OPPURTUNITIES PROVIDED BY REMOTE SENSING DATA FOR WATERSHED MANAGEMENT: EXAMPLE OF KONYA CLOSED BASIN

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ABSTRACT:

Remote sensing data provides great opportunities to be utilized in various steps of watershed management like characterization of watersheds that bear dynamic structure with large land, monitoring the variations within the basin, and conducting various scenario analyses. The high resolution capacity of today's satellite images enables the production of land use/cover data of the basin in shorter period of times. In this study, it is aimed to demonstrate various aspects of remote sensing technology to be further used in watershed management studies. A methodology is developed on the utilization of remote sensing technology consisting of 3 main groups; field surveys, satellite images and ancillary data. The importance of establishing watershed information systems together with databases reflecting the characteristics of watersheds is underlined. Various examples are given from Konya Closed Basin in Turkey that is known as the largest closed basin of the country with a surface area of 5.426.480 ha. The basin owns 17 water bodies out of which 2 of them are RAMSAR sites. Within the scope of the study, the inputs of the information obtained from optical and SAR satellite images in the basin are discussed.

1. INTRODUCTION

Integrated watershed management has been internationally recognized as an important holistic approach towards natural resources management within the context of sustainable development. Countries have already accepted this understanding and great achievements have recently been realized in regard to conserving the natural resources which are mainly water, land and vegetation. The success of various management strategies developed so far depends on the establishment of a good/satisfactory database addressing the '*watershed information system*' (Tanik, 2019). If the database formed stores the minimum data required to define the prevailing characteristics of the watershed of concern, it may further be utilized for various watershed analyses, terrain and/or water quality modelling, and for management of the overall basin (Randhir, 2007; EPA, 2008). Resource inventory required to characterize the watersheds covers the collection, analysis and presentation of data relating to all the resources of the watershed including the following components (UN, 1997);

- Topography and landform
- Geology and geomorphorphology
- Soils
- Climate
- Hydrology
- Ecology.

At this stage, Remote Sensing (RS) technology enables spatial and temporal data of a number of physical attributes about the watershed surface that can be appropriately be utilized to map the extent of land and water bodies at watershed scale, and to monitor their dynamics at regular and frequent time intervals (Huang et. al., 2018).

The objective of this study is to demonstrate the opportunities provided by RS data to be further applied for watershed management. Examples of data produced and/or processed by RS technology are given for Konya Closed Basin (KCB) of Turkey. It is important to note here that these available and produced data are stored in the database of the watershed of concern and it forms an integral part of '*Watershed Information System'*. Every basin has to bear an information system of its own, as each watershed has its intrinsic properties not similar to even the neighbourhood basin.

2. STUDY AREA

KCB located in the Central Anatolia Region of Turkey has been declared as one of the 200 significant ecologically important regions of the world by the World Wildlife Foundation (WWF) (Dursun et al., 2012). It covers almost 7% of Turkey's overall surface area and bears an annual amount of 4,365 billion m^3 of usable water. However, water consumption of 6,5 billion m^3 in the basin points out that there is an annual water deficit of approximately 2 billion m^3. Thus, this basin is known to be one of the significant basins of the country facing water scarcity problems. Semi-arid climatic conditions prevail in the basin. The average annual rainfall was around 407 mm taking into

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account the average of all years from 1923 to 2013. However, this annual precipitation value is found lower in this study that considered the 1984-2017 period. It can be stated that the precipitation value in general is almost half of the country's average value. Larger surface area with less flowing water bodies and 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 vice versa 17% of the groundwater resources. As such, '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% (CCIWR, 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 the Central Anatolia (Celebi and Direk, 2017).

KCB has a variety of surface water bodies as shown in Figure 1. Among the 17 water bodies 3 of them are lakes, whereas the rest are mainly wetlands of high ecological importance. 2 of them (Meke Maar and Kizoren Obrouk) have been declared as Ramsar sites. The water surface areas of each of these water bodies as well as their conservation status are given in Table 1.

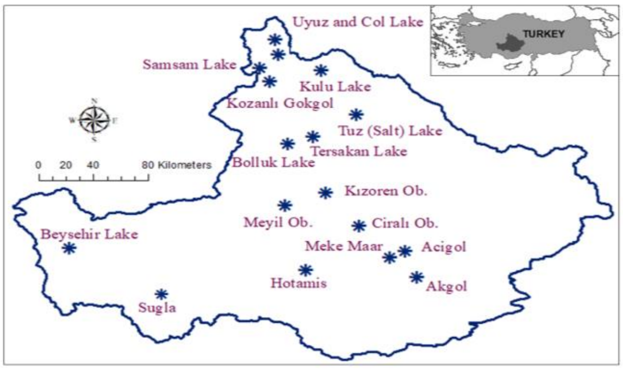

Figure 1. Geographical location of KCB and mean water surface areas of its water resources

Name	Water Surface (ha)	Conservation Status
Tuz Lake	240000	Natural Assets
Beyşehir Lake	73000	Natural Assets, Natural Parks,
Tersakan Lake	11000	Natural Assets
Akgol (Eregli Wetlands)	5000	Natural Assets, Nature Reserves
Bolluk Lake	3800	Natural Assets
Hotamış	5800	-
Kulu Lake	1800	Natural Assets
Col Lake	1500	-
Samsam Lake	830	Natural Assets
Acıgol	400	-
Kozanli Gokgol	650	Natural Assets
Meke Maar	202	Natural Assets, Nature Parks, Ramsar Site
Kizoren Obrouk	127	Ramsar Site
Cirali Obrouk	100	-
Meyil Obrouk	20	-
Uyuz Lake	15	Natural Assets

Table 1. Surface water bodies of KCB and their conservation status (Forestry Statistics, 2010; Url 1)

Musaoglu et. al (2018) conducted a long-term monitoring study of the wetlands in this basin via RS and GIS. The results derived from this study indicate that the surface area of the water bodies in KCB decreased by approximately 23.5% within the inspection years of 1987-2017. 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 (Yagmur et. al. 2018).

3. DATA AND METHODOLOGY

The flow diagram of the methodology developed specifically for this study is shown in Figure 2. The use of RS for KCB basin may be classified in 3 groups; field surveys, satellite data and ancillary data. The already available data and data produced within the scope of the study are placed under these 3 groups that further form the database of the basin. Data analyses are then realized with the gathered, produced and processed data stored in the database for watershed management. Apart from the methodology given, ancillary data is also obtained during the site visits especially from the public authorities, regional institutions and more importantly, public advice and feedback are taken and utilized in the database formed. These details are not shown in the flow diagram of the methodology.

Field surveys consist of spectroradiometer, GPS, levelling and thermal measurements whereas ancillary data is composed on mainly watershed boundaries, meteorological data and digital elevation model of the watershed. Optical and SAR images are both utilized. In this section, various examples on KCB will be presented under the available and produced data categories to enlighten the interested parties on the utilization and integration of RS in watershed management studies.

3.1 Available data

While conducting a study on a specific watershed, the primary work that should be realized is to delineate the watershed boundaries. It is important to fix the total area of concern at the beginning of the study. It is then that the topographical map of the watershed should be formed and illustrated in the form of digital elevation model (DEM). Topography is an important component of resource inventory of a watershed. Figure 3 shows the example of DEM generated from SRTM for KCB.

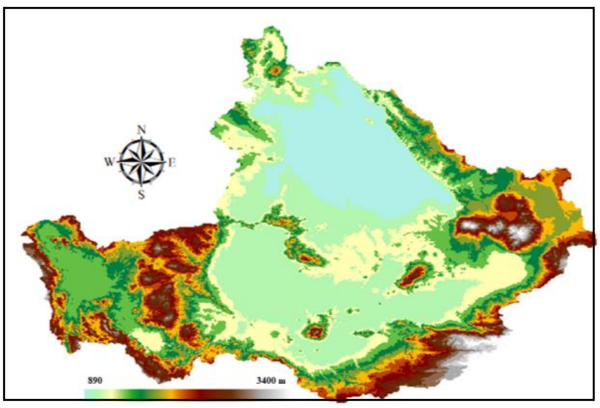

Figure 3. Digital Elevation Model of KCB

The other available data that is of high importance in watershed management efforts is meteorological data including temperature, precipitation, evaporation, etc.

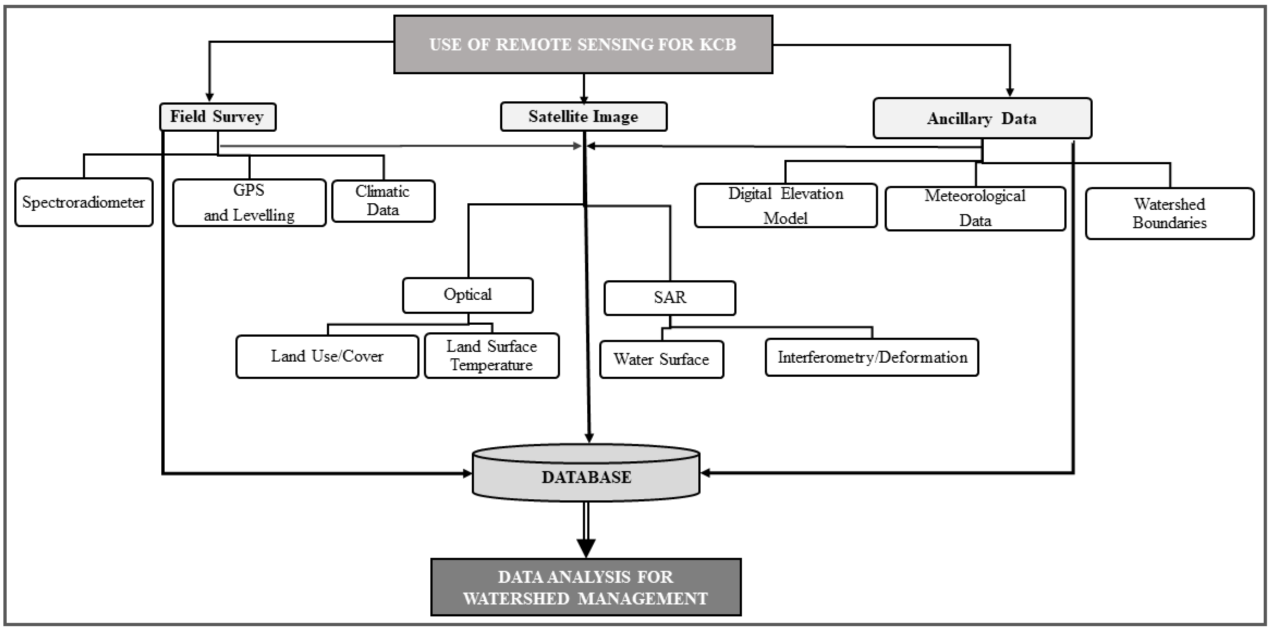

Figure 2. Flow chart of the methodology used

Required data are obtained from the nearest State Meteorological Station(s) representing the overall watershed. Figure 4 (a) and (b) demonstrate the charts of long-term annual average temperature and precipitation values within the 1984-2017, respectively.

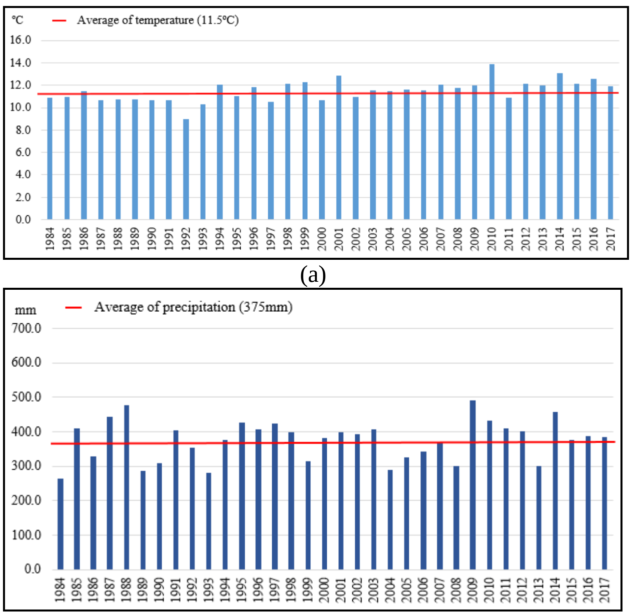

Figure 4. Long term annual average variation of (a) temperature and (b) precipitation values in KCB

As KCB is known as one of the most important agricultural areas of Turkey; dams have been built and put into operation for supplying the irrigation demand of the basin. In general, the basin bears an arid/semi-arid climatic character; and thus, suffers from water resources on the contrary to its fertile soil characteristics. Most of the water streams/rivers get dry during summer. Therefore, dry and hot summers accelerate evaporation leading to more water losses. For example, excess evaporation causes the formation of salt layers of almost 30 cm thickness during summer in the Tuz (Salt) Lake and water loss of the lake was further compensated by diverting water of another nearby water body, and by discharging the treated domestic wastewaters of Konya Province to Tuz Lake via a main drainage channel. However, the situation in the 2 other systems, Meke Maar and Akgol Wetland for example, is quite different. Water feeding and/or diversions from the other water resources have not been experienced so far leading to remarkable water losses. Areal values of the inspected water bodies were calculated from the satellite images at every 10-years interval between 1987-2017, whereas the meteorological data like temperature and precipitation were assessed starting from 1984. In the general evaluation of the overall basin, data of the 12 meteorological stations existing in the basin were considered. However, only the nearby and representative ones were taken into consideration in discussing the climatic conditions of the individual water bodies. Meteorological data were gathered from the State Meteorological Service (DMS).

Hydrological condition of the watershed is also another important available data that can be depicted via RS. As referred in the introduction section, temporal and spatial assessments of water surfaces may be performed via satellite images belonging to various years. Table 1 gives the water surfaces of the water bodies in the KCB as areal values change annually based on either natural and/or anthropogenic effects.

A noticeable areal change has occurred at Akgol Wetland, that is an another internationally recognized water body of the basin, has almost lost its water surface by 96% during a period of 30 years (1987-2017), and thus, it is in danger of extinction (Musaoglu et. al., 2018). This finding is the outcome of inspecting the various satellite images belonging to different years.

3.2 Produced Data

3.2.1 Field Studies: Field spectroscopy is usually used to reach the reflectance information of field spectra. Spectroradiometer and GPS receiver were used to collect samples during the field survey. FieldSpec HH is the model of spectroradiometer with 325-1075 nm spectral range. Position and spectral reflectance of one of the samples from water is given in Figure 5 together with site photos taken during the field surveys. This sample referred in Figure 5 is taken from shallow water of Akgol Wetland. When Figure 5 is examined in depth, it will be seen that the properties of spectral signature of water can be observed. It has high reflectance in green region whereas low reflectance in the NIR region. The spectral reflectance of a water area changes according to its depth and amount of materials present (McCoy, 2005).

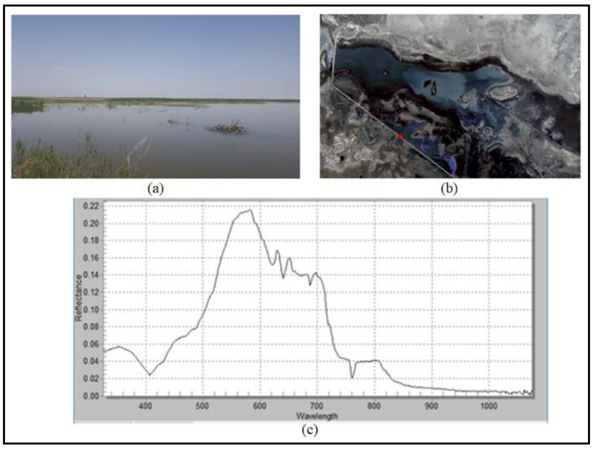

Figure 5: a) Water area, b) location of the water sample, c) spectral reflectance of the water sample

In addition, thermal measurements were also conducted in the study area with thermal termometers providing extra data for climatic evaluation of the basin.

Moreover, levelling at the basin is also carried out to evaluate the accuracy of Sentinel 1 SAR interferometry results. During the field surveys, geometric levelling is used, as one of the traditional measurement methods, to produce elevations in mm precision.

3.2.2 Remote Sensing: Resolution properties of satellite images enable information generation at different scales. It is possible to use different images based on the scale of the final product and on the required land-use/cover classes.

In this study, freely available MODIS, Landsat and Sentinel images are used for producing data at watershed scale. Moreover, Worldview-3 image is utilized to produce detailed information about Akgol Wetland. General characteristics of satellite images used and examples from different satellite images are given in Table 2 and Figure 6.

Sat.	Spatial Resolution	Rad. Res.	Temp. Res.	Spectral Resolution (μm)
MODIS	250m (bands 1-2) 500m (bands 3-7) 1000m (bands 8-36)	12 bit	16 days	36 bands: 1-19 from 0.620 to 0.965 20-36 from 3.66 to 14.28 microns
Landsat -5 TM	Red, Green, Blue, NIR, SWIR 1-2: 30 m TIR: 120 m	8 bit	16 days	Red :0,63-0.69 Green :0,52-0.60 Blue :0,45-0.52 NIR :0,76-0.90 SWIR 1:1.55-1.75 SWIR 2 :2.08-2.35
Landsat -8 OLI	Pan: 15 m Coastal, Cirrus, Red, Green, Blue, NIR, SWIR 1-2: 30 m TIR 1-2: 100 m	12 bit	16 days	Red :0,636-0.673 Green :0,533-0.590 Blue :0,452-0.512 NIR :0,851-0.879 SWIR 1:1.566-1.651 SWIR 2:2.107-2.294
Sentinel 2 MSI	Coastal, Water vapour, SWIR Cirrus: 60m Red, Green, Blue, NIR: 10 m Vegetation Red Edge, SWIR 1-2: 20 m	12 bit	5 days	Red :0,665 μm Green :0,560 μm Blue :0,490 μm NIR :0,842 μm SWIR 1:1.610 μm SWIR 2:2.190 μm
Worldview-3	Red, Red Edge, Coastal, Green, Yellow, Blue, NIR 1-2: 2 m	11 bit	By demand	Coastal: 0.40-0.45 Blue: 0.450-0.510 Green: 0.510-0.580 Yellow: 0.585-0.625 Red: 0.630-0.690 Red Edge: 0.705-0.745 NIR 1: 0.770-0.895 NIR 2: 0.860-1.040

Table 2. Technical specifications of satellite data

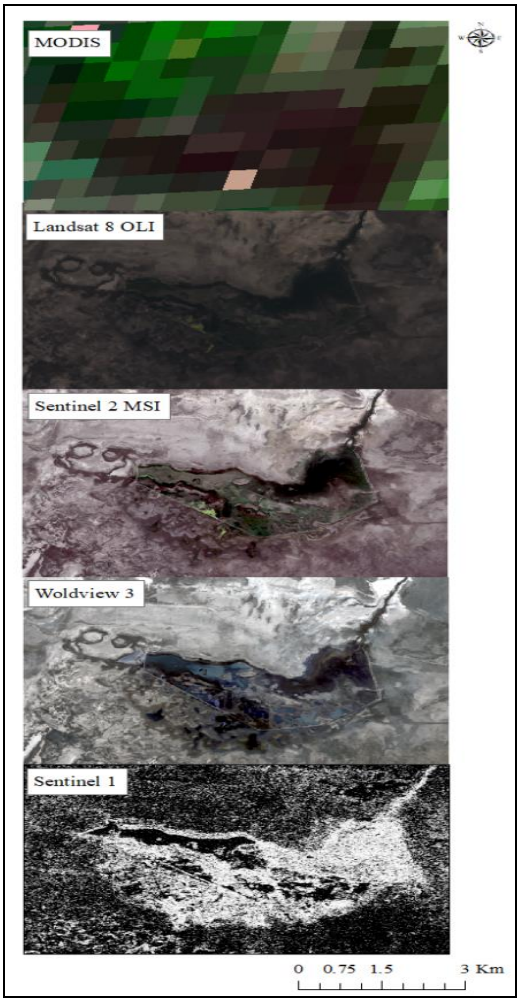

Figure 6. Satellite images for Akgol Wetland

4. RESULTS AND DISCUSSION

4.1 Spectral Indices

Water surface area was calculated with Normalized Difference Water Index (NDWI). NDWI has been widely used for water body detection. Besides NDWI, there are various water indices such as Modified NDWI, Automated Water Extraction Index (AWEI), and Water Ratio Index (WRI) etc. as mentioned in Table 2. Indices use different spectral bands of satellite images. For instance, NDWI uses green and near infrared bands of the satellite image and results varies between -1 and 1. If results are greater than zero, they indicate the water areas.

Figure 7 is an example of NDWI results of the Sentinel 2 for the overall KCB within years 1987-2017. As such, the surface of water bodies varies from year to year, and this situation can be clearly observed from this multi temporal illustration. Similar maps enable the quantification of the water amounts leading to calculations on the water budget of each and/or overall surface water bodies in the basin. These calculations are further utilized by the experts working on watershed management.

Index	Formula	Reference
NDWI	(Bgreen-Bnir)/(Bgreen+Bnir)	Mcfeeters (1996)
MNDWI	(Bgreen-Bswir)/(Bgreen+Bswir)	Xu (2006)
AWEIsh	Bblue+2.5×Bgreen-1.5×(Bnir+Bswir1)-0.25×Bswir2	Feyisa et al. (2014)
AWEInsh	4×(Bgreen-Bswir1) -(0.25×Bnir +2.75×Bswir2)	Feyisa et al. (2014)
WRI	(Bgreen+Bred)/(Bnir+Bswir1)	Shen & Li (2010)

Table 2. Spectral water indices used in this study

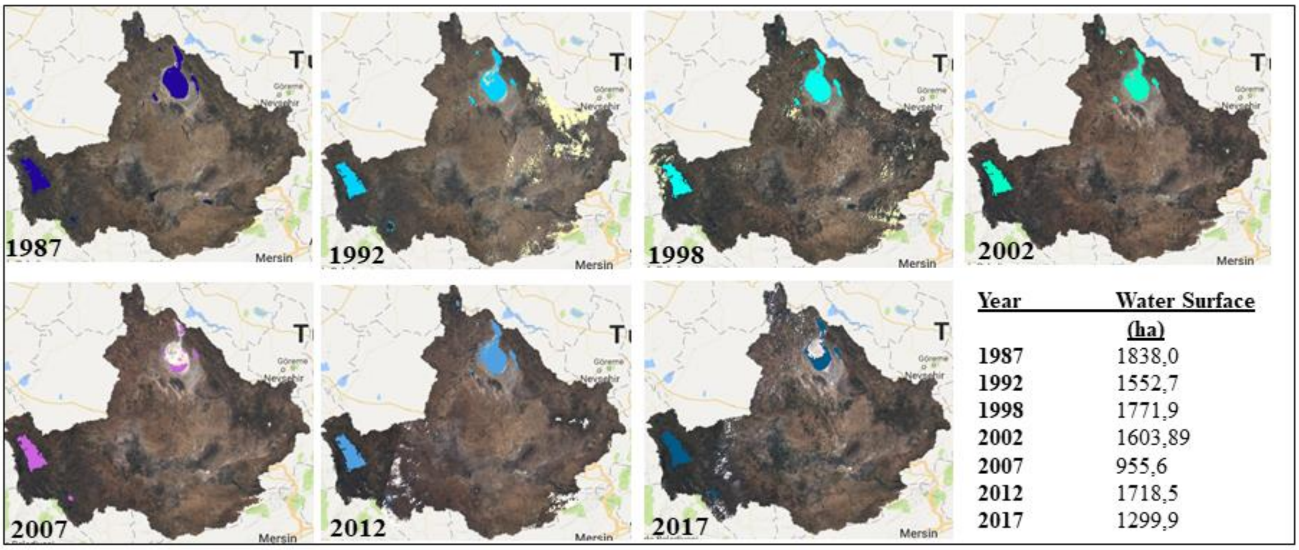

Figure 7. NDWI results for KCB

4.2 Classification

Worldview-3 satellite image, which has high spatial and spectral resolution, was used in classification to reach detailed information. Six classes in the region; deep water, shallow water, vegetation, agricultural area, soil and saline soil were discriminated by Worldview-3 satellite image. For that purpose, support vector machine (SVMs) method was used. SVM is a nonlinear method used to generate an optimum hyperplane in high dimensional feature space (Vapnik, 1999).

The spectral bands; coastal, blue, green, yellow, red, red edge, NIR1, and NIR2 of the satellite image were used as features in order to generate a model. Samples were divided into train and test with K-fold cross validation method. In this method, the value of K parameter was chosen as 10.

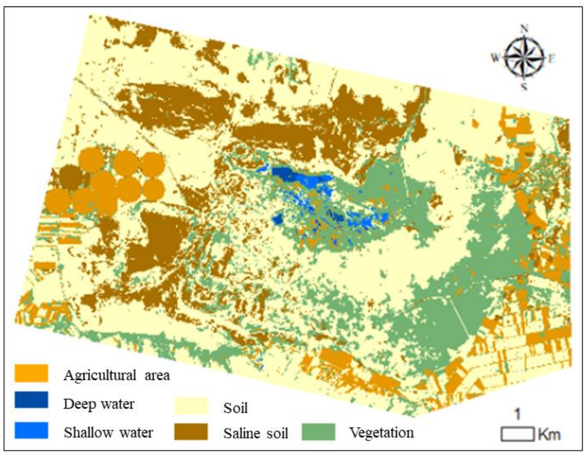

Figure 8. Thematic map produced from Worldview-3 with SVM classifier

A radial basis kernel was selected as kernel type and the hyper-parameters which were cost and gamma of RBF kernel was detected by optimization. Thematic map produced from Worldview-3 with SVM classifier is shown in Figure 8. Overall accuracy of the map produced from Worldview-3 with SVM classifier is 96%.

4.3 SAR processing

SAR images that supply more information about the physical properties more than the spectral properties of the earth. They can reflect the texture of the region. By using this feature of SAR images, surface water areas of lakes have been automatically determined by using Google Engine. For this purpose, a 295-line code index is written that can be applied to Sentinel-1 images. The sample results obtained with this code for Tuz Lake are shown in Figure 9. Surface water area variations can be observed on monthly basis in this figure. Therefore, one can easily determine the changes that occurs within different time lags. Additionally, interferometry pairs were generated by using Sentinel-1 images to determine the vertical changes of the wetlands and their surroundings of Tuz Lake is given in Figure 10. When the interferometry results are compared with levelling, a high positive correlation of 0.90 is obtained. This figure puts forth the changes on the water depths again on the monthly basis. Thus, a high positive correlation (r: 073) is calculated from the results obtained from Figure 9 and 10.

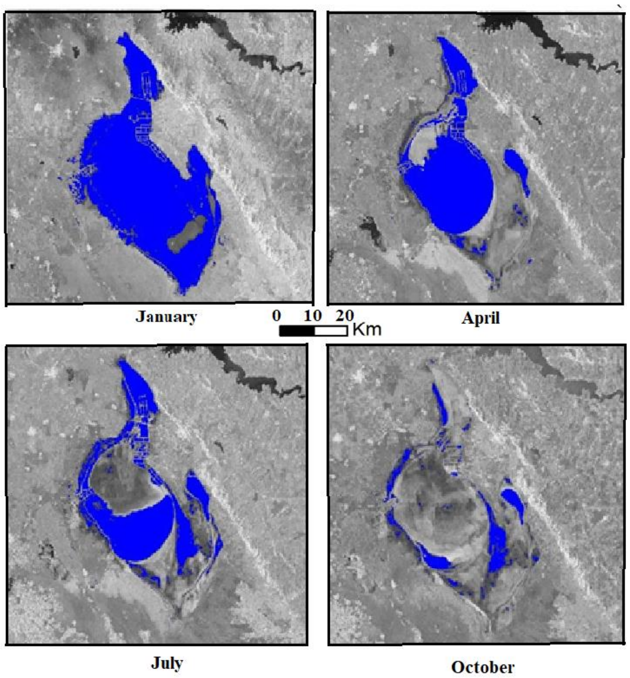

Figure 9. Montly variations of recent water surfaces of Tuz Lake from Sentinel-1SAR images (2018)

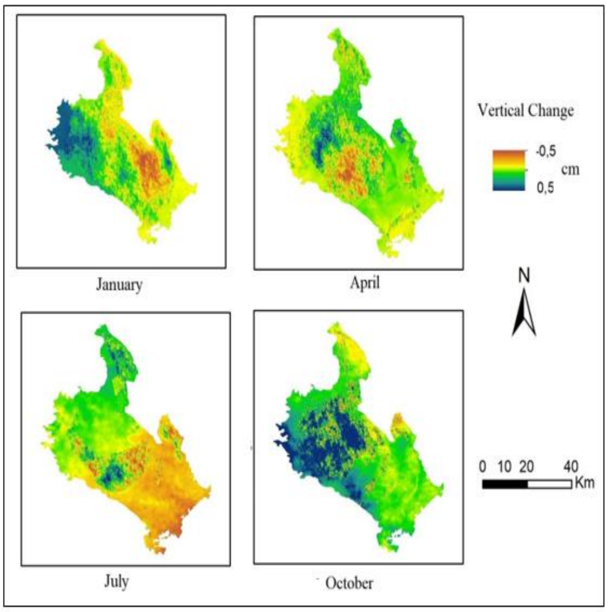

Figure 10. Vertical changes of Tuz Lake (2018)

As a conclusion, it can be stated that NDWI results of Sentinel 2 is more accurate than the others, especially MODIS. Landsat has been providing satellite images since 1970s and thanks to that, it has been generally used for multi-temporal analysis. Besides Landsat, Sentinel 2 satellite image can be used for watershed analysis; however, it has more spatial resolution than Landsat.

For producing more detailed information, high resolution satellite image like Worldview-3 and classification algorithms can be used. Sentinel 1 SAR images provide data for all weather conditions both horizontally and vertically.

Such integrated studies may be extended by adding the pollution criteria of both land and water bodies and by emphasizing on the social aspects of watershed management in future works. It is important to note here that watersheds have dynamic structures as humans always appear at the centre and govern many of the changes detected via RS technology.

All the referred and mentioned data provided with the use of RS are then stored in the database established to the watershed of concern. Further quarries, analyses, modelling, scenario analyses and development of management strategies can be realized. As highlighted in this study, valuable information and data may be compiled with RS technology in a shorter period of time with less cost. Integration of RS technology in watershed studies has gained an ever increasing interest and highly favoured by various disciplines.

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REFERENCES

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/

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.

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.

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.

EPA., 2008. Handbook for developing watershed plans to restore and protect our waters, United States Environmental Protection Agency, Office of Water Nonpoint Source Control Branch Washington, DC. EPA 841-B-08-002, March 2008.

Feyisa, G.L., Meilby, H., Fensholt, R., Proud, S.R., 2014. Automated water extraction index: a new technique for surface water mapping using Landsat imagery. *Remote Sensing of Environment*, 140, 23–35.

Forestry Statistics 2010. A Publication of Official Statistics Programme, Republic of Turkey Ministry of Forestry and Water Affairs, Ankara.

Huang, C., Chen, Y., Zhang, S., & Wu, J., 2018. Detecting, extracting, and monitoring surface water from space using optical sensors: A review. *Reviews of Geophysics*, 56. https://doi.org/10.1029/2018RG000598.

McCoy, R. M. (2005). *Field methods in remote sensing*. Guilford Press, 42-114.

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.

Musaoglu, N. Tanik, A., Gumusay, U.M., Dervisoglu, A., Bilgilioglu, B.B., Yagmur, N, Bakırman, T., Baran, D., Gokdag, F, M., 2018. Long-term monitoring of wetlands via remote sensing and GIS: a case study from Turkey, *2nd International Conference on Climate Change,* Sri Lanka, Colombo, 15-16 February 2018, Proceedings Vol. 2, p. 11-21.

Randhir, O.T., 2007. Watershed Management- Issues and Approaches, IWA publishing, London, UK, 146 p.

Shen, L.; Li, C., 2010, June. Water Body Extraction from Landsat ETM Imagery using Adaboost Algorithm. *In Proceedings of the 18th International Conference on Geoinformatics*, Beijing, China, 1–4.

Tanik, A. 2019. Integrated watershed management. Lecture notes of CBM 546E graduate course at ITU Environmental Science, Engineering and Management Programme.

UN. 1997. Guidelines and manual on land-use planning and practices in watershed management and disaster reduction, United Nations, ST/ESCAP/1781, Economic and Social Commission for Asia and the Pacific, June 1997.

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.

Vapnik, V. (2013). *The nature of statistical learning theory*. Springer science & business media.

Yagmur, N., Bilgilioglu, B.B., Musaoglu, N., Erten, E., Tanik, A. 2018. Temporal changes of lentic system surfaces in Konya Closed Basin, Turkey, 3. ICOCEE 2018, *3rd International Conference on Civil and Environmental Engineering*, Çeşme-İzmir, 24-27 April 2018, Conference E-Book Vol.2., p. 658-668.

Url 1: http://www.kop.gov.tr/upload/dokumanlar/32.pdf (last accessed 1 april 2019)