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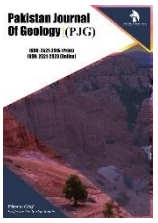

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RESEARCH ARTICLE

ANALYZING THE VEGETATION AND WATER INDICES FOR MANCHAR AND KEENJHAR LAKES IN THE DROUGHT CONDITIONS, 2021 THROUGH REMOTE SENSING

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ABSTRACT

Satellite remote sensing and geographic information system are those technologies that have been proved highly productive in the monitoring of anthropogenic activities and in the development of databases that allows monitoring of wetlands and other protected areas in a systematic way. The Remote Sensing techniques also provides solution to the accessibility problems. The province of Sindh is comprised of many wetlands of which Manchar and Keenjhar Lakes has been studied. Landsat 8 OLI/TIRS satellite images were acquired for the year 2013 and 2021 respectively and different spectral indices like NDVI (Normalized Difference Vegetation Index) and NDWI (Normalized Difference Water Index) were investigated. NDWI and NDVI is showing a positive correlation as the values of Pearson correlation **"r"** is almost near to 1. The NDVI value for both lakes in 2013 was high which is showing dense vegetation covers but on the other hand the NDVI values declines showing sparse vegetation in 2021 which is alarming. The NDWI values for both the lakes were below the threshold level. The main purpose of carrying out this study is to calculate and detect Vegetation covers and level of water stress in the lakes which was not found to be satisfactory as a lot of regions of Sindh in 2021 were facing drought conditions because of less precipitation and shortage of water in rivers. The study proved to be effective in demonstrating the use of satellite remote sensing techniques for wetland monitoring.

KEYWORDS

Spectral indices, Normalized Difference Vegetation Index, Landsat 8, Satellite images, Wetland monitoring, Water stress.

1. INTRODUCTION

Satellite images give a broad scope of environmental monitoring in a convenient way, specifically for those areas which cannot be accessed because of the dense vegetation, topography or other localized factors (van Lóki and Szabó ,2011; Dessel et al., 2008; Varga et al., 2015). Sentinel (ESA) and Landsat (USGS) imageries, has 20 and 30m resolution, and are freely available, this kind of mapping is cost effective and provide observations regarding the changes in an area through their temporal resolutions (Hansen and Loveland, 2012). The spectral resolutions of these satellites are also suitable for land cover maps, along the usual RGB bands.

Pakistan's wetlands have an extensive variety of biodiversity. Pakistan became a member of Ramsar Convention in 1976 aiming to protect and assist sustainable utilization of the resources of the wetlands (Khan and Arshad, 2014). In Pakistan there are considerable amount of communities that are dependent on wetlands for their living and income, Keenjhar Lake is one of the Ramsar site that is facing degradation because of the climatic issues like drought, eutrophication and most important is the pollution that readily effects the life of local people. Keenjhar Lake is the principle source of water provision to Thatta and Karachi (Khan et al., 2017). The increasing pressure on wetlands is making their conditions unstable for future (Khan and Arshad, 2014). Similarly, Manchar Lake is also degraded because of the contaminated and toxic water of power plants, industries and agriculture received from Main Nara Valley Drain (MNVD).

Scientists uses different algorithms and formulas; to modify satellite data into different spectral and vegetation indices. The vegetation health and greenness could be indicated through vegetation index for each pixel in a satellite imagery. The most commonly used index is, the Normalized Difference Vegetation Index. The values of NDVI varies from +1 to -1. Sand, snow or area with barren rocks exhibits very low values of NDVI. Moderate values of NDVI are exhibited by medium vegetation like grasslands or shrubs (0.2 to 0.5). High values of NDVI (0.6 to 0.9) shows dense vegetation covers like that in tropical or temperate forests when its growth stage is at peak (USGS.gov). NDWI is determined by measuring the amount of water molecules in vegetation covers that interact with the incoming sunlight. Two narrow channels are measured at 0.86 µm and 1.24 µm. Unlike NDVI both channels measure the same depth through vegetation covers (Gao, 1996). It may provide effective data on water stress conditions in an area.

2. STUDY AREA

Manchar Lake is the largest lake of Pakistan and is located in district Jamshoro, Sindh Province of Pakistan at a distance of approximately 18 km from Sehwan Sharif. It lies at 67°34´- 67°43 E and 26°23´-26°28´N. There is a seasonal fluctuation in its area with an average of 233 km² and the mean depth variation of Manchar lake is in between 0.5 to 3.75m (Kazi et al., 2009; Jahangir et al., 2014). Keenjhar is a freshwater lake which is located at 68°2'8.98"E and 24°57'8.91"N. It is among the largest lakes of Pakistan, having an area of 13,468 hectare and it supplies water to Keti Bunder, Karachi city and Thatta district (Khan et al., 2012). The lake is

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located approximately at a distance of 113km from the city of Karachi. The map of study area is shown in Figure 1.

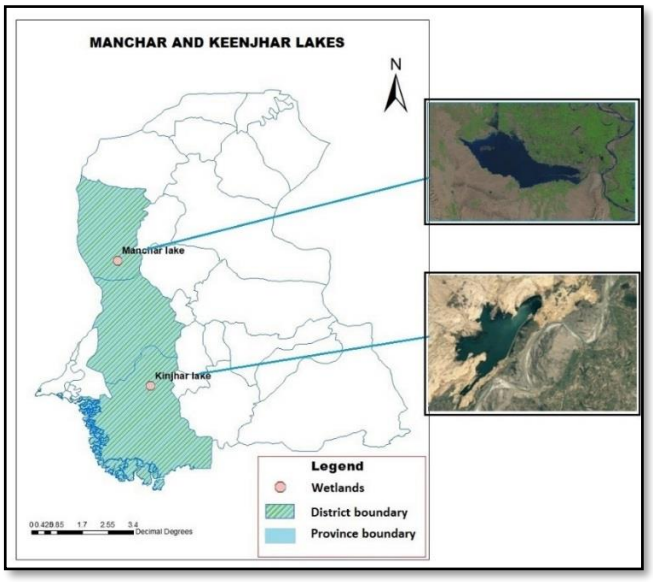

Figure 1: Map of study area showing Manchar and Keenjhar lakes, Province of Sindh, Pakistan.

3. Related Work

A studied the LULC (Land Use/Land Cover) of wetlands comprises of Keenjhar Lake, Manchar Lake and Chotiari Reservoir in Pakistan from (1972 to 2020) and change has been reported (Islam et al., 2021). The vegetation cover of Keenjhar Lake and Manchar Lake has been reduced by 6,337.17 and 558.18 hectares respectively. SAVI analysis confirms that soil profile is degrading continuously which strongly effects the vegetation covers of the wetlands. A group researchers carried out a study and observed that from (1990 to 2020) 1.79% vegetation, 6.73% water, 4.77% desert area and 18.68% wetland has been declined in Manchar lake and Barren land has been increased to 38.1%, so the fertile soil/Land of Manchar lake is converting into barren land which is an alarming situation (Chandio et al., 2021). The lake has two types of problems, low hydrological flow/ low precipitation of water and polluted water of MNV Drain and R.B.O.D which is highly polluted by drainage effluent and agriculture of Sindh and Balochistan.

A group researchers carried out research that is focused on the analysis of spatial-temporal change of Keenjhar Lake and Manchar Lake (Islam et al., 2019). The results showed that there were considerable changes in land cover because of the unexpected climatic patterns, notable fall in the rate of precipitation and uncontrolled anthropogenic activities. These changes had unfavorable impact on public health and on the ecosystem of the wetlands. Some researchers used XGBoost classifier to investigate variations of temporal water areas (Wagle et al., 2020). They combined normalized water indices such as MNDWI, NDVI data and Normalized Difference Built-Up Index (NDBI) over a decade.

A group researchers proposed methods to assess suitable thresholds for identification of features of the water clearly (Ji et al., 2009). Simulation of sensors of various satellite had been done and NDWI had been calculated for each case. Some researchers assesses the spatial- temporal changes in the water bodies including the overflow of water in marshlands by using both the MNDWI and the NDWI to check the usefulness of multi temporal Landsat images (Hui et al., 2008). According to Malthus and Dekker researchers have used satellite data to delineate water bodies; some earlier works has been done on normalized indices and researchers used distinctive derivative studies on subsurface reflectance, high spectral resolution and similar kind of data to get spectral resolution with high reflectance in order to detect inland water bodies (Malthus and Dekker, 1995).

4. Materials and Methods

4.1 Data Collection

Landsat 8 OLI/TIRS images of Manchar and Keenjhar lakes for the years 2013 and 2021 has been downloaded from USGS Earth Explorer (earthexplorer.usgs.gov) with less than 5% cloud cover and all the images are taken from the month of August for the uniformity of the study. Ground truthing had been done through high resolution images. According to (United States Geological Survey 2020) the multispectral bands of Landsat 8 OLI/TIRS has a spatial resolution of 30m and this satellite uses the Universal Transverse Mercator (UTM) as map projection. Its pixel value is 16 –bit. The wavelengths of all the bands are given in Table 1.

Table 1: Landsat 8 OLI/TIRS band wavelengths. (usgs.gov).

Bands	Wavelength (mm)
Band 1 - Coastal aerosol	0.43-0.45
Band 2 - Blue	0.45-0.51
Band 3 - Green	0.53-0.59
Band 4 - Red	0.64-0.67
Band 5 - Near Infrared (NIR)	0.85-0.88
Band 6 - SWIR 1	1.57-1.65
Band 7 - SWIR 2	2.11-2.29
Band 8 - Panchromatic	0.50-0.68
Band 9 - Cirrus	1.36-1.38
Band 10 - Thermal Infrared (TIRS) 1	10.6-11.19
Band 11 - Thermal Infrared (TIRS) 2	11.50-12.51

4.2 Mapping and Raster Calculations

In this study the Images are recalculated and processed for spectral bands in both reflectance and radiance values. Images are clipped according to the desired area of interest. All the mapping and calculations for different spectral indices are done through ArcMap 10.8 software and the KML files were created in Google Earth explorer.

4.3 Normalized Difference Vegetation Index (NDVI)

NDVI was first described by (Rouse et al., 1973). It is used for the detection of healthy and unhealthy vegetation. For healthy vegetation the absorption in the visible channel is high and reflectance is high in the near infrared, on the other side the unhealthy vegetation shows high reflectance values in the visible red portion and in the near infrared the reflectance is decreased. The following formula is used to calculate NDVI:

NDVI = (NIR – Red) / (NIR + Red)

For raster calculation of Landsat 8 OLI/TIRS images the formula can be written as:

NDVI = (Band 5 – Band 4) / (Band 5 + Band 4).

4.4 Normalized Difference Water Index (NDWI)

NDWI is used for the analysis of water bodies. It uses the Green and near infrared bands. In the visible spectrum the clear water shows high reflectance in the blue part that is why water appears to be blue. Low values of NDWI shows water stress in a given region. The formula of NDWI given by (McFeeters, 1996) is written as:

NDWI = (Green - NIR) / (Green + NIR).

For raster calculation of Landsat 8 OLI/TIRS images the formula can be written as:

NDWI = (Band 3 – Band 5) / (Band 3 + Band 5).

4.5 Statistical Analysis

The statistical method used in this study is "Pearson's correlation coefficient" that is represented by **(r).** It is used to determine the correlation between NDWI and NDVI.The Pearson's correlation coefficient ranges from -1 to +1. If the correlation is positive, then both the variables increase or decreases simultaneously and contrarily if the correlation is negative then it indicates that with the increase in one variable the other decreases and vice versa.

5. Results and Discussion

5.1 NDVI of Keenjhar Lake

In correspondence to areas with plants or greenness the ranges of NDVI varies from 0.2 to 1. When it is above 0.5 it gives indication for dense and healthy vegetation covers and the ranges from 0.2 to 0.5 indicates areas with sparse vegetation. (Drori et al., 2020). In Figure 2 (a) the NDVI values

are shown for Keenjhar lake in the year 2021 and in (b) it is shown for the year 2013. The NDVI value in 2013 was above 0.5 which is showing dense vegetation covers but on the other hand the NDVI values declines to 0.41 showing sparse vegetation in 2021.

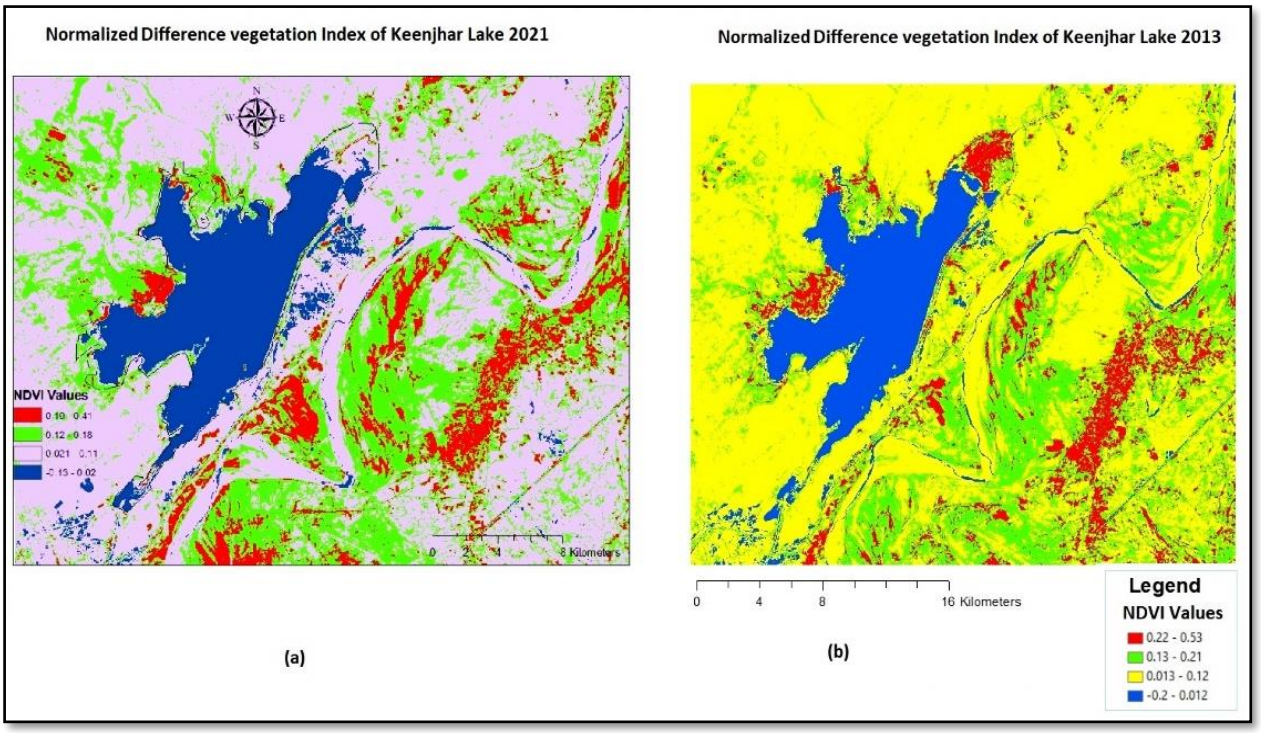

Figure 2: NDVI of Keenjhar Lake in August 2021 and August 2013.

Table 2: Maximum and Minimum NDVI Recorded for Keenjhar Lake.

S.No	NDVI of Keenjhar Lake	NDVI of August 2013	NDVI of August 2021
1	Minimum	-0.2	-0.13
2	Maximum	0.53	0.41
3	Mean	0.165	0.14
4	Standard Deviation	0.51618795	0.381837662

There are many reasons of this decline other than the drought conditions. The ecosystem of Keenjhar Lake is under threat its water quality is highly affected by the industrial effluents from Nooriabad and Kotri industries. The chemical fertilizers in the runoff and 15,000 people visiting the lake weekly during the season is a big source of degradation in the lake (Zaheer, et al., 2012). In Table 2, Maximum and minimum values of NDVI are shown for Keenjhar Lake.

5.2 NDVI of Manchar Lake

The NDVI values are shown in Figure 3 (a) for Manchar lake in the year 2021 and in (b) it is shown for the year 2013. The NDVI values of 2021 and 2013 are the same showing no improvement in the vegetation canopies but from both the images the difference in Land cover is evident. The medium and sparse vegetation is shown with red and green color in both the images which showed a great decline in 2021 as compared to 2013.

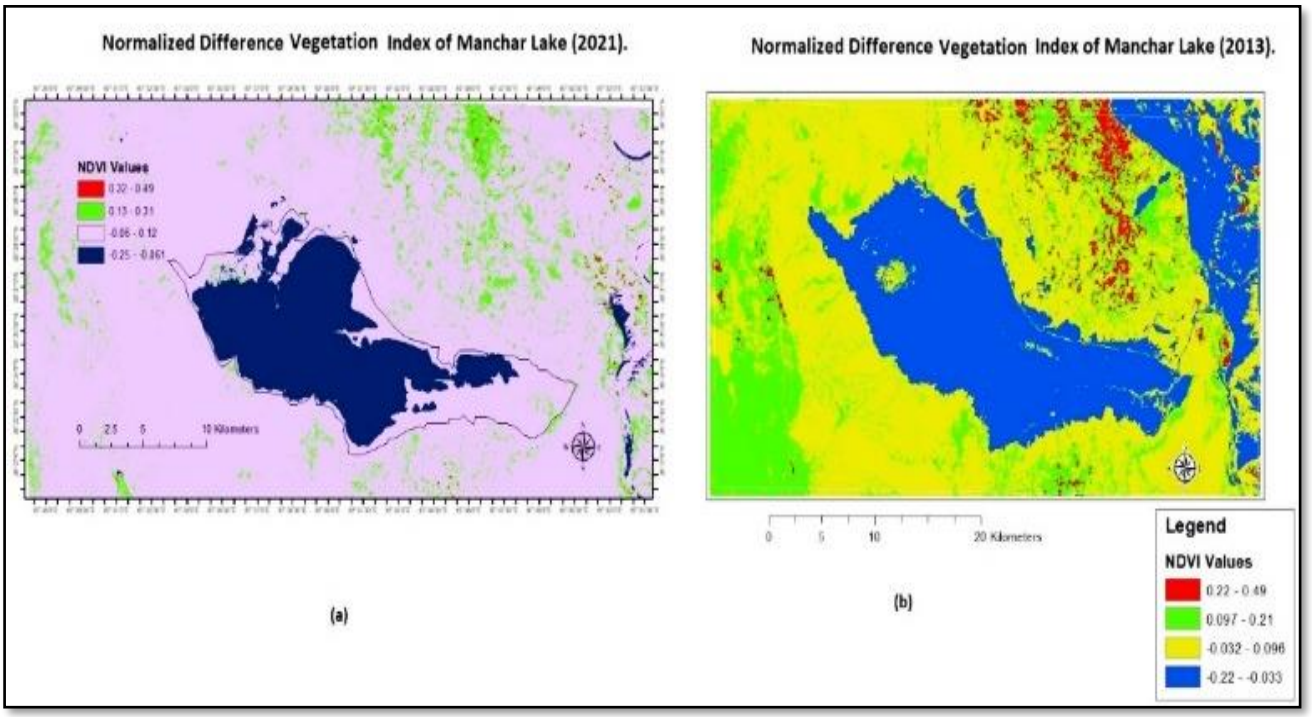

Figure 3: NDVI of Manchar Lake in August 2021 and August 2013.

The volume of water in the lake is also declining and the lake is shrinking. In Table 3, Maximum and minimum values of NDVI are shown for Manchar Lake.

Table 3: Maximum and Minimum NDVI Recorded for Manchar Lake.

S.No	NDVI of Manchar Lake	NDVI of August 2013	NDVI of August 2021
1	Minimum	-0.22	-0.25
2	Maximum	0.49	0.49
3	Mean	0.135	0.12
4	Standard Deviation	0.502045815	0.523259018

Nai Gaj is the main source of water for Manchar Lake coming from the Khirthar Mountain. A project was started by the Federal Government in 1990s, for the drainage of water containing agricultural effluents of Sindh and Baluchistan through R.B.O.D into the Arabia Sea. Removal of 4500 cusecs of wastewater through RBOD was a part of the discharge design (Mahessar et al., 2019). Main Nara Valley Drain (MNVD) of the Manchar Lake receives the contaminated and toxic water from the RBOD making the water quality extremely toxic and leads to the degradation of the lake.

5.3 The Vegetation Condition Index of Study Area

In (Figure 4), The vegetation condition index (VCI) of the relevant districts (Thatta, Jamshoro and Dadu) of the study area is shown under the black polygon for the month of August 2021 and is showing unfavorable VCI values under 0.5 in most of the areas. The vegetation condition index (VCI) was described by (Kogan, 1995). It can compare the closeness of the present month's NDVI to the minimum NDVI that is calculated from the extended record of remotely sensed data (Thenkabail and Gamage, 2004). Its values varies from 0 to 1. An extreme dry month could be indicated if its values are equal or close to 0 with poor vegetation condition. VCI with a value of 0.5 shows good vegetation covers and the values close to 1 shows the best conditions of vegetation (Jain et al., 2009). VCI can detect drought conditions better than the NDVI. It is obtained by the following formula: VCI = (NDVI – NDVImin / NDVImax – NDVImin) × 100.

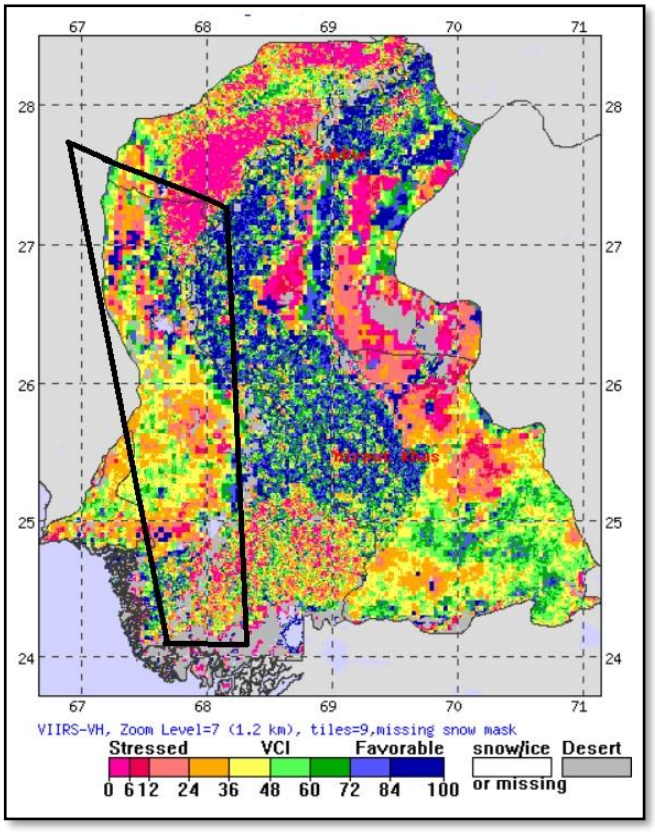

Figure 4: Vegetation condition index (VCI) of the districts of study areas, August 2021. (Image courtesy NOAA STAR).

5.4 NDWI of Keenjhar and Manchar Lake

When the NDWI values of the study area were compared to the NDWI values categorized by (Gulacsi and Kovacs., 2015). It is clearly evident that moderate drought condition prevails in Manchar lake and weak drought condition prevails in Keenjhar lake as shown in Figure 5. NDWI values varies from -1 to +1, depending upon the vegetation types. Plants with high content of water shows high NDWI values and low for low vegetation cover. When there is a condition of water stress in a given region as in the study area then the NDWI values declines. It has been proved useful for the monitoring of drought conditions and different studies showed that drought warnings can be given in advance using NDWI (Ceccato et al., 2002; Gu et al., 2007). The results were also compared with the report of National Drought Monitoring Centre, Islamabad. According to Fortnightly Drought Watch Bulletin. National Drought Monitoring Centre, Islamabad, drought conditions were observed in the month of August 2021 in different districts of Sindh Province. Mild drought is observed in Umerkot Tharparkar, Badin Mirpurkhas, Thatta, Hyderabad and Sajawal while Moderate Drought is observed in Nawabshah, Dadu, Khairpur Jamshoro, Sanghar and Larkana.

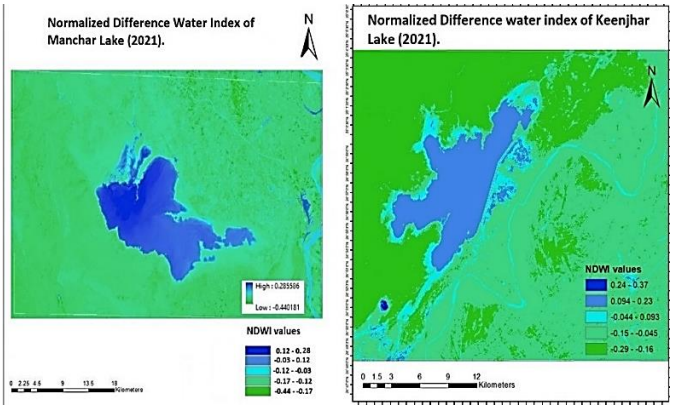

Figure 5: Normalized Difference Water Indices of Manchar and Keenjhar lakes in August 2021.

5.5 Correlation Between NDWI and NDVI

The scatter plot as shown in Figure 6 is showing a positive linear correlation in between both the variables for keenjhar lake. The points are lying near an upward sloping line. The significant value p< 0.05, which is statistically significant, and the value of **r** is 0.968 showing a strong correlation in between NDWI and NDVI. Similarly, for Manchar lake the value of **r** is 0.974 showing a strong correlation.

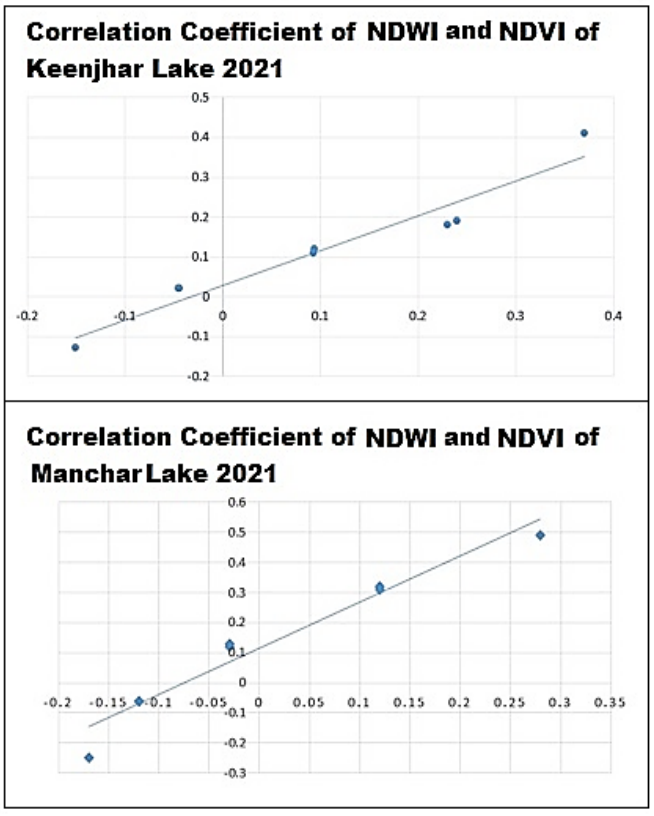

Figure 6: Scatter plot of Pearson's correlation coefficient.

6. Conclusion

The present study reveals that the indices which are calculated using remote sensing techniques provides good characterization of the spatial distribution of water bodies and vegetation covers. The multi temporal analysis of NDVI for the year 2013 and 2021 acquired with Operational Land Imager (OLI) sensor showed that the vegetation health had declined over the passing years in both the lakes rather than improving and by using these indicators efficient and sustainable policies should be made by the management to resolve the issues of degradation across the lakes. NDWI had performed very well in this study by clearly indicating the drought conditions in the lake and showing great water shortage. Drought is a natural disaster that Sindh and Baluchistan is facing from quite a long time and in order to cope with it strong measures should be taken to make the land suitable for vegetation in which micro irrigation, desalination and solar pumps could be brought under consideration. In situ investigation of the results obtained from remote sensing techniques could increase the efficiency of wetland monitoring in future.

Novelty Statement

This research helps in predicting the health of crops and vegetation in drought prone areas and give indications in order to overcome the challenges that climate changes are putting on the wetland's environment.

References

Ceccato, P., Flasse, S., and Gregoire, J.M., 2002. Designing a spectral index to estimate vegetation water content from remote sensing data: Part 2. Validation and applications. Remote Sensing of Environment., 82, Pp. 198-207.

Chandio, N., Chandio, N., Panhwar, M.A., Mahar, M.H., 2021. Spatio-Temporal Change Assessment of Lake Manchar Pakistan And Lake Aral Kazakhstan Using Normalized Difference Vegetation Index.

Drori, R., Dan, H., Sprintsin, M., Sheffer, E., 2020.Precipitation-Sensitive Dynamic Threshold: A New and Simple Method to Detect and Monitor Forest and Woody Vegetation Cover in Sub-Humid to Arid Areas. Remote Sens., 12, Pp. 1231.

Gao, B.C., 1996. NDWI—A normalized difference water index for remote sensing of vegetation liquid water from space. Remote sensing of environment., 58 (3), Pp. 257-266.

Gu, Y., Brown, J.F., Verdin, J.P., and Wardlow, B., 2007. A five-year analysis of MODIS NDVI and NDWI for grassland drought assessment over the central Great Plains of the United States. Geophysical Research Letters, Pp. 34.

Gulacsi, A., Kovacs, F., 2015. Drought monitoring with spectral indices calculated from MODIS satellite images in Hungary. Journal of Environmental Geography., 8, Pp. 11-20.

Hansen, M.C., Loveland, T.R., 2012. A review of large area monitoring of land cover change using Landsat data. Remote Sensing of Environment., 122, Pp. 66-74.

Hui, F., Xu, B., Huang, H., Yu, Q., Gong, P., 2008 Modelling spatial-temporal change of Poyang Lake using multitemporal Landsat imagery. International Journal of Remote Sensing, 29, Pp. 5767–5784.

Islam, H., Abbasi, H., Karam, A., Chughtai, A.H., Ahmed Jiskani, M., 2021. Geospatial analysis of wetlands based on land use/land cover dynamics using remote sensing and GIS in Sindh, Pakistan. Science Progress, 104 (2), Pp. 00368504211026143.

Islam, H., Abbasi, H., Sultana, G., Ahmed, M., and Chughtai, A.H., 2019. Spatial-temporal change assessment of Manchar and Keenjhar Lake using RS and GIS. Sindh University Research Journal (Science Series), 51 (2), Pp. 223-230.

Islam, M., and Sado, K., 2006. Analyses of ASTER and Spectroradiometer data within situ measurements for turbidity and transparency study of lake Abashri. International Journal of Geoinformatics., 2, Pp. 31-45.

Jackson, R.D., Slater, P.N., Printer, P.J.,1983. Discrimination of growth and water stress in wheat by various vegetation indices through clear and turbid atmosphere. Remote Sensing of the Environment., 15, Pp. 187-208.

Jahangir, T.M., Khuhawar, M.Y., Leghari, S.M., Mahar, M.T., Mahar, K.P., 2014. Water quality and sediment assessment of Manchar Lake, Sindh, Pakistan: aftereffects of the super flood of 2010. Arabian Journal of Geosciences., 8 (5), Pp. 3259.

Jain, S.K., Keshri, R., Goswami, A., Sarkar, A., Chaudhry, A., 2009. Identification of drought-vulnerable areas using NOAA AVHRR data. Int. J. Remote Sens., 30, Pp. 2653–2668.

Ji, L., Zhang, L., and Wylie, B., 2009 Analysis of dynamic thresholds for the normalized difference water index. Photogrammetric Engineering and Remote Sensing, 75, Pp. 1307–1317.

Kazi, T.G., Arain, M.B., Jamali, M.K., Jalbani, N., Afridi, H.I., Sarfraz, R.A., Baig, J.A., Shah A.Q., 2009. Assessment of water quality of polluted lake using multivariate statistical techniques: A case study. Ecotoxicology and Environmental Safety., 72 (2), Pp. 301.

Khan, A.A., and Arshad., S., 2014. Wetlands of Pakistan: Distribution, Degradation, and Management. Pakistan Geographical Review., 69 (1), Pp. 28-45.

Khan, I.S., Hashmi, M.U.A., Safi, A., and Latif., T.A., 2017. A Review: Vertebrate Biodiversity, Environmental Hazards and Ecological Condition of Keenjhar Lake, Pakistan. Canadian Journal of Pure and Applied Sciences., 11 (1), Pp. 4091-4102.

Khan, M.Z., Abbas, D., Ghalib, S.A., Yasmeen, R., Siddiqui, S., Mehmood, N., Zehra, A., Begum, A., Jabeen, T., Yasmeen, G., and Latif, T.A., 2012. Effects of environmental pollution on aquatic vertebrates and inventories of Haleji and Keenjhar Lakes: Ramsar Sites. Canadian Journal of Pure and Applied Sciences., 6 (1), Pp. 1759-1783.

Kogan, F.N., 1995 Droughts of the late 1980s in the United States as derived from NOAA polar-orbiting satellite data. Bull. Am. Meteorol. Soc., 76, Pp. 655–668.

Lacaux, J.P., Tourre, Y.M., Vignolles, C., Ndione, J.A., Lafaye., M., 1986. Classification of ponds from high-spatial resolution remote sensing: Application to Rift Valley Fever epidemics in Senegal. Remote Sensing of Environment., 106, Pp. 66–74.

Lóki, J., Szabó, J., 2011. Changes of the forests of "Nagyerdő" in Debrecen with remote sensing techniques. Nyíregyháza: Nyíregyházi Főiskola Turizmus és Földrajztudományi Intézet, Pp. 309-321.

Mahessar, A.A., Ansari, K., Arain, G.M., Kori, S.M., Qureshi, S., Qureshi, A.L., 2019. Impact of Right Bank Outfall Drain-I (RBOD-I) / Main Nara Valley Drain (MNVD) on Manchar Lake, Sindh, Pakistan. Engineering, Technology and Applied Science Research., 9 (6), Pp. 5074-5079.

Malthus, T., and Dekker, A., 1995 First derivative indices for the remote sensing of inland water quality using high spectral resolution reflectance. Environment International, 21, Pp. 221–232.

McFeeters, S.K., 1996. The use of normalized difference water index (NDWI) in the delineation of open water features. International Journal of Remote Sensing, 17, Pp. 1425-1432.

Pakistan Meteorological Department, 2021. National Drought Monitoring Centre, Islamabad., 1-15 August 2021. Fortnightly Drought Watch Bulletin.

Rouse, J.W., Haas, H.R., Schell, A.J., Deering, W.D., 1973. Monitoring vegetation systems in the Great Plains with ERTS. Third ERTS Symposium, NASA SP-351., 1, Pp. 309–317.

Subramaniam, S., Saxena, M., 2011. Automated algorithm for extraction of wetlands from IRS RESOURCESAT LISS III data. ISPRS-Int. Arch. Photogram. Remote Sens. Spat. Inf. Sci, Pp. 193–198.

Thenkabail, P.S., Gamage, M., 2004. The Use of Remote Sensing Data for Drought Assessment and Monitoring in Southwest Asia; Iwmi: Colombo, Sri Lanka., 85, Pp. 25.

Tucker, C.J., 1979. Red and photographic infrared linear combinations for monitoring vegetation. Remote Sensing of the Environment., 8, Pp. 127-150.

United States Geological Survey., 2020. USGS EROS Archive - Landsat Archives - Landsat 8 OLI (Operational Land Imager) and TIRS (Thermal Infrared Sensor) Level-1 Data Products. https://www.usgs.gov/centers/eros/science/usgs-eros-archive-landsat-archiveslandsat-8-oli-operational-land-imager-and?qt-science_center_objects=0#qt science_center_objects.

US Geological Survey., 2010. Greenness of the Conterminous U.S.—What is NDVI? Retrieved January 2, from http://ivm.cr.usgs.gov/whatndvi.php.

Van Dessel, W., Van Rompaey, A., Poelmans, L., Szilassi, P., 2008. Predicting land cover changes and their impact on the sediment influx in the Lake Balaton catchment. Landscape Ecology., 23, Pp. 645-656.

Varga, Z., Czedli, H., Kezi, C., Lóki, J., Fekete, Á., Biro, J., 2015. Evaluating the Accuracy of Orthophotos and Satellite Images in the Context of Road Centerlines in Test Sites in Hungary. Research Journal of Applied Sciences., 10, Pp. 568-573.

Wagle, N., Acharya, T.D., Kolluru, V., Huang, H., and Lee, D.H., 2020 Multi-temporal land cover change mapping using Google Earth Engine and ensemble learning methods. Applied Sciences, 10, Pp. 8083.