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Analysis of Surface Water Extraction and Change Detection Over Barur Lake, India

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Water is one of the most essential and devastating element in the world. The lack of access to water and its abundance can be a serious threat to human life. These two circumstances may create a difficult situation against the sustainability of human life. Inadequate access to water causes drought, affects agriculture and on other side high level water availability in urban areas affects daily life. Hence, mapping and analysing of the surface water of the earth benefits from such impacts. Therefore, this study analysis evaluates the performance of available Landsat-8 OLI images for mapping water bodies and to obtaining precise Normalized Differential Water Index (NDWI) extraction. Change detection analysis of the obtained data shows that the area of the surface water body keeps on changing every year. The surface area of the lake has undergone a drastic change in the year 2019.

Keywords: Barur Lake, NDWI, Remote Sensing, Change Detection, Surface Water Extraction, Landsat

1 Introduction

Surface water mapping can be performed using a variety of remote sensing data sets, including low spatial effect high spatial resolution, optical satellite images such as LIDAR (Light Detection and Ranging) and SAR (Synthetic Aperture Radio)[1-5]. A Modified version of NDWI, MNDWI (Modified Normalized Differential Water Index) is used with the help of medium infrared (MIR) to improve open water properties, while effectively suppressing the land and vegetation and soil features of the area of interest[6-8]. An experiment addresses ETM+ images and proposed an extraction method which is adaptive, based on the NDWI for accurately extracting water from a remote sensing image by the auto-segmentation histogram method to separate water from background and water pixels. It selects seed points, which makes it easier to identify the growing size of the local water surface with the help of window template search and functional classification of water body partitioning[9]. However, it is difficult to find a normalized water index by such a large number of functions. Hence, multispectral remote sensing data is used to obtain the enhanced spectral signature of the vegetative index and water bodies with a DWT (Discrete Wavelet Transformation) and SVD (single value decomposition) method, with the need to detect different water tables normalized index[10]. However, because of the high risk in around, MNDWI established a pixel-based classification with a pixel-based process to identify the clear water through which it is classified as clear, green, and volatile, and with the object image segmentation for efficient separation of water bodies[11]. Accordingly, it is easy to define the free surface water boundary by removing moisture / muddy lake water, and the combined cap change, hue saturation value (HSV) colour change, vector analysis, high-pass filtration, and material separation based on water index calculation[12]. The Images of water codes were computed for selected water sample pixels with the support of integrated sub-pixel spectral analysis and object-level multi-scale extraction method in adaptive local areas, resulting in integrated cap change, dye concentration value vector analysis, high-pass filtration can be occur[13]. Landsat images were used to predict and analyse the surface water area changes of Shala, Abidada and Langani lakes from year 1973 to 2014,

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using NDWI and Automatic Water Extraction Index (AWEI)[14]. Utilizing NDWI and MNDWI, changes in urban surface water levels are predicted and the result shows, increase in the urban aquatic ecosystem Manggala District and decrease in urban surface watersin coastal areas such as Tamalate, Tamalanrea, and Biringkanaya due to construction activities[14]. From Landsat ETM + 2000 and TM 2010 images, NDWI, MNDWI, WRI (water ratio index), NDVI (normalized differential vegetation index) and AWEI codes were calculated to evaluate the performance of the extraction of surface water. The NDWI-PC (Principle Component) method for change detection is followed by a dramatic decrease in the surface area of Lake Urmia between the year 2010 and 2013[15].

Using geometric and radiometrically corrected Landsat imagery of Kyoga Lake, the various factors has been determined such as the variability of surface water with climate change, static precipitation and drought intensity index[16]. However, it is not possible to obtain a high-quality pixel with the water feature. Therefore, it is made possible with a linear iterative clustering approach and a convolutional neural network (CNN) with 99.14% accuracy[17]. Similarly, the Otsu threshold is used to increase the accuracy in the imagery. It can be applied to stationary waters and can be used for generating the simple water table (SWT) index[18]. Accordingly, a surface water conversion map of the Sopradinho reservoir is carried out to measure turbidityusing Landsat images[19]. In addition basedon NDWI, new Synthetic Aperture Radar (SAR) was used for dynamic monitoring of surface water of Lake Ebinur, which has optimal accuracy of 99.94%[20].

Therefore, the main objective of this study is to distinguish water bodies from Landsat image with enhanced water index surface features and pre-process it. For this purpose, the NDWI approach has been used to identify surface water bodies from satellite dataand the change detection analysis has been carried out in the surface water area.

2 Materials and Methods

The geographical area of Barur Lake, latitude 12° 18′42″ N and longitude 78° 18’50″ E is located in Tamil Nadu, India.The area of the waterfront is 2.63 square kilometres and a small lake. The study area is a mix of small urban and rural areas, including aquatic lakes, ponds and vegetation, agriculture and a river system surrounded by unused land. Images of the water bodies used in this works are obtained from the Landsat-8 OLI_TIRS using the Earth Explorer through the visual interpretation process.

The Environment Information System software (ENVIS) tool is used for pre-processing of images obtained from Landsat-8 OLI_TIRS. To reduce the runtime of image processing, a subset of the image over Barur Lake, India is selected using the ROI option given in the ENVIS tool. Pre-processing activities such as atmospheric correction and radiometric calibration are performed, which converts the value of image current digital numbers into reflectance values. Dark object subtraction (DOS) atmospheric correction is carried out in the obtained Geographically Indexed Image File Format(GeoTIFF) images. NDWI is calculated from the pre-processed image for the extraction of surface waters. From the obtained raster, furthermore, the transition detection for a subset of the surface water body has been made. The flow of the research work comprises of Landsat image selection, Image pre-processing, radiometric calibration for atmospheric selection, image processing, NDWI calculation, surface water extraction, change detection and threshold analysis.

2.1 NDWI

The Normalized Difference Water Index (NDWI) is a parameter used to track dynamic changes in the water content of aquifers by using green and NIR spectral bands, as in[21]. Therefore the mathematical expression of the NDWI is given in the Eq. 1.

$$NDWI = \frac{X_{GREEN} - X_{NIR}}{X_{GREEN} + X_{NIR}} \quad \text{... (1)}$$

Where, X_{GREEN} − Green Band and X_{NIR} − Near Infrared Band.

These images are obtained from Landset-8 using Earth Explorer. Furthermore, atmospheric correction is performed and the images are used to calculate the NDWI. Using the expression (1) MNDWI is determined by replacing the NIR band with SWIR band to remove the built-up areas[22]. NDWI is an appropriate parameter to map surface water bodies. Infrared wavelengths of water bodies have strong absorption and low radiation properties up to the spectral bands. NDWI can improve the current information on water. It distinguishes aquatic plants from vegetation and structured urban and semi-urban land forms. This makes it possible to obtain highly rated water bodies. The RGB image of the geological study area was obtained from Landsat-8 OLI_TIRS from the study area. The spectral elements in the RGB image cannot accurately distinguish water bodies and vegetation, because both the aquatic and vegetative reflectance is green. In addition, in order to enhance and obtain the fine edges of water bodies, it is preferred to choose the separate bands which have different spatial resolution and the NDWI was calculated.

2.2 Data Selection

In the study, Landsat 8 images available from Earth Explorer are used. The image acquisition date for the period between January to May of the year 2015 to 2020 is utilised from Landsat 8's Route 143 and 51st line. The RGB map of the study area using Landsat 8 subset of the Barur Lake of the OLI image data used. Table 1 show the data used in the study which is obtained from Landsat 8(OLI_TIRS) which has standard bands of specific wave length and Resolution.

2.3 Paired samples t-test

The paired sample t-test follows image pre-processing techniques which comprises, determination of DN form the sensor, the Radiance, TOA reflectance and surface reflectance. The analysis of multiple data sets over a period of time, radiometric calibration and its corrections are essential. The image obtained from the Land sat sensor has only the electromagnetic radiation source digital number (DN) for each pixel. To obtain a true surface reflection or brightness value, radiometric errors must be ignored, based on factors such as atmospheric conditions and the angle of azimuth and the height of the sun. To neglect atmospheric effects, atmospheric corrections must be made to provide surface reflectance values, for which the dark object subtraction method is used, where each pixel value is subtracted from the path radian value. GeoTIFF with metadata format is available from USGS (United States Geological Survey). ENVIS software is used to convert the USGS GoeTIFF to metadata. With the "MTL.TXT" file, the optical band data can be converted to ToA reflectance value, improving the quality and interpretation of remote sensing data.

Table 1 — Data used for the study

Sl. No.	Data	Image
1		LC08_L1TP_143051_20150122_20170413_01_T1
2		LC08_L1TP_143051_20160210_20170330_01_T1
3	Landsat 8	LC08_L1TP_143051_20170401_20170414_01_T1
4		LC08_L1TP_143051_20180114_20180120_01_T1
5		LC08_L1TP_143051_20190101_20190130_01_T1
6		LC08_L1TP_143051_20200120_20200128_01_T1

2.4 Surface Water Extraction

To determine the surface water area, NDWI was calculated for Landsat 8 OLI_TIRS of the years 2015, 2016, 2017, 2018, 2019 and 2020 data sets. The calculation of water index was carried out on the basis of raster calculation. Positive numerical values are recognized as water bodies and negative numerical values as land surfaces. Likewise, the NDWI is calculated for the year from 2015 to 2020.

2.5 Change Detection

The NDWI was calculated from Landsat 8 OLI, for surface water body extraction. Aimed to calculate NDWI, the NIR (near-infrared) band is chosen because it is strongly absorbed by water and strongly reflected by vegetation and topographic surfaces. The pre-processed images are used to separate the water bodies from the land surfaces to predict the changes in the surface area of the water bodies. Hence, the image difference map is obtained for each two sets of data and thresholding is carried out. Otsu's algorithm[23] has been used to improve the accuracy of the change detection image. It separates the foreground and background pixels in the image.

3 Results and Analysis

Figure 1(a) shows the water logged area of BARUR Lake in the year 2015 from which change detection of the water body for the year 2016, 2017, 2018, 2019 and 2020 is calculated. The surface water area change of the study area between the years 2015 and 2020. NDWI of the study area was calculated for the years 2015, 2016, 2017, 2018, 2019 and 2020 from Landsat 8 OLI. The total surface area of the lake is estimated to be 2.63 square kilometres. The surface area of the lake was reduced to 2.00 square kilometres by the year 2015 and remained to be the same in the year 2016.

The red colour area shown in the Fig. 1 indicates the reduction of surface water area and the blue area indicates the area where the water is logged. Figure 1(b) indicates the surface water change detection map for the years 2015 and 2017.The estimated surface water area of the lake for the year 2017 is 1.19 square kilometres and it is figured out that there is a significant reduction in the surface area of water by 0.81 square kilometres.The change detection map is

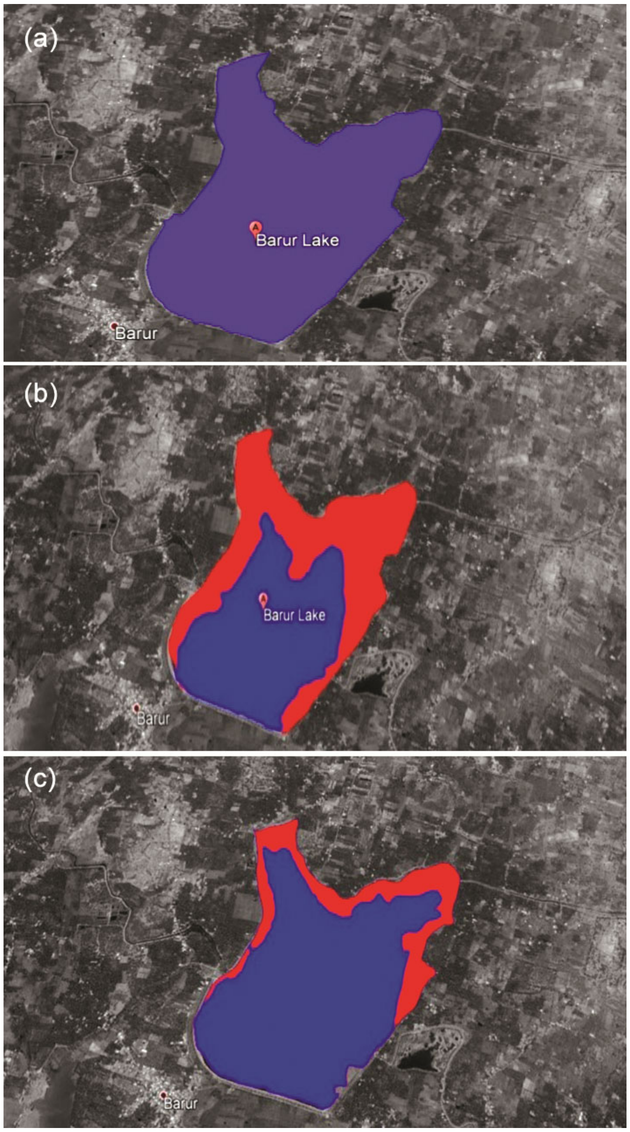

Fig. 1 — Change Detection for the year: (a) 2015 (b) 2015 & 2017 (c) 2015 & 2020

determined for the year 2015 and 2018. The surface water area is calculated as 1.24 square kilometres and noticed that the surface water area increased by 0.05 square kilometres compared to the previous year. For the year 2019, surface water area is computed as 1.17 square kilometres, which indicates a decrease in surface water compared to the year 2018. Fig. 1(c) displays the surface water area change detection for the year 2020 and the surface water for the year is 1.30 square kilometres. Surface water has increased by 0.13 square kilometres compared to the year 2019. Over all, the analyse shows that the surface water has increased and decreased twice from the year 2015 to 2020 alternatively.

4 Conclusions

In this study Landsat 8 images are used to analyse the extraction of surface water bodies in a small lake and the detection of changes in surface water.The pre-processing of Landsat imagery provides the impressive results. Surface water bodies are extracted using the NDWI index, which separates the water bodies from the terrain surfaces. Change detection has been carried out based on thresholding and the results of the survey analysis show that the Little Lake Barur, exhibits continuous changes in its surface water area over the period 2015 to 2020. In the year 2019, the maximum surface area is left out of the water compared to the year 2015. Considering the period from for the year 2015 to 2020, surface water is significantly reduced to 1.17 square kilometres in the year 2019. It is conclude that the surface water of the lake is decreased and increased couple of the times alternatively from the year 2015 to 2020. Further, the study and analysis can be extended by using other change detection algorithms and comparison can be carried out.

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