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LONG-TERM MONITORING OF WETLANDS VIA REMOTE SENSING AND GIS: A CASE STUDY FROM TURKEY

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Abstract: Remote sensing that is a low cost data source capable of making temporal observations has more advantages than the traditional methods to obtain land-use/cover change maps. In this study, temporal land-use/cover change of surface water bodies in Konya Closed Basin was evaluated via Landsat satellite images for the past 30 years. The basin, located in Central Anatolia Region of Turkey, faces water scarcity problems; however, wet agricultural activities are still favoured and practiced. Therefore, water resources are becoming more important than ever; public complains about long-lasting drought conditions and on lessening of surface water resources. There are 16 surface water bodies, and 3 of them are lakes; whereas the rest are wetlands of importance. Two of them are Ramsar sites. Results indicate that the surface area of the water bodies in Konya Closed Basin declined by approximately 23.5% within the inspection years. One of the important wetlands of the basin named as Akgol Wetland has almost lost its water surface by 96% at the same time interval, and is in danger of extinction. Thus, this vulnerable wetland has been focused on in the study. The decrease of water surface in the wetland is matched with the meteorological conditions.

Keywords: Wetland, Konya Closed Basin, Akgol Wetland, Turkey, Remote Sensing, Geographic Information System

Introduction

Wetlands are among the world's important natural resources and vulnerable ecosystems (Wdowinski et al., 2006; Wu, 2018). They are fertile ecosystems and form a suitable habitat for a wide variety of flora and fauna (Costanza et al., 2011). They have hydrological functions such as regulation of water regimes, storage of water, prevention of floods, coastal stabilization, control of erosion, acquisition of groundwater, deposition of sediments and pollutants, stabilization of local climatic conditions (Bergkamp & Orlando, 1999), and ecological functions like preserving biological diversity, providing ecological balance and critical habitat for many migrating birds (Coban, 2017). They also have a special precaution as part of the cultural heritage of mankind (Wu and Liu, 2015). Moreover, they also provide important economic benefits that include use as a water source, provision of fisheries, agriculture, timber and other building materials, provision of energy resources through peat and plants, use of wildlife resources, transportation and utilization of wetland products, recreation and tourism. Wetlands in the matter of their hydrological and energy transfer characteristics provide balance between natural phenomena especially precipitation and temperature (Korkanc, 2004). In addition, wetlands are among the most important ecosystems in terms of carbon emission (Meng, 2016) and an optimal natural environment for the long-term storage of atmospheric CO_2 (Frolking et al., 2011).

Despite the numerous and valuable functions of wetlands, natural and anthropogenic activities in the long-run spoil their well-being, making their management a crucial business. Over the last few decades importance of wetlands has even become more pronounced and their functions are better understood as areal reductions all over the world by more than 50% since 1900 is recognized (UNESCO-WWAP, 2003; Gallant et al., 2007).

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The International Panel on Climate Change (IPCC) attracted the attention of society to global warming of over 2^0C and a CO_2 concentration in the atmosphere over 450 ppm. IPPC report suggested that CO_2 emissions should be reduced by 25-40% until 2020, and by 90% until 2050 to stay below these critical values (Algedik, 2012). In that sense, control and protection of wetland ecosystems may be appropriate for an overall climate change mitigation strategy (Bergkamp and Orlando, 1999). Need for information in supporting wetland management is multi-scalar from global to regional and national assessments as depicted by Rebelo et al. (2009). Remote Sensing (RS) and Geographic Information Systems (GIS) are modern tools of technology utilized for detecting, monitoring and management of natural resources and environment (Garg, 2015). Analysing and extracting reliable and consistent information via RS technology enables to form a base dataset to be further utilized for monitoring and mapping wetlands (Durduran, 2010) that has so far proven to be an efficient, helpful and frequent application tool in over large areas with low cost and time (De Roeck et al., 2008; Adam et al., 2010; Klemas, 2014). Optical and radar remote sensing obtained from many different satellite sensors such as Landsat MSS/TM /ETM + (Ji et al., 2009), SPOT (Dehouck et al., 2012) and AVHRR (Prigent et al., 2001) have been used for wetland identification and observation, prediction of biological parameters and classification of vegetation cover (Simard et al., 2006; Evans and Costa, 2013). After a thorough survey in RS science, it is seen that Landsat images are more suitable for extracting water bodies due to the SWIR band that have as used by Mcfeeters (1996), Xu (2006), Ji et. al. (2009) and by Sheng et al. (2016).

Turkey, based on its geographic location, contains many natural wetlands as it is under the effect of different climatic conditions, forming a bridge between Europe and Asia continents. An important characteristic of the country is that it is a point of attraction for some endangered and migratory birds, and the two main migration routes cross over the country. According to the Ramsar Convention, 135 wetlands of Turkey are of '*International Importance*'. Majority of these sensitive and vulnerable areas have international reserves regarding water birds and fish species. Konya Closed Basin (KCB) located in Central Anatolia is one of the 25 river basins of Turkey and houses 13 wetlands. Actually, it has 16 water bodies of which 3 are lakes. One of the internationally recognised wetlands of the basin is Akgol Wetland known to be an abundant one regarding its biodiversity in the past years. Ayranci, Ivriz and Godet Dams put into operation in 1958, 1984 and 1988, respectively, have started to cut the water flow to Akgol; thus, considerable decrease in the water area and in turn, in the volume has occurred. The surface area of Akgol had been around 21.500 ha till 1960's; since then, majority of it had been lost due to water drainage, water cuts and to withdrawals for agricultural irrigation. Moreover, semi-arid character of the region is another bottle-neck of the wetland as its only water feeding is by precipitation which tends to decrease through the climate change effects in the near future.

In this study, temporal changes of KCB in general and Akgol specifically were analysed using RS data in a period of about 30 years (1984-2017). Long-term meteorological data including precipitation, temperature and evaporation values were also considered in the evaluation of the findings derived from satellite images. Relationship between climate data and wetland water change is evaluated chronologically based on the images belonging to different years. All the results achieved were compiled and integrated in a GIS environment; a convenient system that will be able to make further queries.

Study Area

KCB located in Central Anatolia of Turkey has been declared as one of the 200 ecologically significant regions of the world by WWF International (Dursun et al., 2012). It covers 7% of Turkey's surface area and bears total annual usable water resources of 4,365 billion m^3. However, water consumption of 6,5 billion m^3 points out that there is an annual water deficit of approximately 2 billion m^3. Semi-arid climatic conditions prevail in the overall basin. The average annual rainfall in the basin was around 407 mm taking into account the average of all the available years from 1923 to 2013. However, this annual precipitation value is found lower in this study that considered only 1971-2015 period. It can be stated that the precipitation value in general is almost half of the country's value. Larger surface area with less flowing water bodies, lower precipitation with higher evaporation are the significant characteristics of the basin; however, an interesting water balance is observed (CCIWR, 2016). This basin consists of only 2% of the country's overall surface water resources and whereas 17% of the groundwater resources. This fact can be briefly summarized as '*KCB is a basin that bears the minimum surface water resources while owning the highest groundwater resources*' (DMP, 2015).

Agricultural areas cover almost 55.5% of the basin followed by forests and semi-natural areas by 37.4% (DGWM, 2016). The rest of land-use distribution is shared by urbanized areas and water surfaces. The region's agricultural production capacity has a strategic importance for Turkey's food supply, although; KCB has the least amount of rainfall in Central Anatolia (Celebi and Direk, 2017).

Akgol Wetland in KCB and its vicinity is an important biogeographic region with different habitats, rich biological diversity and microclimate as shown in Figure 1. Akgol was the largest wetland area in Turkey in 1950s with a surface area of 24.000 ha. Average elevation of the region is 998 m. The south of the wetland is covered by the extensions of the Taurus Mountains and the east, west and north sides are surrounded by flat steppe areas. There are also some volcanic elevations. This wetland has started losing its water within years due to human-induced activities and to natural climatic changes. As such, its natural boundaries have changed. The total surface area of Akgol till 1960's had been around 21.500 ha and almost 16.200 ha of this amount had been dried since then. The main reasons that led to a considerable decrease in the water level were primarily water cut to the wetland due to river diversions during the operation of the dams, and secondly, the drying of lakes was so common these days due to fight against malaria disease; thus, combating with malaria accelerated the drying practice.

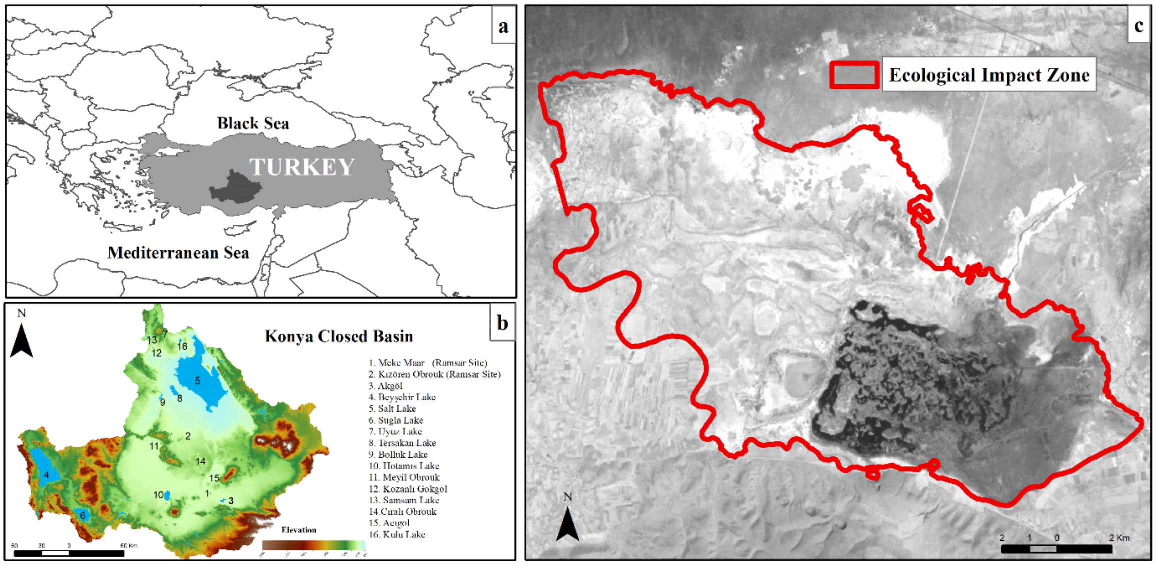


Figure 1 Geographical location of (a) Turkey, (b) Konya Closed Basin (KCB), (c) Akgol Wetland

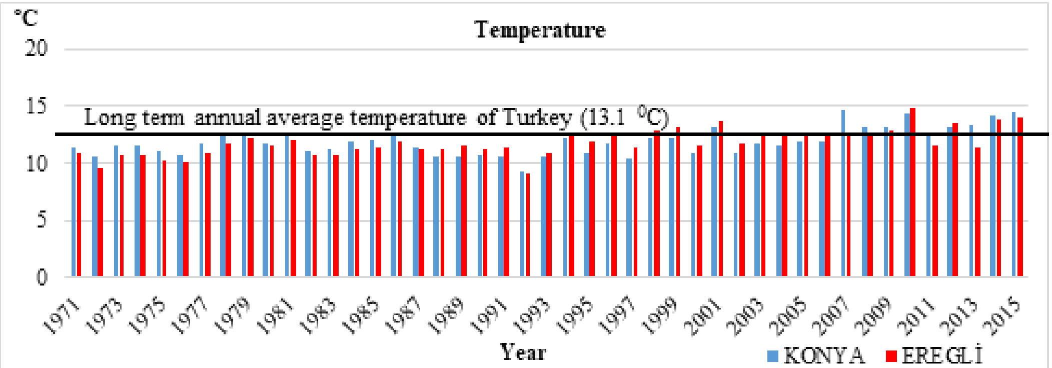
Materials and Methods

LANDSAT 5 TM, LANDSAT 7 ETM+ and LANDSAT 8 OLI data were used to determine the temporal changes of KCB and Akgol Wetland. General information about LANDSAT images that were downloaded from the USGS website is given in Table 1.

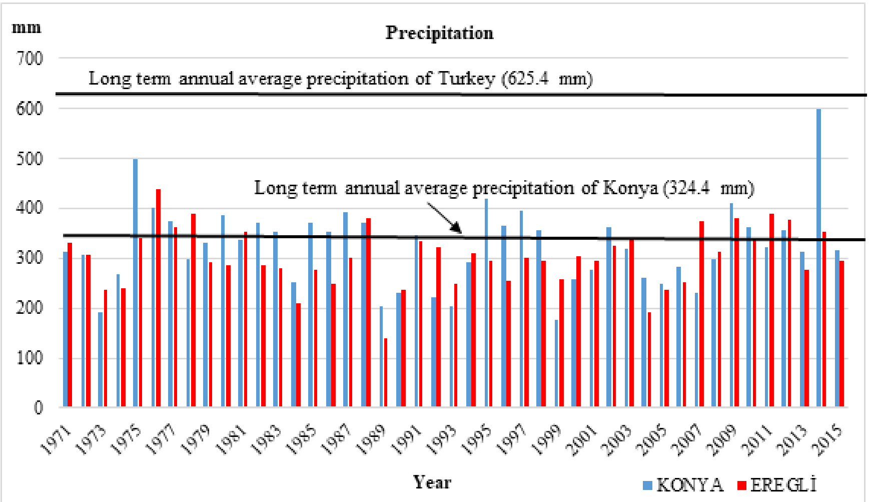
Table 1 Landsat data used in the study

Satellite (µm)	Spectral Resolution	Spatial Resolution(m)	Radiometric Resolution	Temporal Resolution
LANDSAT 5 TM (1987 and 1998)	7 Bands (0.45-2.35)	B1,B2,B3,B4 B5,B7:30 B6:120	8 bit	16 days
LANDSAT 7 ETM+ (2007)	8 Bands (0.45-2.35)	B1,B2,B3,B4 B5,B7:30 B6:60 B8:15	8 bit	16 days
LANDSAT 8 OLI (2017)	9 Bands(0.433-2.30)	B1,B2,B3,B4 B5,B7,B9:30 B6:60 B8:15	16 bit	16 days

Meteorological data was obtained from the State Meteorological Service (SMS) both for Konya Province that represents the entire basin and also for Eregli Meteorological Station representing the Akgol Wetland. These data that covered temperature and precipitation values between 1971- 2015 for both of the stations were considered together with the water covered areas classified from the processed satellite images at different times (Figure 2).



(a)



(b)

Figure 2 a) Mean temperature, b) mean precipitation values of Konya and Eregli meteorological stations

It is seen from the long-term temperature data that both of the stations illustrated almost similar degrees all throughout 45 years. The temperature of KBC is well below the Turkey's long-term average annual temperature; however, temperature presented a slightly increasing trend after 2000s. The average annual precipitation of Konya is observed as half of Turkey's rainfall underlying the fact that the basin is of semi-arid character. The precipitation seems to increase after 2007 and even pass the average annual value.

Satellite images after the mid of 1970's have started to be utilized for obtaining data that are further used in the modelling and management of water surfaces. Remote sensing (RS) has more advantages than the traditional methods of land-surface water mapping because it is a low-cost and reliable information source that is capable of making high-frequency and repeatable observations. For extracting information regarding surface water bodies, algorithms such as classification and indexes have been developed as they are the key points for transferring remotely sensed images into information for practical applications as Li et al. (2013) referred. Normalized Difference Water Index (NDWI) is commonly used to extract the water surface area. This index is designed to maximize the reflectance of a water body by using green wavelength, minimize the low reflectance in Near-IR, and take advantage of the high reflectance in Near-IR of vegetable and soil features (Li et al., 2013). Results vary between -1 and +1; where the water covered areas always take positive values. For image processing ERDAS 2016 software was used.

NDWI = (Green – Near Infrared) / (Green + Near Infrared)

Numerous studies have focused on land use/cover and change detection by using satellite data. Fu et al. (2013) applied classification algorithms to thirty-seven Landsat MSS/TM/ ETM+ satellite images from 1976 to 2010, the HJ-1A CCD image dated 2010 and the SPOT5 image dated 2005 to obtain spatial-temporal analysis of wetland landscape pattern characteristics for Yellow River Delta, China. Higgins and Caretta (2017) made comparisons between a Landsat satellite-derived history of lake surface area, local precipitation records, and corresponding anthropogenic activity in Tanzania and the results showed the impacts of agricultural and historical practices in the region. More recently, Hird et al. (2017) used Sentinel 2A images applied difference vegetation index (NDVI) and NDWI for wetland mapping in Alberta, Canada. Tangud et al. (2018) produced land cover maps for 1986, 1995, 2000, 2006 and 2004 years by using LANDSAT satellite image and Support Vector Machine Method. They found a strong negative correlation between grassland and barren land indicating that grassland degradation in this region is due to the regional modernization over the past 28 years. Finally, Arsanjani (2018) used GlobeLand30-2000 and GlobeLand30-2010 data to identify the rates and types of land change across different continents.

Given the large amount of environmental data that needs to be compiled for effective analysis, GIS was used as an efficient tool for organising, storing, analysing, displaying and reporting the spatial information. It allows the creation and modification of the analysis that makes the best use of available data. It is useful for wetland studies as remotely sensed data together with other available data are an opportunity to exploit the capability of GIS. This is because a fundamental cost of starting and operating a GIS system is data input. Five major steps of GIS spatial analysis for environmental and ecological studies include (but not limited to) (Dhanapal, 2012);

- Defining criteria for the analysis,
- Defining data needs and base map,
- Acquisition and preparation of the data as thematic maps,
- Creating GIS model/overlays,
- Evaluating results and refinement of the model.

Rawashdeh (2011) used GIS and change detection techniques to evaluate the efficiency of an automatic change detection method in mapping the changes that took place after the implementation of newly irrigated areas in dry zones. For this aim LANDSAT TM 1983 and LANDSAT ETM+ satellite images were used. Hadeel et. al.(2011) studied environmental degradation by using multi-temporal satellite data and GIS. Borfecchia et. al. (2014) used remote sensing data derived from digital surface model, LANDSAT, MODIS satellite data and GIS to support the photovoltaic potential assessment in urban areas. Agapiou et al. (2016) made water leakage detection using remote sensing, field spectroscopy and GIS in semiarid areas of Cyprus.

In this study, 1/25.000 scale topographic maps were used as basic maps. "Contour" and "elevation point" layers in the 1/25.000 scaled topographical maps and the digital elevation model (DEM) of the land were obtained as raster to make 3D analyses of the study area. To analyse urban pressure, borders of the settlements and demographic data were integrated to GIS media. For this aim, village locations around the Akgol Wetland were digitized from the topographical maps and transferred to GIS by using ARCGIS 10.1 Software. Then, population data of the villages around the wetland obtained from Turkish Statistical Institute were transferred into the system as a layer attribute. The location of the environmental infrastructure units of solid waste landfill that was established at the edge of the wetland's buffer zone, and the domestic wastewater treatment plant of Eregli district whose treated water is discharged to Akgol were digitized by using satellite images and the attributes such as width and volume of the stabilization ponds in the wastewater treatment plant were added to the system. Examples of created layers in GIS are illustrated in Figure 3. Land-use/cover classification processed from the satellite data were also added to the GIS environment. A web-based GIS has been implemented and published using the specified layers. The website is accessible from http://eregliakgol.itu.edu.tr

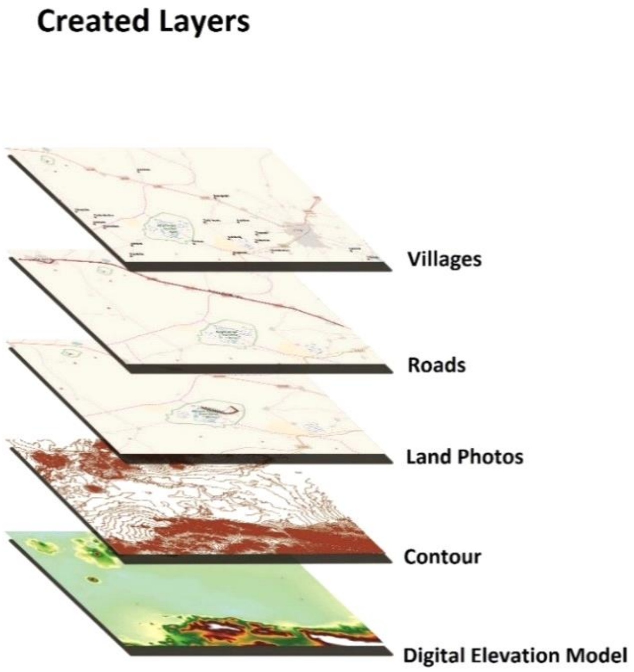


Figure 3 Examples of created layers in GIS

Results and Discussion

Temporal changes of water bodies in KCB and Akgol wetland were evaluated separately. All the index results are given in Figure 4 and Figure 5, respectively. The values of NDWI are shown in grey tone; however, the thresholds were determined and water covered areas are indicated in blue. Four satellite images belonging to 1987, 1998, 2007 and 2017 were selected as representative data indicating the reduction in water surfaces both in KCB and Akgol Wetland. According to these results, KCB has declined by approximately by 23.5% throughout the inspection period of 30 years. Akgol Wetland in Figure 4 that shows the entire KCB was just observable in 1987; but then onwards, in the large scale of KCB, it almost disappeared. Figure 5 specifically highlighted Akgol. While the water surface area of the wetland was 2958.4 ha in 1987, it decreased as 1153.9 ha in 1998, and it was only 12.7 ha in 2007. Suddenly, its surface water area has reached 117.2 ha in 2017 by the only feeding source that is precipitation.

Figure 6a demonstrates the total water surface area in KCB within the inspection time, whereas similar presentation is shown for Akgol Wetland at the same time lag. Akgol Wetland has almost decreased by 96% and is in danger of extinction. A long dike with a height 1.65 m was built by the Regional Directorate of State Hydraulic Works at part of the wetland from where high amounts of water escaped with the aim of regaining the wetland functions that have been lost with time, and of structurally strengthening the wetland to hold more water to overcome the negative effects of climate change. This technical construction was realized in July-September 2013 that targeted to end in a wetland with a water surface area of approximately 340 ha (Dervisoglu, et. al., 2017).

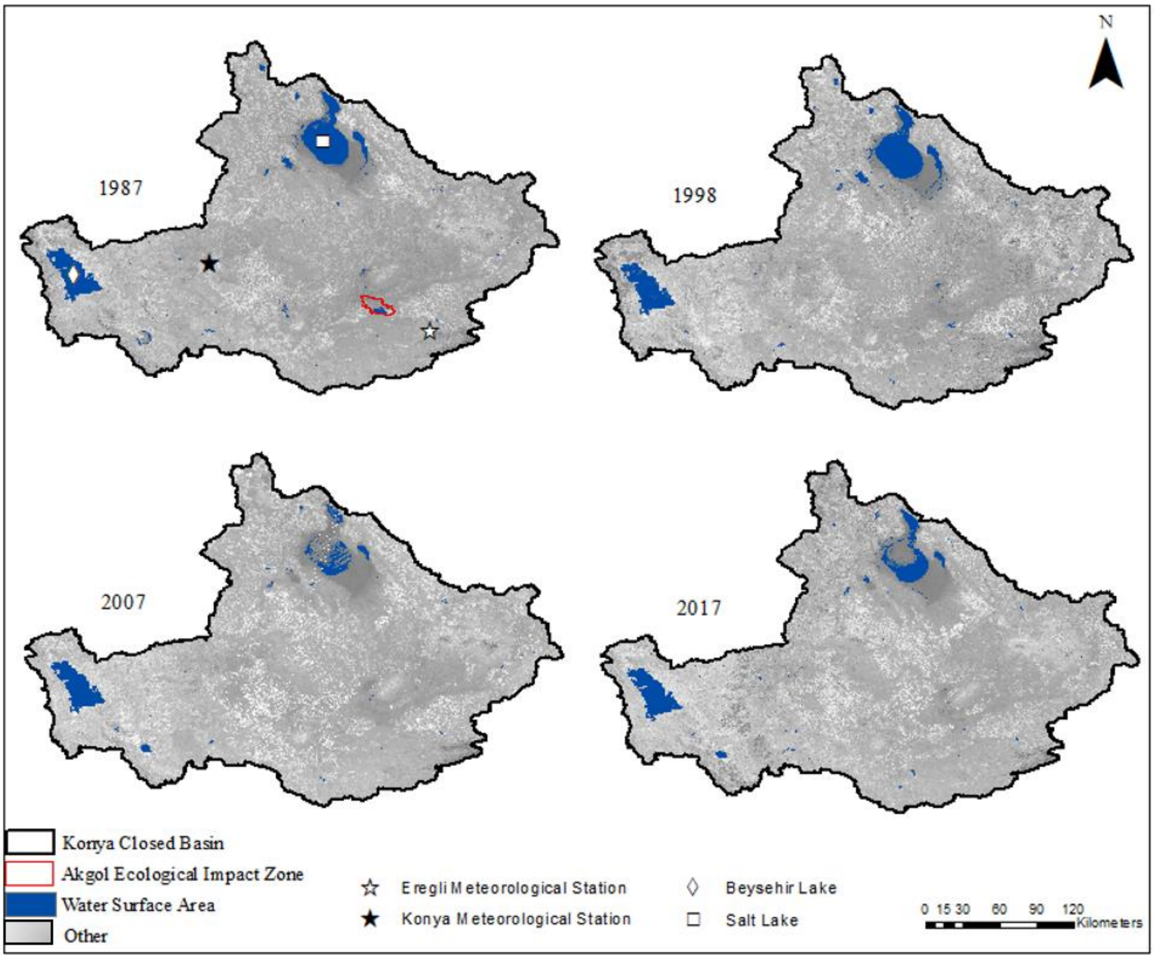


Figure 4 Temporal changes of water surface area in Konya Closed Basin

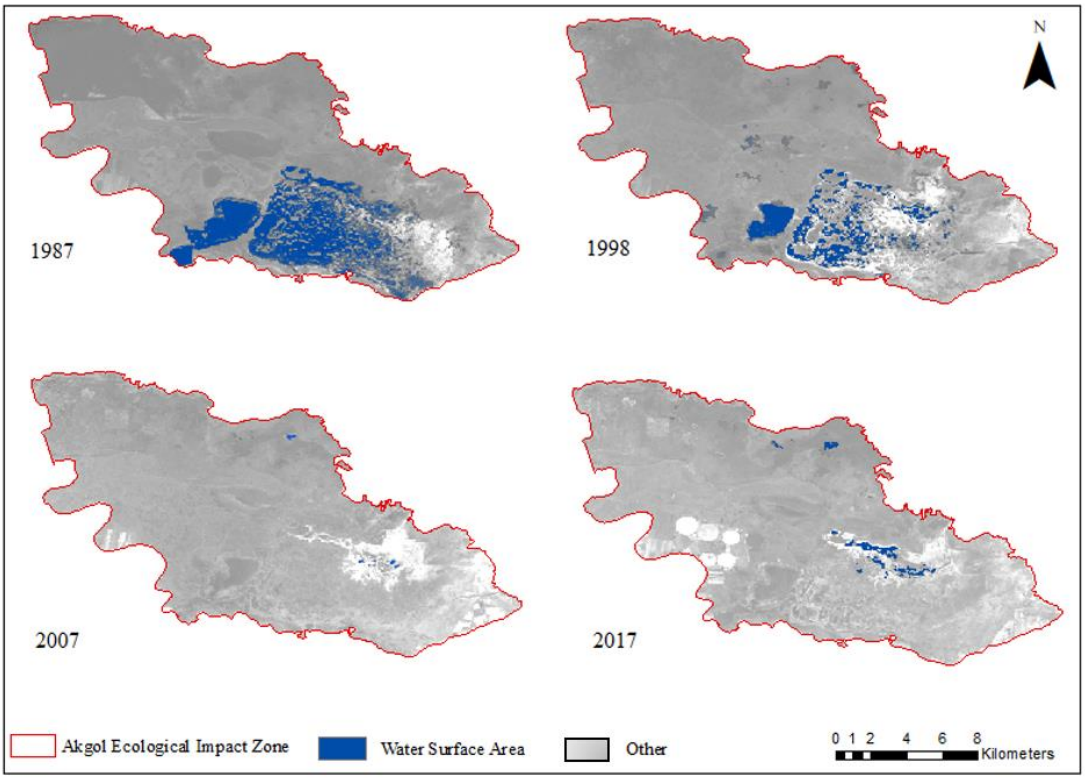
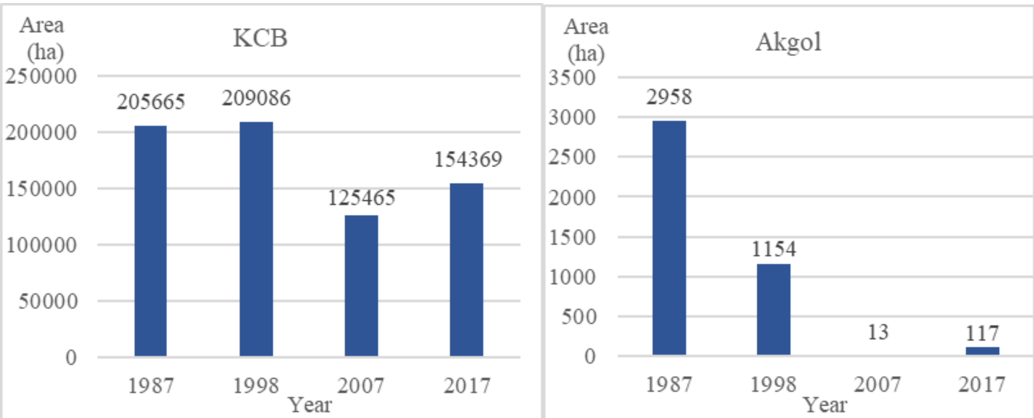


Figure 5 Temporal changes of water surface area in Akgol Wetland



(a) (b)

Figure 6 Water surface areas of (a) KCB, and (b) Akgol Wetland

Conclusions and Recommendations

Water potential of KCB is foreseen to be decreasing with time which may cause even more water deficit in future according to the outputs of climate change impacts on water resources project. Simply, the overall situation puts forth the losses in water holding capacity of these natural water bodies where majority of them are wetlands. Within this study, the changes in water volume are inspected in the past 30 years. The findings achieved designated the reality that surface water resources are declining with time. These alarming results actually urged the authors to focus more on a vulnerable watershed of the basin and inspect its physical situation. The results provided are for the decision-makers and related authorities in charge of the water related works in the basin. As such, multi-temporal change detection by using remotely sensed imagery has become a useful tool in gathering information on the status of the wetlands for the decision- makers and local authorities. By utilizing the remotely sensed data, one can generate wetland maps which may give rise to the estimation of its functions and services as well to further assessment of the gains and losses within years.

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References

Adam, E., Mutanga, O. & Rugege, D., 2010, Multispectral and hyperspectral remote sensing for identification and mapping of wetland vegetation: a review. *Wetlands Ecology and Management*, 18 (3), 281-296.

Agapiou, A., Dimitrios, D. A., Kyriacos T. & Hadjimitsis, D. G., 2016, Water leakage detection using remote sensing, field spectroscopy and GIS in semiarid areas of Cyprus. *Urban Water Journal,* 13:3, 221-231.

Algedik, O., 2012, Assessment Report on climate change action plan, Heinrich Böll Stiftung Association-Turkey Representative (in Turkish).

Arsanjani, J. J., 2018, Characterizing and monitoring global landscapes using GlobeLand30 datasets: the first decade of the twenty-first century, *International Journal of Digital Earth*, (online).

Bergkamp, G. & Orlando, B.,1999, *Exploring Collaboration between the Convention on Wetlands (Ramsar, Iran 1971) and the UN Framework Convention on Climate Change*. Climate Initiative, IUCN, Washington, USA.

Borfecchia, F., Caiaffa,E., Pollino, M., Cecco, L. D., Martini, S., Porta, L. L. & Marucci, A., 2014, Remote Sensing and GIS in planning photovoltaic potential of urban areas. *European Journal of Remote Sensing*, 47 (1), 195-216.

Celebi, M., Direk, M., 2017, Farmer behaviours and sustainable water management in semiarid Konya Closed Basin in Turkey. *International Journal of Advanced Biological and Biomedical Research*, 6(1), 441-450.

Coban, A., 2017, The effect of climate change on wetlands and the situation of wetlands in Turkey, *The Turkish Journal of Occupational/Environmental Medicine and Safety*, 2.1 (3), 3-3.

Costanza, R., Kubiszewski, I., Ervin, D., Bluffstone, R., Boyd, J., Brown, D. and Shandas, V., 2011, Valuing ecological systems and services. F1000 Biology Reports, 3.

CCIWR, 2016, Climate Change Impact on Water Resources Project, Ministry of Forestry and Water Affairs, General Directorate of Water Management [Online]. Date of access: 21/04/2018 http://iklim.ormansu.gov.tr/Eng/

DGWM, 2016. Technical Assistance for The Conversion of River Basin Action Plans into River Basin Management Plans, Ministry of Forestry and Water Affairs, Directorate General for Water Management, TR2011/0327.21-05-01-001.

De Roeck, E. R., Verhoest, N. E. C., Miya, M. H., Lievens, O., Batelaan, A. T. and Brendonck, L., 2008, Remote sensing and wetland ecology: A South African case study. *Sensors,* 8 (5), 3542-3556.

Dehouck, A., Lafon, V., Baghdadi, N. and Marieu, V., 2012, Use of optical and radar data in synergy for mapping intertidal flats and coastal salt-marshes (Arcachon Lagoon, France). Proceedings of the Geoscience and Remote Sensing Symposium (IGARSS) 2012, pp. 2853-2856.

Dhanapal, G., 2012, GIS-based environmental and ecological planning for sustainable development, Geospatial World, [Online]. Date of access: 21/04/2018.

https://www.geospatialworld.net/article/gis-based-environmental-and-ecological-planning-for-sustainable-development/

Dervisoglu, A., Musaoglu, N., Tanik, A., Gumusay, U., Senol, A. and Bakirman, T., 2017, Monitoring the effect of an impoundment built for rehabilitation of Akgol Wetland- Turkey. Proceedings of the ICOCEE 2017 Cappadocia, Turkey, pp. 601-610.

DMP, 2015, Konya Closed Basin Drought Management Plan Project, Ministry of Forestry and Water Affairs, General Directorate of Water Management. Date of access: 21/04/2018. http://www.suyonetimi.gov.tr.

Durduran, S. S., 2010, Coastline change assessment on water reservoirs located in the Konya Basin Area, Turkey, using multitemporal Landsat imagery. *Environmental Monitoring and Assessment*, 164, 453–461.

Dursun, S., Onder, S., Acar, R., Direk, M. and Mucevher, O., 2012, Effect of environmental and socioeconomically change on agricultural production in Konya Region. Proceedings of International Conference on Applied Life Sciences (ICALS2012), Turkey, pp. 19- 36.

Evans, T.L. & Costa, M., 2013, Land cover classification of the Lower Nhecolandia Sub-region of the Brazilian Pantanal Wetlands using ALOS/PALSAR, RADARSAT-2 and ENVISAT/ASAR imagery. *Remote Sensing of the Environment*, 128, 118–137.

Frolking, S., Talbot, J., Jones, M. C., Treat, C. C., Kauffman, J. B., Tuittila, E. S. and Roulet, N., 2011, Peatlands in the Earth's 21st Century climate system. *Environmental Reviews*, 19, 371–96.

Fu, X., Gaohuan, L., Siyue, C., Chong, H., Fadong, L. 2013, Spatial temporal analysis of wetland landscape pattern under the influence of artificial dykes in the Yellow River Delta. *Chinese Journal of Population Resources and Environment*, 11 (2), 109-117.

Gallant, A. L., Klaver, R. W., Casper, G. S. and Lannoo, M. J., 2007, Global rates of habitat loss and implications for amphibian conservation. *Copeia*, 2007(4), 967-979.

Garg, J. K., 2015, Wetland assessment, monitoring and management in India using geospatial techniques. *Journal of Environmental Management*, 148, 112-123.

Hadeel, A., Jabbar, M., & Chen, X., 2011, Remote sensing and GIS application in the detection of environmental degradation indicators. *Geo-spatial Information Science*, 14, 1, 39-47.

Higgins, L., Caretta, M. A. 2018, Lake extent changes in Basotu, Tanzania: a mixed-methods approach to understanding the impacts of anthropogenic influence and climate variability. *Landscape Research*, DOI: 10.1080/01426397.2017.1416599

Hird, N. J. Delancey, E. R., McDermid, G. J., Kariyeva, J. 2017, Google earth engine, open-access satellite data, and machine learning in support of large-area probabilistic wetland mapping. *Remote Sensing*, 9 (12), 1315.

Ji, L., Zhang, Li. & Wylie, B.K., 2009, Analysis of dynamic thresholds for the normalized difference water index. *Photogrammetric Engineering & Remote Sensing*, 75(11), 1307-1317.

Klemas, V. V., 2014, Advances in Coastal Wetland Remote Sensing. Proceedings of the 2014 IEEE/OES Baltic International Symposium (Baltic), Talinn Estonia.: Date of access: 18/04/2018 http://ieeexplore.ieee.org/xpl/mostRecentIssue.jsp?punumber=6879365

Korkanc, S., 2004, Place of wetlands in watershed system. *ZKÜ Bartın Journal of the Faculty of Forestry*, 6(6), 117-126. (in Turkish)

Li, W., Du, Z., Ling, F., Zhou, D., Wang, H., Gui, Y., Sun, B. & Zhang, X., 2013, A comparison of land surface water mapping using the normalized difference water index from TM, ETM+ and ALI. *Remote Sensing*, 5, 5530–5549.

McFeeters, S. K., 1996, The use of the Normalized Difference Water Index (NDWI) in the delineation of open water features. *International Journal of Remote Sensing*, 17(7), 1425-1432.

Meng, L., Roulet, N., Zhuang, Q., Christensen, T. & Frolking, S., 2016, Focus on the impact of climate change on wetland ecosystems and carbon dynamics. *Environmental Research Letters*, 11, 100201.

Prigent, C., Matthews, E., Aires, F. & Rossow, W. B., 2001, Remote sensing of global wetland dynamics with multiple satellite data sets. *Geophysical Research Letters*, 28(24), 4631-4634.

Rawashdeh, S. B.A., 2011, Evaluation of the differencing pixel-by-pixel change detection method in mapping irrigated areas in dry zones. *International Journal of Remote Sensing*, 32 (8), 2173-2184.

Rebelo, L. M., Finlayson, C. M. and Nagabhatla, N., 2009, Remote sensing and GIS for wetland inventory, mapping and change analysis. *Journal of Environmental Management*, 90 (7), 2144-2153.

Sheng, Y., Song, C., Wang, J., Lyons, E.A., Knox, B.R., Cox, J.S. & Gao, F., 2016, Representative lake water extent mapping at continental scales using multi-temporal Landsat-8 imagery. *Remote Sensing of Environment*, 185, 129-141.

Simard, M., Zhang, K.Q., Rivera-Monroy, V.H., Ross, M.S., Ruiz, P.L., Castaneda-Moya, E., Twilley, R.R. and Rodriguez, E., 2006, Mapping height and biomass of mangrove forests in Everglades National Park with SRTM elevation data. *Photogrammetric Engineering and Remote Sensing*, 72, 299–311.

Tangud,T., Nasahara,K.,Borjigin, H. & Bagan, H, 2018, Land-cover change in the Wulagai grassland, Inner Mongolia of China between 1986 and 2014 analysed using multi-temporal Landsat images. *Geocarto International*, DOI: 10.1080/10106049.2018.1478457

UNESCO-WWAP, 2003. Water for people – water for life. The United Nations World Water Development Report, United Nations Educational, Scientific and Cultural Organization (UNESCO), United Nations World Water Assessment Programme (WWAP), UNESCO Publishing and Berghahn Books, Barcelona.

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

Wdowinski, S., Kim, S., Amelung, F. and Dixon, T., 2006, Wetland InSAR: A new space-based hydrological monitoring tool of wetlands surface water level changes. Proceedings of the Glob Wetland Symposium, Frascati, Italy, pp. 6.

Wu, Q., 2018, GIS and remote sensing applications in wetland mapping and monitoring. *Comprehensive Geographic Information Systems*, (2), 140-157.

Wu, G., and Liu, Y., 2015, Capturing variations in inundation with satellite remote sensing in a morphologically complex large lake. *Journal of Hydrology*, 523, 14-23.