pans to which water pumped in from lake during the study period is around 4.513 km$^2$ (cyan, blue and pink colored areas).

Furthermore, the water was pumped from the lake to the 4.513 km$^2$ of salt pans. The amount of pumped water is approximately 6.77 million m$^3$. Considering the depth of salt pans are about 1.5m, for 33.4 km$^2$ area at total, 50.1 million m$^3$ water was pumped from the lake to the salt pans for production.

**Table C.** Color table of water existence at each date

| Channel | Red | Green | Blue |
|---|---|---|---|
| Color | May 28 | August 16 | September 1 |
| Red | ✓ | - | - |
| Green | | ✓ | - |
| Blue | - | - | ✓ |
| White | ✓ | ✓ | ✓ |
| Yellow | ✓ | ✓ | - |
| Pink | ✓ | - | ✓ |
| Cyan | - | ✓ | ✓ |
| Dark | - | - | - |

## 6. CONCLUSION

The spatial and temporal analyses of feeding and living areas of flamingos for the Lake Acigol were performed. The changes in feeding areas were examined in addition to the salt production activities determined for the same period. It was seen that, while the lake area and the feeding areas of flamingos were reducing, the water was pumped from the lake to the salt pans. However, to evaluate the effect of the industry quantitavely, detailed hydrological water budget research must be done for the region.

## REFERENCES


Balkız, Ö., 2005, Türkiye Flamingo (Phoenicopterus roseus) Kış Gözlem Raporu, (Flamingo winter observation report of Turkey) Doğa Derneği Yayınları, Ankara, Türkiye.

Balkız, Ö., Özesmi, U., Pradel, R., Germain, C.,Sıkı, M., Amat, J.A., Rendon- Martos, M., Baccetti, N., Bechet, A., 2009, An update of the status of the Greater Flamingo Phoenicopterus roseus in Turkey, Flamingo, Special Publication-1.

Birdlife International, 2004, Birds in Europa: population estimates, trends and conservation status, BirdLife conservation series, no:12, BirdLife International, Cambridge,Pp:374

Gündoğan, İ. , Mordoğan, C. , Helvacı, C.,1995, Türkiye'deki Acı Göllerden Sodyum Sülfat Üretimi, (Sodium sulfate production from brackish lakes in Turkey) Endüstriyel Hammadeler Sempozyumu, Köse ve Kızıl (eds),21-22 Nisan 1995, İzmir

Karaman, M., 2011, Determination of Recent Lake Shore Biomineralization Areas and Hidrogeochemical Parameters via in-situ and Remote Sensing Methods in Lake Acigol, Phd Thesis Reports, Pamukkale University, Denizli.

Karaman, M., Uça Avcı, Z.D., Budakoğlu, M., Taşdelen,S., 2010, Determination of sulfate ion distribution of Lake Acigol (Denizli) by object-based classification method , 2. Jeolojik Uzaktan Algılama Sempozyumu (Symposium of Geological Remote Sensing-II-II)

Kahraman, D., 2007, Identification of bird species, detecting numbers and protection of birds in Acigol, M.Sc. Thesis of in Biology, Pamukkale University, Denizli,104s.

Kılıç,D.T., Eken, G., 2004, Türkiye'nin önemli kuş alanları- 2004 Güncellemesi, (Important bird areas of Turkey, Update-2004) Doğa Derneği, Ankara, Turkey,Pp:232

Mutlu, H. , Kadir, S. ve Akbulut, A., 1999, Mineralogy and water chemistry af the Lake Acıgöl (Denizli), Turkey: Carbonates and Evaporates, vol. 14, no. 2, 91-99.

Nager, R.G., Johnson A.R.,Boy V., Rendon- Martos, M., Calderon, J., Cezilly, F., 1996, Temporal and spatial variation in dispersal of Greater Flamingo (phoenicopterus ruber roseus), Oecologia, 107,204,211

Ogilve, M. A. O. C. ,1986, *Flamingos*. Great Britain, Alan Sutton Publishing Limited.

Özesmi, U., Sıkı, M., Balkız, Ö., 2008, Flamingoların (Phoenicopterus Ruber) Akdeniz Metapopülasyonlarının Medellenmesi (Modeling the mediterranean metapopulation of flamingos'), Tubitak 103Y182 Proje Raporu,Ankara

Urhan, R., Kahraman, D., Aslan, A., 2010, Bir Tuz Gölü örneği olarak Acigol(Denizli)'ün kuş varlığı, problemleri ve koruma öncelikleri, (As a sample of salt lake, the presence of birds, problems and conservation priorities of Lake Acigol), 20.Ulusal Biyoloji Kongresi,21-25 Haziran, Denizli,Türkiye

Tasdelen, S., Budakoglu, M., Kumral, M., Karaman, M., Karabel, B., 2010, Dissolved Sulfate Budget of a Hypersaline Lake; Acigol, SW Anatolia Turkey, SEG 2010 Conference Proceeding Book, October 2 -5 2010, Keystone, Colorado, USA.

Xu, H., 2006, Modification of normalized difference water index (NDWI) to enhance open water features in remote sensed imagery, International Journal of Remote Sensing, 27:14, 3025-3033.

Yarar, M. and Magnin, G., 1997, Türkiye'nin Önemli Kuş Alanları, (Important bird areas of Turkey, Doğal Hayatı Koruma Derneği, İstanbul, Türkiye, 313 s, 89-91

URL-1, Animals, Flamingos, Seaworld, (Last Access:20.01.2011) http://www.seaworld.org/infobooks/Flamingos/fadapt.html

URL-2, Animals, Flamingos, SeaWorld, (Last Access:20.01.2011) http://www.seaworld.org/infobooks/Flamingos/fdeath.html

URL-3, Animals, Flamingos, SeaWorld, (Last Access:29.01.2011) http://www.seaworld.org/animal-info/info-books/flamingo/physical-characteristics.htm

URL-4,Yakader, (Last Access:20.01.2011) http://www.yakader.org/mynet_resimlerim/flamingo_1.jpg

URL-5, Dazkırı İlçe Kaymakamlığı, (Last Access:29.01.2011) http://www.dazkiri.gov.tr/kustur23.jpg

URL-ALKIM, (Last Access:29.01.2011) http://www.alkim.com/tr/kurumsal/tarihce.aspx


## ACKNOWLEDGEMENTS


Authors would like to thank to USGS for Landsat5-TM images, to Tasdelen et al. (2011) for Lake Acigol Bathymetry Map, to Turkey Ministry of Environment and Forest.