AN ASSESSMENT ON NUMEROUS TECHNIQUES TO DISCERNMENT WATER BODIES USING IMAGE PROCESSING

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Abstract: Regular change in climate affects the existence of water on Earth. With the presence of remote sensing techniques, it became easy to analyze water bodies on Earth. There have been numerous techniques used to discernment water bodies from high-resolution satellite imagery. To get accurate results, it is essential to eliminate the effect of the forest, clouds, shadow, and constructed area from input imagery. Some of the most commonly used methods are segmentation and morphology technique, single-band threshold method, Multiband spectral relationship method, supervised classification, unsupervised classification and numerous water indices methods (Normalized Difference Vegetation Index, Normalized Difference Water Index, Modified normalized difference waters index and Automated Water Extraction Index with shadow & non-shadow variants). This paper reviews the diverse approach of water body delineation that accomplished on the Saryu River around Ayodhya, Uttar Pradesh, India region. All the multispectral imagery data accumulated by Landsat-8 (OLI) satellite on 2nd February 2019 has used in the assessment.

Keywords: Water; Remote Sensing; Supervised classification; Indices methods; Ayodhya; Landsat-8.

Introduction:

Water is indispensable for the existence of life on Earth. It is a crucial part of the Earth's environment and is tremendously affected by climatic change [1]. Efficacious water resources planning and management continuously observe the delineation of water assets at reservoirs, ponds, lakes, and rivers. This is paramount for irrigation purposes, protection of wetlands, estimation of drinking water, and flood prevention. With the coming of remote sensing techniques, it became tranquil to observe the change in environment, vegetation, land cover, and discernment of water bodies. From the last two decades, the remote sensing technique efficacious used for data collection and exploration purposes. The remote sensing technique has so many advantages, as it provides accurate and real-time information about climate and environmental change on little cost [2].

With the launch of Landsat satellites, it became tranquil to collect paramount data from high resolution and multispectral imagery. These satellite data immensely beneficial for the detection of land use and changes in land cover over a time period. On Earth's surface, water has a paramount land cover; many scholars have analyzed it and demonstrate numerous techniques to discernment water bodies using Landsat imagery. To observe water resources with high accuracy and little implementation cost, diverse water indices techniques have been evolved in the last decade. To get accurate results, it is essential to eliminate the effect of the forest, clouds, shadow, and constructed area from input imagery. Some of the most commonly used methods are segmentation and morphology technique, single-band threshold method, Multiband spectral relationship method, supervised classification, unsupervised classification and numerous water indices methods (Normalized Difference Vegetation Index, Normalized Difference Water Index, Modified normalized difference waters index and Automated Water Extraction Index with shadow & non-shadow variants) [3].

To getting remote sensing substantive data and information, the spectral profile is one of the highly paramount for it. Satellite imagery continuously collects proceeding information about external radiation and reflection of electromagnetic waves from various ground entities. Generally, open water resources have feeble reflectivity of about 4% in the visible region compared to other ground entities like vegetation, soil, and constructed area, etc. Due to the extreme absorption power of open water resources, its reflectivity diminishes to around 2.5% in the near-infrared region, and it became easier to discriminate water resources from vegetation, soil, constructed area, and other ground entities. Fig.1 shows the spectral profile of water, constructed area, vegetation, and soil for various bands of Landsat-8 satellite [4].

This paper reviews the diverse approach of water body delineation on Saryu River around Ayodhya, Uttar Pradesh, India, with the help of multispectral imagery data accumulated by Landsat-8 (OLI) satellite.

STUDY AREA AND COLLECTION OF DATA

The study area is the Saryu River around Ayodhya, Uttar Pradesh, India Region. It originated from Sarmul, Uttrakhand passes through Bahraich flows towards Ayodhya, Uttar Pradesh, and finally flows into Ganga near Chhapra, Bihar. The river travels around 350 Km distance before merging into Ganga. The Latitudes and Longitudes of Saryu river around Ayodhya are 26˚48'40.20"N and 82˚11'56.34"E, respectively.

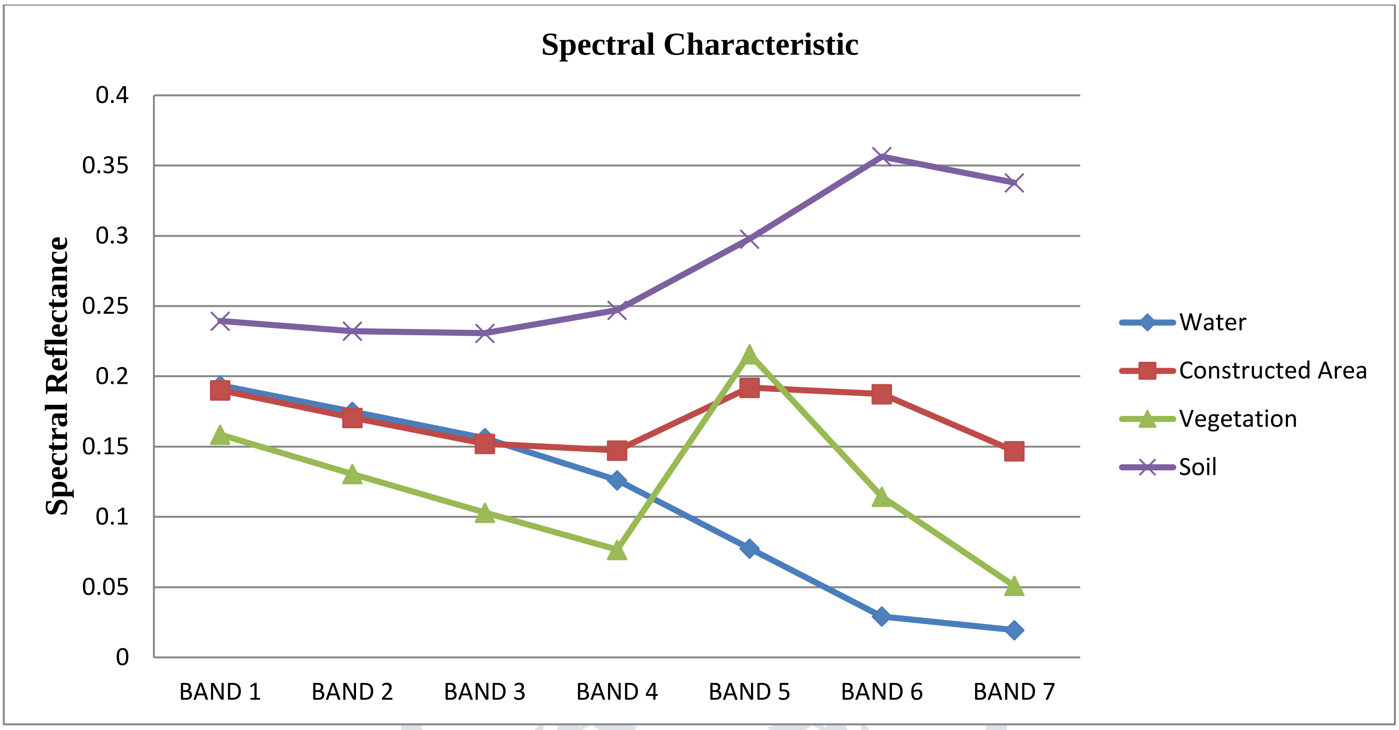

Fig.1: Spectral profiles of four standard ground entities for the original seven bands of Landsat-8 Satellite

The Landsat-8 satellite Level 1 imagery with metadata obtained on 2nd February 2019 with 0.00% cloud cover was used in this study. This Landsat-8 metadata was collected from the U.S. Geological Survey's remote pixel open source portal. The imagery was projected to a Universal Transverse Mercator (UTM) Zone 44 North coordinate system with the World Geodetic System (WGS)-84 datum. The specifications of sensors, resolutions, and numerous bands with wavelengths for Landsat-8 satellite shown in Table 1.

Table 1: Specifications of Landsat-8 Satellite Data

Satellite	Sensor	Path/Row	Year	Band	Wavelength (µm)	Resolution (m)
LANDSAT-8	OLI (Operation Land Imager)	143/41	February-2019	B1-Coastal	0.435-0.451	30
				B2-Blue	0.452-0.512	
				B3-Green	0.533-0.590	
				B4-Red	0.636-0.673	
				B5-NIR	0.851-0.879	
				B6-SWIR1	1.566-1.651	
				B7-SWIR2	2.107-2.294	
				B8-Panchromatic	0.503-0.676	15
				B9-Cirrus	1.363-1.384	30

Related Work:

Supervised Classification: Supervised classification signifies that the user has wholly authorized to 'supervise' the classification. It is one of the highly precise and accurate techniques used for the discernment of water resources using image processing. The initial step to perform supervised classification is the collection of training data. In this process, the user designates the numerous spectral signatures or pixel values to water, constructed area, vegetation, and soil other ground entities from a known training site. This training data set is used to construct a classification algorithm, and based on that algorithm, it enables the computer system to acknowledge the spectral signatures of the similar features spontaneously and classify the entire image. Generally, in supervised classification, maximum likelihood classification, or support vector machine classification algorithm were used to recognize water resources [5].

Unsupervised Classification: Unsupervised classification signifies that it is a computer-automated classification technique, and the user has not entirely authorized to 'supervise' the classification. It is a pixel-based classification technique, where the user just designates the number of classes, and the spectral classes are generated entirely based on the spectral dissemination characteristic of the ground entities in the input imagery. The clustering algorithm has been used to perform an unsupervised classification; the foremost objective of clustering is to regulate the natural, analytical grouping of the data. The similar kinds of pixels are grouped in conjunction based on their spectral similarities. The primary aspiration is to make sure the pixels of similar classes have minimum distance, and pixels of different classes have maximum possible distance. The computer employs specific information to analyze and generate the grouping of data into various classes from the input image. Initially, the user has to mention about some parameters like maximum iterations and the change threshold percentage, which designate when to finish the classification process [4].

Single-band threshold method: Generally, open water resources have feeble reflectivity in the visible region compared to other ground entities. Due to the extreme absorption power of open water resources, its reflectivity continuously diminishes in the near-infrared region and mid-infrared region, So it became easier to discriminate water resources from other ground entities. The single band threshold technique takes advantage of the difference between various ground entities and water in their spectral characteristics. The discernment of water resources can comfortably be achieved by establishing a befitting threshold on the near-infrared band. Although a single band threshold method is one of the most straightforward techniques used for the discernment of water resources, it cannot delineate minuscule water resources and remove shadows [6,7].

Multiband spectral relationship method: It is difficult to delineate minuscule water resources, unused lands, and shadow. Thus, analytical interpretation of the combination of multiple bands with their spectral characteristic is used to acquire a new technique for the discernment of water resources. It established that only water resources have the characteristic of

$$(BAND_3 + BAND_4) > (BAND_5 + BAND_6)$$

Where $BAND_3$, $BAND_4$ signify the reflectance on green & red bands of the visible region and $BAND_5$, $BAND_6$ signify the reflectance on NIR & SWIR1 bands of infrared region.

This technique furnishes effective results compared to a single band threshold technique for the discernment of water resources but cannot remove the shadows. J. Wang (2004) has amalgamated above mentioned characteristic equation and $BAND_5/BAND_3 < 0.9$ to discernment water bodies and perceives that this technique was more appropriate discernment water bodies of mountainous terrain [8].

Normalized difference water index (NDWI): Normalized difference water index is one of the most extensively used techniques for the discernment of water resources. It was retrieved from the ratio index and recommended by McFeeters (1996). The perception behind this technique is to intensify vegetation and other ground entities and suppress the water bodies. So it is tranquil to discernment water resources from processed imagery. Based on Landsat-8 imagery, the general equation to calculate NDWI is as follows;

$$NDWI = (BAND_3 – BAND_5) / (BAND_3 + BAND_5)$$

$BAND_3$ signifies the reflectance on the green band in the visible region, and $BAND_5$ signifies the reflectance on the NIR band in the infrared region.

The range of NDWI values from -1 to +1, and to segregate water bodies and other ground entities, zero is treated as the threshold value. However, this technique does not consider the interference from bare land and mountains, and it cannot correctly segregate the built-up characteristics from water bodies [9].

Modified Normalized difference water index (MNDWI): To eradicate the shortcoming of NDWI, a modified normalized difference water index was recommended by Xu (2006). In this index, the NIR band used in NDWI was replaced by the SWIR1 band of Landsat-8 imagery. The general equation to calculate MNDWI is as follows;

$$MNDWI = (BAND_3 – BAND_6) / (BAND_3 + BAND_6)$$

Where $BAND_3$ signifies the reflectance on the green band in the visible region, and $BAND_6$ signifies the reflectance on the SWIR1 band in the infrared region.

With the preference of these wavelengths, the reflectance of water characteristic escalate using green band, the reflectance of soil & vegetation characteristic also escalate using SWIR1 band, and the resultant of these magnify the reflectance of water resources. Same as NDWI, zero is treated as the threshold value for MNDWI; but the manual regulation of the threshold has executed the supplementary realistic result in the discernment of water resources. MNDWI is accomplished to correctly segregate the built-up land, soil, and vegetation characteristics from open water resources. As a comparison with various indices, MNDWI provides near-perfect results; but the elimination of shadows is not accomplished by this technique [10-13].

New water index (NWI): Based on supplementary finding and anatomization of water resources and other ground entities spectrum characteristics in Landsat metadata, Ding (2009) recommended a new water index (NWI). The new water index uses multiple bands from visible & infrared region at the same time. The blue band of the visible region and NIR, SWIR1, SWIR2 bands of the infrared region is used to evaluate NWI. The general equation to calculate NWI is as follow;

$$NWI = [BAND_2 – (BAND_5 + BAND_6 + BAND_7)] / [BAND_2 + (BAND_5 + BAND_6 + BAND_7)]$$

Where $BAND_2$ signifies the reflectance on the blue band of the visible region and $BAND_5$, $BAND_6$, $BAND_7$ signify the reflectance on NIR, SWIR1 & SWIR2 bands of the infrared region [14].

Automated Water Extraction Index (AWEI): To further ameliorate the accuracy in the discernment of water resources from multispectral satellite imagery using threshold technique**,** a new water extraction index was recommended by G.L. Feyisa (2014). The automatic water extraction index (AWEI) comprises two indices, such as $AWEI_{nsh}$ and $AWEI_{sh}$. To abbreviate the entanglement in the segregation of water resources from other ground entities, AWEI effectively used an amalgamation of various spectral bands of visible and infrared regions. The main objective of AWEI is effectively used to escalate the segregation of water resources and non-water resources by bands augmentation, numerous mathematical expressions, and put in variegated coefficients. Eradication of non-water resources, encompass with build-up area, dull surfaces have accomplished in $AWEI_{nsh}$. The general equation to calculate $AWEI_{nsh}$ is as follow;

$$AWEI_{nsh} = 4\times (BAND_3 – BAND_6) – (0.25 \times BAND_5 + 2.75 \times BAND_7)$$

Where $BAND_3$ signifies the reflectance on a green band of the visible region and $BAND_5$, $BAND_6$, $BAND_7$ signify the reflectance on NIR, SWIR1 & SWIR2 bands of infrared region.

AWEInsh does not accomplish the eradication of shadows. To further ameliorate the accuracy in the discernment of water resources by eradication of shadows, $AWEI_{sh}$ is constructed by G.L. Feyisa. The general equation to calculate $AWEI_{sh}$ is as follow;

$$AWEI_{sh} = BAND_2 + 2.5 \times BAND_3 – 1.5 \times (BAND_5 + BAND_6) – 0.25 \times BAND_7$$

Where $BAND_2$, $BAND_3$ signifies the reflectance on blue & green band of the visible region and $BAND_5$, $BAND_6$, $BAND_7$ signify the reflectance on NIR, SWIR1 & SWIR2 bands of infrared region.

This index with subscript ‘sh’ comprehensively elucidates the issue of shadows and escalates discernment of water resources in an urban area with shadow and other dull surfaces [15].

Normalized Difference Vegetation Index (NDVI): The normalized difference vegetation index effectively used for appraises vegetation structure and segregates them from lower reflective water resources. It is one of the extensive maneuver techniques to specify the relative density and health of vegetation. It uses bands of the visible and infrared region with spectral characteristics to escalate vegetation and suppress the water bodies. Based on Landsat-8 imagery, the general equation to calculate NDVI is as follows;

$$NDVI = (BAND_5 – BAND_4) / (BAND_5 + BAND_4)$$

Where $BAND_5$ signifies the reflectance on the NIR band in the infrared region, and $BAND_4$ signifies the reflectance on the red band in the visible region.

The range of NDVI values from -1 to +1; zero as a threshold has been used for the segregation of vegetation and other entities. The positive value of NDVI conveys the presence of vegetation; small negative values exhibit the appearance of snow, soil, rock, and higher negative value emphasizing the water resources [16-17].

Segmentation and morphology technique: In this technique, initially, the actual colour image is transformed into a grey scale image, so it contained water bodies of lower density as dark segments and other ground entities of higher density as a bright segment. In the next stage, by applying a fixed threshold to the processed image, it escalates water bodies as white pixels and other ground entities as black pixels. After that, the morphology method is performed on the processed image. Operations of erosion and dilation eradicate white segments that do not characterize the water body. With the use of the Gaussian low pass filter, the noise elements and small entities with a dark pixel from the image are entirely eradicated. Finally, by the use of linear amalgamation of images emphasize the water bodies present in the image [18-19].

Conclusion:

The paramount significance of water reservoir estimation, wetland preservation, observing deluge ambit, the transformation of coastline, and immense assessment of water bodies have accomplished by discernment of water enlightenment as expeditiously and realistically. In this paper, we have exhibited an assessment of numerous techniques to discernment water bodies using image processing. The outcome for some of the techniques mentioned above is shown in Fig.2.

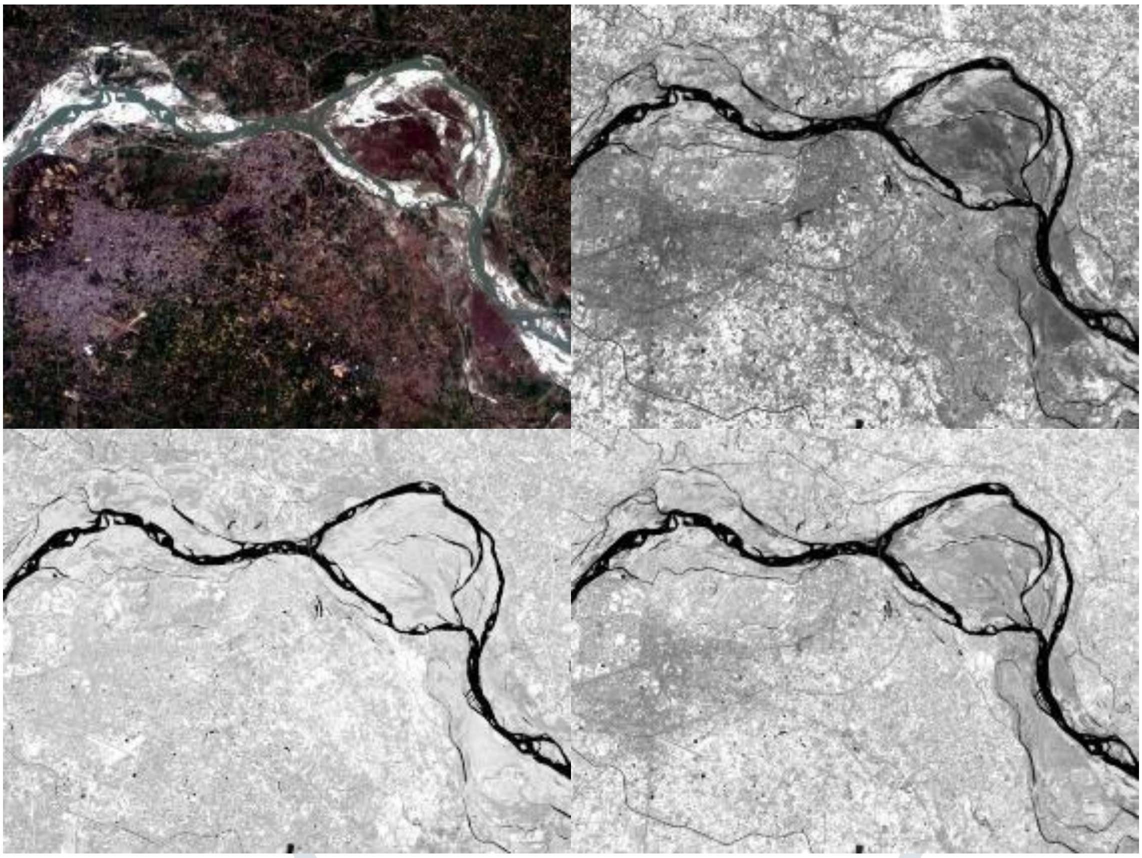

Fig.2: Saryu River around Ayodhya, Uttar Pradesh, India Region (Original True Colour, Single Band Threshold Method, MNDWI and $AWEI_{sh}$)

Every designated technique used for the discernment of water bodies has the edge over other techniques and also possess certain limitations. The single-band threshold method is one of the most straightforward techniques, but it cannot be able to delineate minuscule water resources. The Multiband spectral relationship method furnishes effective results compared to a single band threshold technique, and it was more appropriate to discern water bodies of mountainous terrain. Numerous indices techniques are competent for the discernment of water enlightenment expeditiously, and by deploying a befitting threshold, they exhibit outcomes that are realistically for delineation of water resources. $AWEI_{sh}$ exhibit more desirable outcomes as it can eradicate the issue of shadows and escalates discernment of water resources in an urban area with shadow and other dull surfaces. Supervised classification exhibits superior outcomes, but it is lengthy and more tangled. This technique prerequisite the researcher must have enlightenment about the area of interest.

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