International Journal of Innovative Research and Review ISSN: 2347 – 4424 (Online)
An Online International Journal Available at http://www.cibtech.org/jirr.htm
2016 Vol. 4 (1) January-March, pp.26-37/Das and Pal
Research Article

IDENTIFICATION OF WATER BODIES FROM MULTISPECTRAL LANDSAT IMAGERIES OF BARIND TRACT OF WEST BENGAL

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ABSTRACT
Present work concentrates on extraction of water bodies of the Barind tract of west Bengal using multi-spectral Landsat imageries. This work also aims to investigate the suitability of indices used for extracting water bodies from Landsat imageries. Barind tract is drained a good number of rivers with their complex evolution and shifting of courses. As a result of that 1% of total area is covered by water bodies of different kinds like oxbow lakes, left channel, water logging palaeo-channels, seasonally inundated wetlands etc. over fast changing land use, land cover scenario, the wet lands are also exposed to vulnerability. Climate change issue, changing land surface temperature etc., are also some vital challenges which wetlands are experiencing that are found to be difficult for combating. So, scientific assessment of wetland area change is very vital for monitoring and providing decision support for wetland management. In present work six indices are used for extracting water bodies and each index are compared with higher resolution google earth image based product. Ultimately, it is forwarded that which index is least suited for accurate water body extraction. NDVI, NDWI, MNDWI, NDMI, WRI and AWEI are applied for extracting water bodies and NDWI shows more accurate estimate of water body. If such accurate measurement is possible, certainly it will provide a good data support and based on which water body conservation planning strategy will be devised.

Keywords: *Water Body Extraction, Indices, Barind Tract, Multispectral Images and Threshold Limit Identification*

INTRODUCTION
Wetlands are complex and rich diverse ecosystem showing land transitional between terrestrial and aquatic system (Cowardin *et al.,* 1979). In a broader sense it is defined as shallow water area or low land or depressions that are inundated or saturated by surface or ground water temporarily or permanently with a prevalence of vegetation, animal and microorganism.

Wetlands may be fall into different categories, on the basis of hydrology (shallow marsh, deep marsh, shallow open water), (Sather, 1976) geomorphology (lacutrine, riverine, shoreland wetland and flood plain wetland etc), (Cowardin *et al.,* 1979) abiotic and biotic components etc. (Mitra *et al.,* 2005). Identification of accurate category is essential for assessment of wetlands.

At present wetlands cover only 6 % of total land area of the earth, but it contributes significant ecological value as well as economic assistance (Curie *et al.,* 2007). From ecological point of view wetlands carried out essential services like water quality improvement, flooding control, sediment traps, ground water replenishment, retention of phosphorous and nitrogen, and recycling of others element etc (Curie *et al.,* 2007).

But its economic benefits are not directly valued and appreciated by community, except some common economic value such as fish production, (Rai, 2008; Liu *et al.,* 2010) water supply to agricultural field, timber production and recreation sites etc (Brander *et al.,* 2006).

Growing awareness about the importance of wetlands has drowned attention of many scientist and environmentalist. For last 50 years wetlands remained a vital topic on which numbers of article and research paper have been written.

Considering its importance numbers of protocol and policies have been taken at national and international level to conserve wetlands. Yet there is a gap between policy making and implementation of these policies. This is because of unlike developed countries, in developing countries like India; there is lack of awareness at local level. Still wetlands are considered here as a wasteland or fallow land. As the population pressure has increased farmers are forced to exploit their land for livelihood support (Bayley *et al.,* 2012).

Growing demands of land for agriculture, newly residential area, land for infrastructure and industries which lead to encroachment of wetlands and related degradation.

Present causes of wetland modification and degradation is not only for anthropogenic pressure but also related to some natural causes like cumulative climatic shifts influence hydrological and geomorphological processes (Ridell *et al.,* 2010).

With growing advanced technology remote sensing provides greater advantages than any other traditional methods of wetland and surface water body identification, because it is less time consuming, low cost, reliable source and is capable of high frequency repeatable observations (Wenbo *et al*., 2013).

Among several satellite imageries Landsat imageries is a widely used source of data in remote sensing. It provides 40 years of continuous imageries which are helpful for continuous observation of earth surface. There are several water body information extracting algorithms have been developed which fall into two main categories: the general feature classification method including supervised and unsupervised classification and the thematic water body information detection method (Feyisaa *et al.,* 2014). The present study is based on the thematic water body information detection method.

A number of indices are designed to highlight surface water bodies in remotely sensed imagery for example, Water Ratio Index (WRI), Normalized Difference Vegetation Index (NDVI), Automated Water Extraction Index (AWEI), Normalized Difference Water Index (NDWI) etc. (Xu *et al.,* 2014; Gautam *et al*., 2015; McFeeters, 1996).

There is a definite algorithm set up for each index which gives a threshold value, by which we can easily differentiate water body from non-water body (Rokni *et al.,* 2014). But all these indices are not suitable to detect water bodies in all spatial and temporal extent due to mixed water pixel in the image, confusion of water bodies with background noise and variation in threshold in temporal and spatial extent. (Jiang *et al.,* 2014; Gu *et al.,* 2008; Jiang *et al.,* 2014).

Therefore, variation in threshold value is necessary for better result (Sahu, 2014). Considering this problem, the present study focuses on comparative analysis of these indices to detect surface water bodies from Landsat imageries and to find a suitable and more accurate index which is best performing index for the detection of surface water bodies of the Barind tract of west Bengal.

Study Area

The Barind tract of west Bengal is a distinct physiographic unit comprising a series of uplifted blocks of terraced land covering 2637.66 sq. mile (679038.39 hectare) with latitude extension between 24°52´20´´ to 26°29´16´´ and longitudinal extension between 87°47´32´´ to 89°00´29´´ (figure 1).

Its southern boundary is delineated by the left bank of Mahananda River, western part by Fulhar River, northern part by Balason River and eastern part by Atrei river basin.

Geomorphologically it is divided into active flood plain, inactive flood plain, extended flood plain, uplands, piedmont & fan, swampy water logged area etc. but a vast area of Barind tract is fall under inactive flood plains and uplands.

Hence, out of total area, only 1 % (6536.6 hectare) area is covered by various surface water bodies. The barind tract is mainly composed of alternating sand, silt and clay layer with average elevation of 35m to 50m from mean sea level.

Average rainfall of this region is 1250mm, occurring mainly from late April to October and temperature ranging from 25° to 35°c.

MATERIALS AND METHODS

There is sequential procedure for the identification and extraction of water body (figure 2). It includes collection of Landsat satellite imageries (from USGS earth explorer), its processing, analysis and output generation.

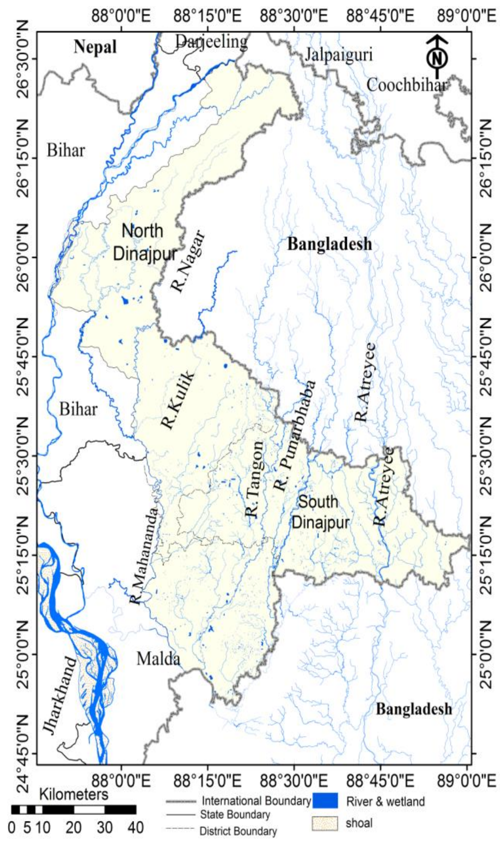

Figure 1: Study Area

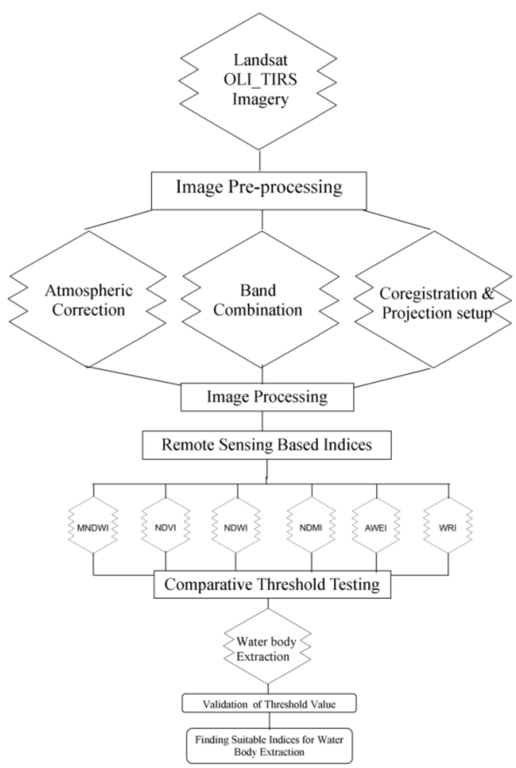

Figure 2: Flow Diagram Showing a Brief Methodological Proceeding

Data Sets: Various data sets have been used in this study. Details of study material are shown in table 1.

Table 1: Details of Study Material

Purpose	**Data Used**	**Data Source**
Administrative Boundary Delineation (State & International Boundary)	Malda District Map of Census of India, North & South Dinajpur District Map of Census of India. 2011	District Bureau of Statistics Office., Topographical Map
River Boundary Delineation (Atrei, Punorvaba, Tangon, Kulik, Nagar, Fulhar & Mahananda river)	Google Earth Imagery of 2014	Google Earth Map
Water-body Detection	Landsat 8 satellite imageries of 2014	USGS Earth Explorer

After the collection of Landsat imagery from USGS earth explorer necessary correction have been done by defining UTM zone 45 North projection using WGS-84 datum. All others information of Landsat OLI_TIRS is shown in bellow (Table 2).

Table 2: Detail Information about Landsat OLI_TIRS

Landsat 8	OLI_TIRS	139/43, 139/42 138/43, 138/42	16.11.2014 (Post-Monsoon)	30	Band 1 (Blue) 0.433–0.453 Band 2 (Blue) 0.450–0.515 Band 3 (Green) 0.525–0.600 Band 4 (Red) 0.630–0.680 Band 5 (NIR) 0.845–0.885 Band 6 (SWIR-1/ MIR) 1.560– 1.660 Band 7 (SWIR-2) 2.100–2.300	USGS Earth Explorer

Methodology

Image Pre-Processing: Landsat OLI_TIRS imagery has been used for the identification of water body in this region.

But initially raw satellite imagery is not useful for extraction of information. To make it useful, the following preprocessing steps are applied: Radiometric corrections, atmospheric correction to maintain image resolution by using ERDAS IMAGINE 9.2 software and mosiacking & co-registration have been done by using Arc-GIS 10.2 software.

Image Processing: Six selected widely used indices including Normalized Difference Water Index (NDWI) (Gao, 1996), Normalized Difference Moisture Index (NDMI), Modified Normalized Difference Water Index (MNDWI), Water Ratio Index (WRI), Normalized Difference Vegetation Index (NDVI) and Automated Water Extraction Index (AWEI) are used to detect water body (Table 3).

In most of the above stated index, NIR band is widely used to detect water body for example NDWI, NDMI, WRI (Gautam *et al.*, 2015; Rokni *et al.*, 2014) in which water body is represented by positive value, and NDVI where water body indicated by negative value (Xu *et al.*, 2014).

Sometimes NIR band also includes built up area for example NDWI. To eliminate this problem modified NDWI (MNDWI) is being applied (Gu *et al.*, 2008).

All these indices are calculated by using raster calculator of Arc-Gis10.2 version software. At first a theoretical threshold value has been used for each index to detect water body and compared with the value, which is extracted from google earth imagery (Rokni *et al.*, 2014).
Later a modified threshold is determined by trial and error method for each index and again compared with google earth imagery. Finally a comparison is also made between theoretical and manually adjusted threshold value.

Table 3: Remote Sensing Based Water Feature Indices

Index	Equation	Remark	Reference
Normalized Difference Water Index	NDWI = (Green − NIR)/(Green + NIR)	Water has positive value	McFeeters, 1996; Gao, 1996
Normalized Difference Moisture Index	NDMI = (NIR − MIR)/(NIR + MIR)	Water has positive value	Wilson *et al.*, 2002
Modified Normalized Difference Water Index	MNDWI = (Green − MIR)/(Green + MIR)	Water has positive value	Xu, 2006
Water Ratio Index	WRI = (Green + Red)/(NIR + MIR)	Value of water body is greater than 1	Shen *et al.*, 2010
Normalized Difference Vegetation Index	NDVI = (NIR − Red)/(NIR + Red)	Water has negative value	Rouse *et al.*, 1973;
Automated Water Extraction Index	AWEI = 4 × (Green-MIR) − (0.25 × NIR + 2.75 × SWIR)	Water has positive value	Feyisa *et al.*, 2014;

RESULTS AND DISCUSSION

Extraction of Water Bodies and Estimation of Error: Except NDWI the result of each index shows significant variation in the water body area as per the theoretical threshold and manually adjusted threshold.
The theoretical value of NDWI, in which water body is represented by positive value, shows accurate surface water body area with respect to area measured from google earth image. Among all other indices NDMI showing highest variation in both theoretical and manually adjusted threshold and degree of deviation for NDMI from actual water body area is highest.
Another index modified NDWI (MNDWI) shows high deviation of water body area regarding to theoretical value.
But manually adjusted value is very close to actual value. Theoretical value for both indices NDVI & AWEI show less water body area to actual area. But WRI represents relatively less variation than MNDWI, NDVI and AWEI.
But one problem is noted with the manual adjustment i.e. sometimes low agricultural land and settlement area is included in the water body area and some permanent water body is excluded. Their relative position is mismatched to google earth base map.
Therefore, after manual adjustment of threshold, the value of NDMI, MNDWI still largely deviated from actual surface water body area.

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Table 4: Thresholding for Different Indices

Index	**Category**	**Theoretical Thresholding (Value = 0)**		**Manual Thresholding**		**Deviation**	
		No. of Pixel	**Area (Hectares)**	**No. of Pixel**	**Area (Hectares)**	**In Pixel Count**	**In Area (Hectares)**
NDWI	Water-body	72804	6552.36	**Unchanged** 72804	6552.36	0	0
	Non-Water-body	7472067	672486.03	7472067	672486.03	0	0
NDMI	Water-body	4297481	386773.29	**(Value = 0.18)** 129718	11674.62	4167763	375098.67
	Non-Water-body	3247390	292265.1	7415153	667363.77	4167763	375098.67
NDVI	Water-body	36483	3283.47	**(Value = 0.0186)** 60227	5420.43	23744	2136.96
	Non-Water-body	7508388	675754.92	7484644	673617.96	23744	2136.96
MNDWI	Water-body	605880	54529.2	**(Value =0.15)** 72254	6502.86	533626	48026.34
	Non-Water-body	6938991	624509.19	7472617	672535.53	533626	48026.34
AWEI	Water body	49	4.41	**(Value =-9000)** 72798	6551.82	72749	6547.41
	Non-Water body	7544822	679033.98	7472073	672486.57	72749	6547.21
WRI	Water-body	Theoretical Value >1 167021	15031.89	**(Value = 1.11)** 75101	6759.09	91920	8272.8
	Non-Water-body	7377850	664006.5	7469770	672279.3	91920	8272.8

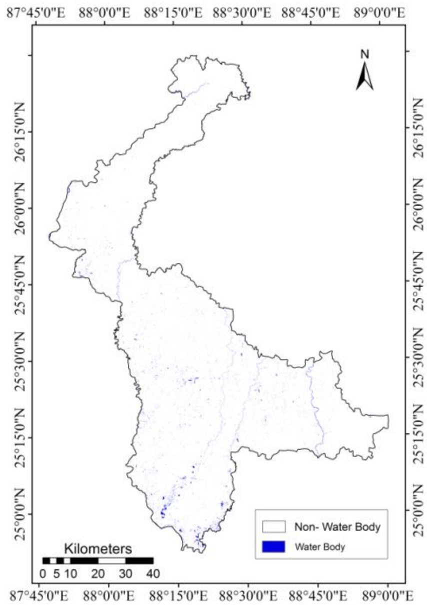

Figure 3: Theoretical Threshold (0) of NDWI in Post Monsoon

Here theoretical threshold value of NDWI gives better representation of water body, so there is no need of manual adjustment (figure 3).

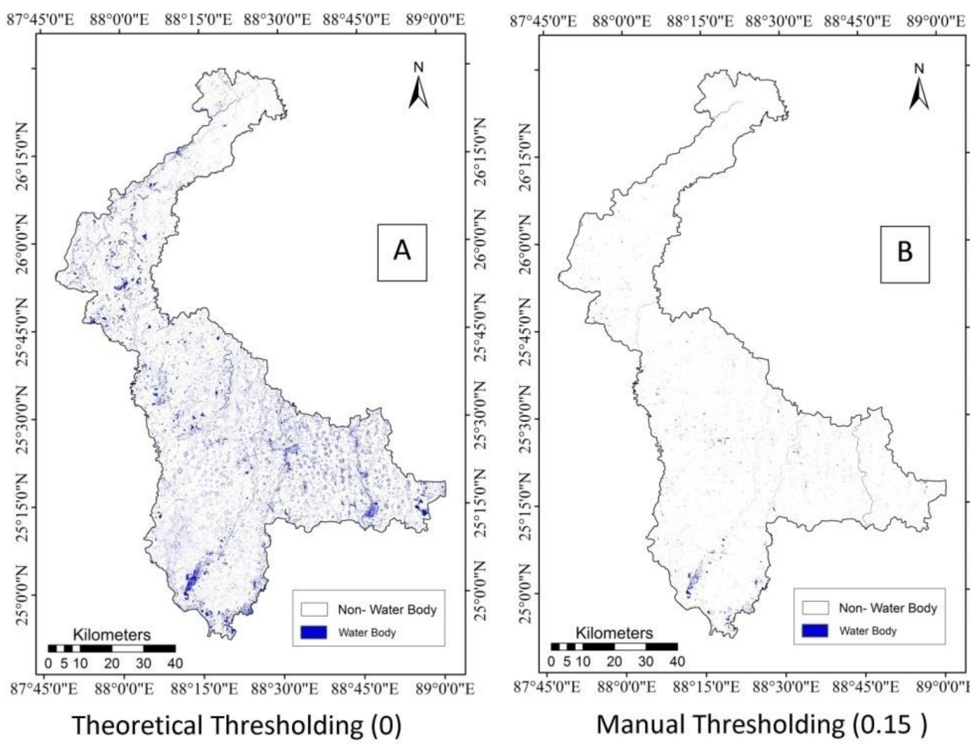

Figure 4: Comparison of MNDWI Results of Barind Region between Theoretical and Manually Adjusted Threshold

MNDWI was developed for elimination of background built-up area. Still it also includes built-up area in water body (figure 4). Manual adjustments of threshold successfully remove this problem.

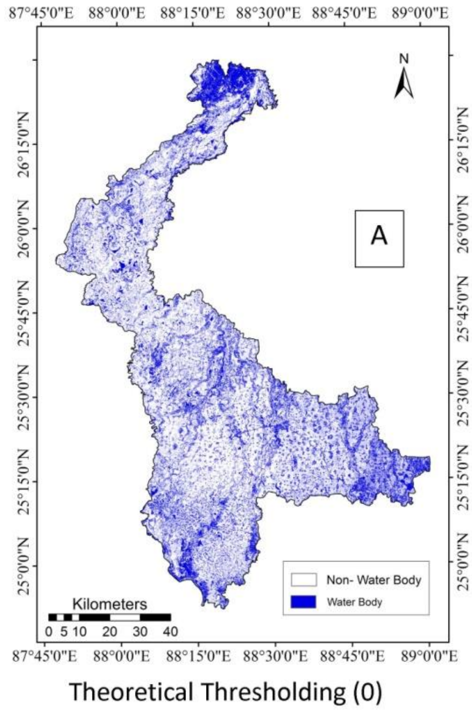

Figure 5: Comparison of NDMI Results of Barind Region between Theoretical and Manually Adjusted Threshold

NDMI is useful for detection of vegetation liquid quantity; therefore it includes all green agricultural fields in water body area (Figure 5). Even after manual adjustment of threshold, a large area of agricultural field is included in water body area.

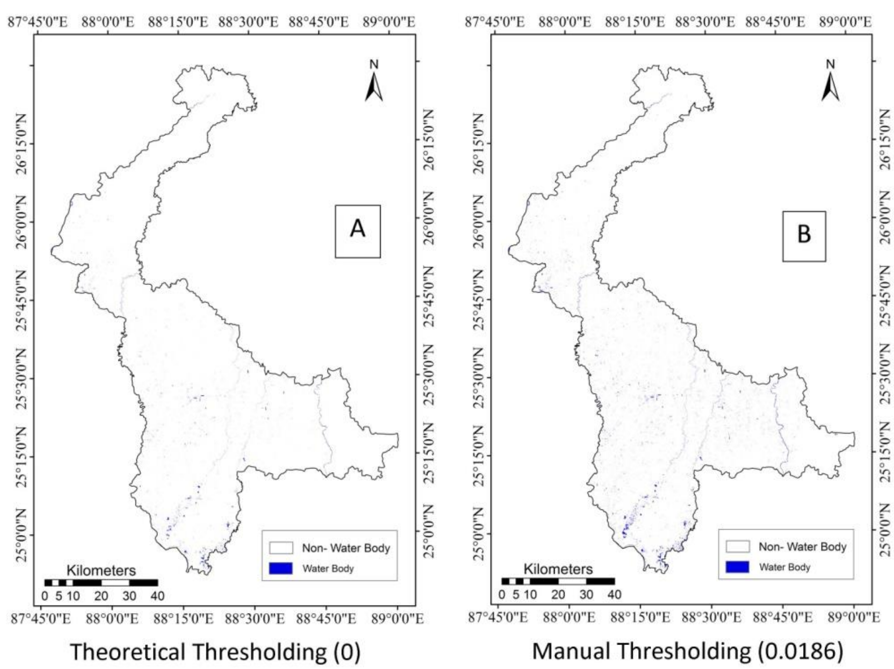

Figure 6: Comparison of NDVI results of Barind Region between Theoretical and Manually Adjusted Threshold

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As NDVI is used for separating vegetation cover so, theoretical value of NDVI shows relatively less area of surface water body compared to actual area (figure 6). But manually adjusted threshold gives very close to actual area measured from google earth imagery.

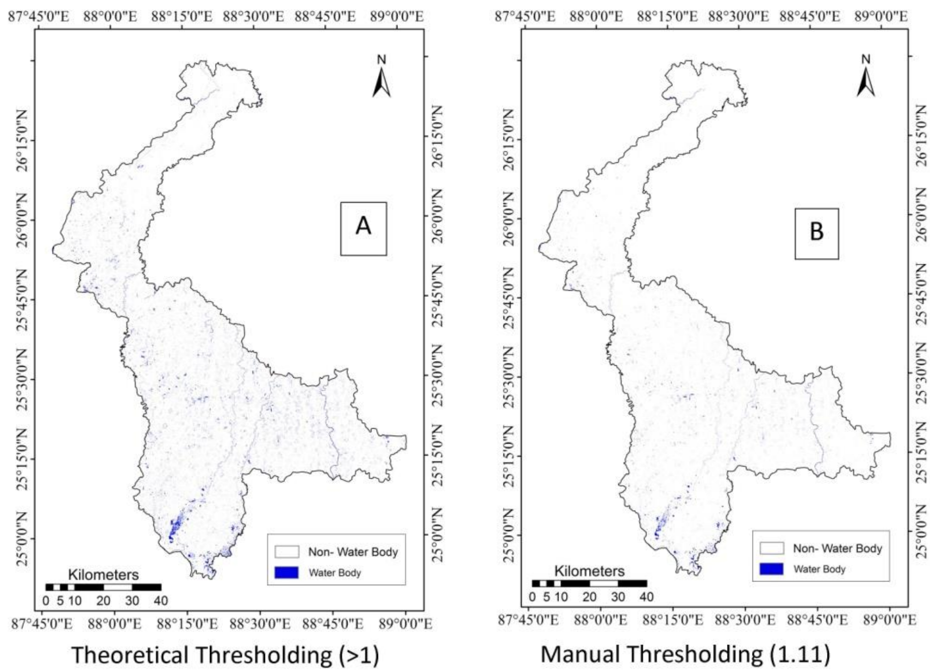

Figure 7: Comparison of WRI results of Barind Region between Theoretical and Manually Adjusted Threshold

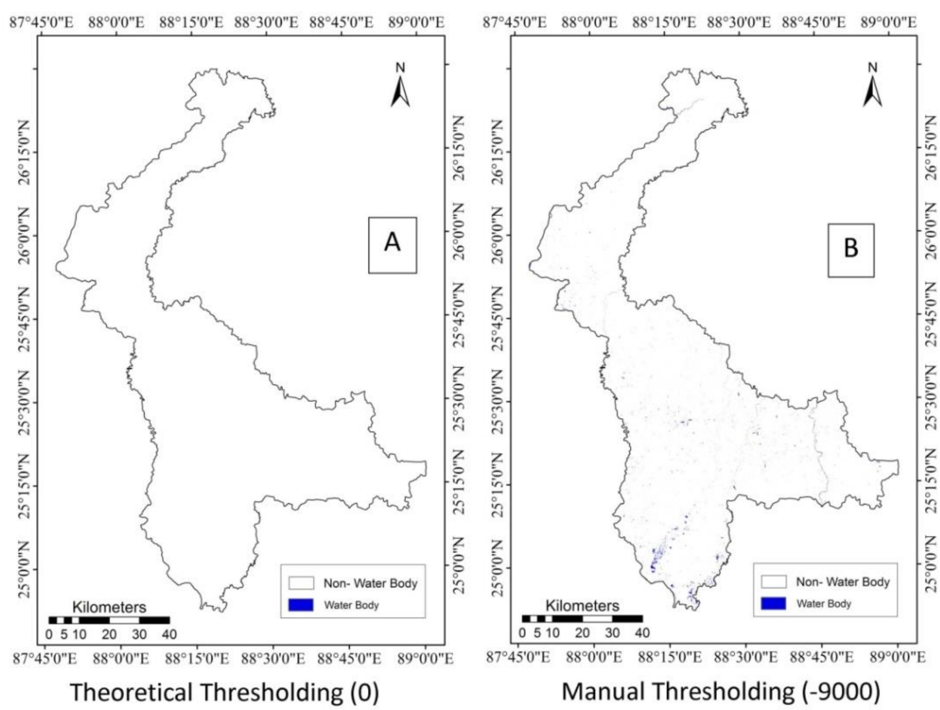

Figure 8: Comparison of AWEI results of Barind Region between Theoretical and Manually Adjusted Threshold

Theoretical value of AWEI shows (figure-) lowest water body area (4.41 hectare).

Validation of Threshold Values and Priority of Indices

For accuracy assessment, both theoretical threshold and manual threshold is compared with actual value calculated from google earth imagery, and percentage of error from actual data and deviation of error between theoretical and manual threshold is also measured (table 5). Result indicates, NDWI has lowest error (0.24%) and AWEI has highest error (99.93%) as per theoretical threshold. But reverse results are found in error of manual adjusted threshold. Here, AWEI shows lowest error (0.23%) but relative position of water body has displaced from its actual position in google earth imagery. MNDWI represents highest error (87.49%) even after manual adjustment of theoretical threshold.

Table 5: Accuracy Assessment with Google Earth Image and Calculation of Error

Indices	Actual Area of Surface Water Body (Hectare)	Theoretical Threshold Area (Hectare)	Manual Adjusted Threshold Area (Hectare)	Error from Theoretical Threshold (%)	Error from Manual Adjusted Threshold (%)	Deviation of Error
NDWI	6536.6	6552.36	6552.36	0.24	0.24	0
NDMI	6536.6	386773.29	11674.62	98.3	44	54.3
MNDWI	6536.6	54529.2	6502.86	88.01	0.52	87.49
WRI	6536.6	15031.89	6759.09	56.52	3.29	53.23
NDVI	6536.6	3283.47	6710.4	49.77	2.6	47.17
AWEI	6536.6	4.41	6551.82	99.93	0.23	99.7

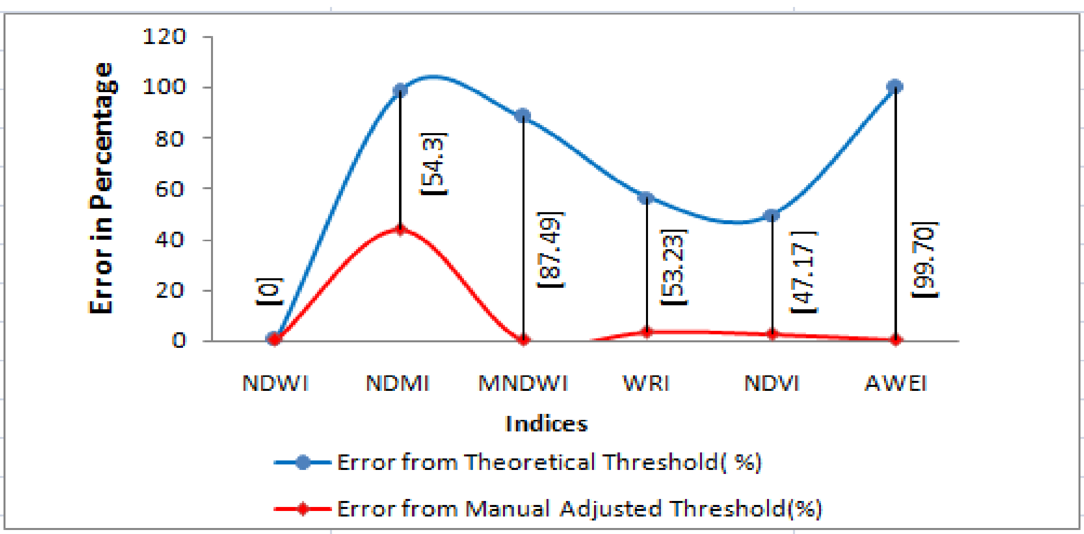

Figure 9: Deviation of Error from Theoretical Thresholds to Manual Thresholds

Deviation of Number of Pixel of Water Body from Theoretical to Manual Threshold for Different Seasons

As accuracy assessment of manually adjusted threshold gives two indices which have almost similar value, so a problem is faced for selection of suitable index. To eliminate this confusion comparative analysis has been done to indicate deviation between theoretical threshold and manual threshold for each index. The result shows high deviation of water body pixel in every selected index (figure 10). Only

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NDWI represents zero deviation between theoretical and manual threshold. But NDMI represent highest deviation (water body pixel 4167763). NDVI also represents less deviation after NDWI (table 4).

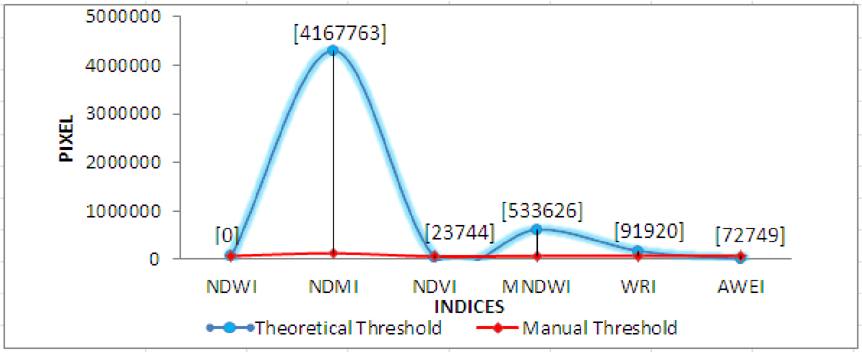

Figure 10: Deviation of Theoretical Threshold from Manual Threshold of Calculated Water Body Pixel

Initial field visit on 16 sites in very random fashion has made it clear that out of total visited sites, 87% water bodies are characterized by deep water bodies with perennial characters and rest proportion retains seasonally inundated water bodies. Pre monsoon season records either very shallow water or partially moist water without water stagnation. From such limited field visit, it is very difficult to infer that the models of spatial water bodies are valid. Still, with some limited field data, it can be asserted that the models are constructed in right manner.

Conclusion

The present study aimed to successfully extract surface water body of barind tract of west Bengal. After comparative analysis of various indices, NDWI was selected as a best performing water body extraction index for this region, because its value is very close to actual value of google earth imagery. Though NDWI includes some built-up area to water body, but here, barind tract is less populated area and a vast area is included in agricultural field. So, problem of inclusion of background built-up area into water body area is eliminated.

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