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Automatic Delineation of Water Bodies Using Multiple Spectral Indices

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ABSTRACT

In our study, Land and water surface changes in Lake Chilika from 1996 to 2014 were dileneated by using multi-temporal Landsat images and soupportsof the spectral water indexing method. In our research, we used indices i.e Normalized Difference Water Index (NDWI), Modified NDWI (MNDWI) and Automated Water Extraction Index (AWEI). The MNDWI, NDWI and AWEI provide the best result for extracting surface waterbody and find out spatiotemporal changes of the Chilika lake .by applying Landsat images through GIS software. The NDWI can be utilized for interpretation of the areal extent of water bodies every imageries of Land Sat data.. But,WRI and MNDWI are restricted for use only in images that have the MIR band. MNDWI provides for a sophisticated and refined estimation of the extent of surface water bodies within the Chilikalake.

Keywords: Remote Sensing, Surface Water Extraction, Water Indices

I. INTRODUCTION

Water or aquatic resource is an essential part of ecosystems and irreplaceable strategic resources for human survival and social development.It balances ecosystems and maintains climate variation, carbon cycling, and so on Hence, its humanness, accurate and automatic extraction is a challenge.Remote sensing has been successfully applied as it facilitates to harness natural resources effectively.It gives different spatial, spectral, and temporal resolutions provide a synoptic view of information that have become primary sources, which being widely applied for observing and extracting surface water.In past years, various contributions and researchers had been drawn toward the recognition of water bodies from remotely sensed images [Bagan et.al 2012., Zhu et.al 2011., Lu et.al 2011.,Du et.al 2011., Sun et.al 2011., Alesheikh et.al 2007., Lopez-Caloca et.al 2008., El-Asmar et.al 2011., Xu et.al 2010., Delju et.al 2012., Eimanifaret.al 2007., Sima et.al 2013., Ghaheri 1999] Now a day at that place are several numbers of water extraction techniques are utilized in multi-temporal Remote sensing.Which can be categorized as follows: (a) thematic map classification by visual interpretation, which is highly accurate, but labor-intensive (b) density slicing of a single or single-band thresholding band, which is fixed threshold in a given spectral band [15,16–18] (c) calculating two-band spectral water indices (Jain, Saraf, Goswami, & Ahmad, 2006; McFeeters, 1996; Rogers & Kearney, 2004; Xu, 2006), which combines two or more bands by mathematic ratios; and (d) classification of multispectral data using unsupervised [40] and supervised techniques [23–27].Among these, the most commonly used category is the spectral indices due to restraint, low price, and superior performance for identification of water bodies. These models are usually calculated from two to four bands; the Green, near-infrared, mid-infrared and shortwave infrared portions of the spectrum. McFeeters (1996) introduced the Normalized Difference Water Index (NDWI) to extract, open water features using the green and near-infrared band of Landsat TM. Still, Xu (2006) establish that the NDWI threshold of 0 does not accurately enable discriminating built-up surfaces from water pixels. Xu (2006) therefore he proposed a another index, called Modified Normalized Difference Water Index (MNDWI), where McFeeters (1996) NDWI was modified by replacing band 4 by band 5 of Landsat 5

TM. The MNDWI indices are now more widely used for various applications, including surface water mapping, land use/cover change analyses and ecological research (Davranche, Lefebvre, &Poulin, 2010; Duan&Bastiaanssen, 2013;Hui, Xu, Huang, Yu, & Gong, 2008;Poulin, Davranche, & Lefebvre, 2010). Normalized Difference Moisture Index (NDMI) (Wilson, E.H.; Sader, S.A. (2002)). Water Ratio Index (WRI) (Shen, L.et al. (2010)). Normalized Difference Vegetation Index (NDVI) (Rouse, J.W. et al. (1973)) and Automated Water Extraction Index (AWEI) (Feyisa, G.L et al. (2014)) are the most usual ones.Water body extraction is an important undertaking in different fields. In this paper, we detect the seasonal changes of the water body.

There are two types of seasonary data, we using here one is the pre- monsoon and another is post monsoon data to identify the changes of water body and land from the Landsat images. There are some indices are used to extract the water body from the land surface. The indices which are given here MNDWI, NDMI, NWDI, NDVI, WRI, AWEI. Automatic delineations is a completed process due to the presence of the water-saturated zone at the land, water boundary .Several spectral water indexes have been prepared to extract water bodies from remotely sensed imagery, usually by counting on the normalized difference images and its bands and giving an appropriate threshold to segment the result into two classes (land and water). In this study, satellite images are derived MNDWI, NDMI, NWDI, NDVI, WRI, AWEI, the indices used to extract lake water bodies from TM and OLI images.

STUDY Site

Asia's largest brackish water lagoon Chilika (19°28′ –19°54' N &85°06' –85°35' E) on the east coast of India is the largest brackish water lagoon in Asia and Ramsar site wetlands of international importance. TheChilika lagoon is separated into four ecological sections, i.e.Southern part is marine in nature, the central part is brackish in nature, while the northern region is dominated by fresh water, and an outer channel sector which is marine in summer and fresh water in the monsoon season.TheChilikalagoonisHydrologically influenced by the Mahanadi, because the drainage basin of Chilikalagoonlies between the rivers flowing into Mahanadi and Chilika.

LOCATION MAP

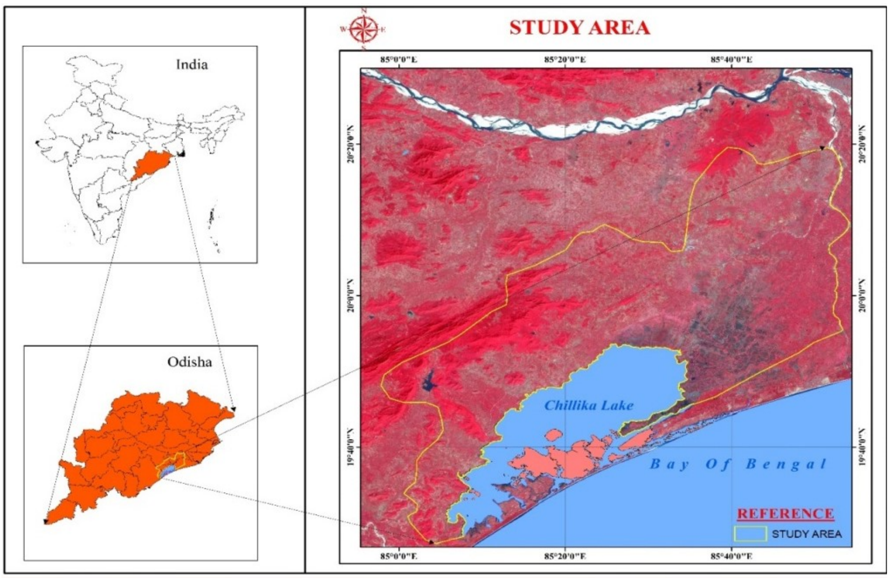


Figure 1. Location map

DATA DESCRIPTION:

The spatial data such as, topographical map,satellite imagery of Landsat data (MMS, TM, ETM+, OLI) bands. SRTM (DEM) data were acquired at a scale of 1:50,000.

Landsat-4 &5	**λ (μm)**	**Resolution (m)**
Band1-Blue	0.45-0.52	30
Band2-Green	0.52-0.60	30
Band3-Red	0.63-0.69	30
Band4-NIR	0.76.0.90	30
Band5-SWIR1	55-1.75	30* 120
Band6-Thermal	10.40-12.50	120
Band7-SWIR2	2.80-2.35	30

Landsat8 OLI	**λ(μm)**	**Resolution(m)**
B1-Ultra Blue(Costal/Aerosol)	0.43-0.45	30
B2-Blue	0.45-0.51	30
Band 3-Green	0.53-0.59	30
Band 4-Red	0.64-0.67	30
Band 5-NIR	0.85-0.88	30
Band 6-SWIR1	1.57-1.65	30
Band 7-SWIR2	2.11-2.29	30
Band 8-PAN	0.50-0.68	15
Band 9-CIRRUS	1.36-1.38	30*
Band 10-Thermal IR1	10.60-11.19	30*
Band 11-Thermal IR2	11.50-12.51	30*

After the collection of data from various sources, put all these data into computer by different method for different types of data as because GIS is totally based on computer, different method for input of data are used , because data these are used for the project are not in same from are spatial data and some are nonspatial so their procedures for the input of the data also varies, most of them are in analog form so first of them convert them to digital form by using scanner, and enter internet simply download them from internet to the computer.

	Satellite	**Sensor**	**Year**	**Wavelength (μm)**
Dataset of Pre-Monsoon	Landsat5	TM (L 4-5)	26 November1995	30
	Landsat8	OLI /TIRS	26 November2013	30
Data set of Post-Monsoon	Landsat5	L(4-5TM)	18 April 1996	30
	Landsat5	L(4-5TM)	7May 1997	30
	Landsat8	OLI-TIRS	4April 2014	30

II. METHODOLOGY

- **DATA PROCESSING:**

  Often a large portion of the data entered into GIS requires some kind processing and manipulation in order to make it confirm to a data types geoprocessingsystem and data structure that is compatible with the system.

- **PREPROCESSING**

Furthermore, since all of the individual bands were originally obtained as a Digital Number (DN) values, the original DN values had to be converted in to radiance, and then in to reflectance.

- **RADIOMETRIC CORRECTION:**

  Several factors independent of ground features can significantly affect spectral reflectance as measured at the sensor. Normalization of data accounts to reduce the non-land cover induced radiometric valuation between temporally separate images.

- Absolute correction.
- Relative correction.

- **ABSOLUTE CORRECTION**:

  Absolute correction takes into consideration measured atmosphericconditions, sensor gain and offsets, solar irradiance and solar zenith at the of image acquisition.

- **RELATIVE CORRECTION:**

  Relative correction is an alternative to absolute correction where the data on atmospheric condition is not available for historic datasets. It is corrected in two ways

1. Adjusting individual bands of data within a single image
2. Normalizing bands in images of multiple datasets relative to a identified reference image

The entire process of radiometric correction involves following steps.

1. Conversion of DN values to spectral radiance (at the sensor).
2. Conversion of spectral radiance of apparent reflectance (TOA) using Mean solar Exo-atmospheric irradiance.
3. Relative radiometric normalization.

- **RADIANCE CONVERSION**

In the first step raw digital numbers are converted to radiance using satellite header information using following formula.

Spectral radiance ($L\lambda$) = (LMAX –LMIN / Grey levels)* DN+ L.MIN

Where,

LMAX& LMIN = Maximum & minimum spectral radiance (mw cm-2 ster-1µm-1)

DN = Digital number

*Grey levels = $2^{\text{radiometric resolution}}-1$

*Example: for 8 bit data = [(2^8) -1]= 255

- **RADIANCE to TOA CONVERSION**

In the next step, the radiance is converted to top of the atmosphere (TOA) reflectance or apparent reflectance. The following formula is used for TOA conversion. The sun elevation angle is derived using header file. The date of pass of satellite data used for calculation of Julian day. Means solar ex-atmospheric constant (E_o) values for IRS series and Landsat-TM data

TOA ($P\lambda$) = (π*$L\lambda$* d^2)/(E_0* COS (Θ))

L_λ=Spectral Radiance (mw cm^{-2} $ster^{-1}$ μm^{-1})

d^2 = Sun distance in astronomical unit (AU)

Θ = Sun zenith angle in radians

E0 =Means solar Exo-atmospheric irradiance (mw cm^{-2} μm^{-1})

- **DATA MANAGEMENT:**

A relational database file containing all the attribute data's are created in the MS-EXCEL. For the data management, this is very much essential. Data management gives the creation of and access to the database itself. These function provide consistent methods for data entry; retrieval, deletion, and etc. modern database management system isolate the user from the details of data storage, such as particular data organization on a mass storage medium.

- **DATA PROCESSING THROUGH GIS:**

GIS is a s to make a decision making tool, it helps us to make us to efficiently store, capture, retrieve, manipulate or analyse the data and displayed all forms of geographically referenced information . For various project it provides a very reliable and less time consuming process to do any work than the conventional method.

Validation of results using Root Mean SquareError

The RMSE is used to measure the difference betweenvalues predicted by a model and actual values. These individual differences are also called residuals, and theRMSE serves to aggregate them into a single measure ofpredictivepower.The RMSE of a model prediction with respect to theestimated variable *X* model is defined as the square rootof the mean squared error.

RMSE = $\sqrt{(\sum_{i=1}^{n}(X_{obs,i}-X_{model,i})^2/n)}$

where$X_{obs,i}$represents the observed values of the *i*thobservation and $X_{model,i}$represents the predicted valuesat location *i*.

III. INDEX FOR WATER BODY EXTRACTION

1.Normalized Difference Water Index (NDWI)

The Normalized Difference Water Index (NDWI) wasfirst suggested by to detect surface waters in wetlandenvironments and measure surface water dimensions.The NDWI for TM and ETM sensors is defined by following. As a result, water features have positive values and areenhanced. Vegetation and soil features usually have zeroor negative values and are suppressed.

$$NDWI = band2 - band4/ band2 + band4$$

2.Modified Difference Water Index (MNDWI)

The MNDWI method suggested by has beencommonly used and is a powerful index that canextractwater bodies. It is expressed by . The resulting values representing the water featureshave positive values because of their higher reflectance inband 2 than in band 5, and non-water features have neg-ative NDWI values . A threshold value for MNDWI(e.g., simply a value of zero) can be set to segment theMNDWI results into two classes (water and non-waterfeatures).

$$MNDWI = band2 - band5 \ band2 + band5$$

3.Automated Water Extraction Index (AWEI)

The main aim of the AWEI is to maximize theseparability of water and non-water pixels using banddifferencing, addition and application of differentcoefficients. Accordingly, two separate equations areproposed to effectively suppress non-water pixels andextract surface water with improved accuracy .Themathematical definition of AWEI is given in Eqs. Below.

$$AWEInsh= 4x(\rho band2 - \rho band5) - (0.25x\rho band4 + 2.75x\rho band7)$$

AWEIsh= ρband1 + 2.5xρband2 − 1.5x(ρband4 + ρband5) − 0.25xρband7

whereρ variables are the reflectance values of spectralbands of Landsat 5 TM: band 1, band 2, band 4, band 5and band 7. *AWEInsh*is formulated to effectively elimi-nate non-water pixels, including dark, built-up surfacesin areas with urban backgrounds, and *AWEIsh*further improves the accuracy by removing shadow pixels that *AWEInsh*may not effectively eliminate.

Index	Equation	Remark	Reference
Normalized Difference Water Index	NDWI = (Green − NIR)/(Green + NIR)	Water has positive value	[1]
Normalized Difference Moisture Index	NDMI = (NIR − MIR)/(NIR + MIR)	Water has positive value	[2]
Modified Normalized Difference Water Index	MNDWI = (Green − MIR)/(Green + MIR)	Water has positive value	[3]
Water Ratio Index	WRI = (Green + Red)/(NIR + MIR)	Value of water body is greater than 1	[4]
Normalized Difference Vegetation Index	NDVI = (NIR − Red)/(NIR + Red)	Water has negative value	[5]
Automated Water Extraction Index	AWEI = 4 × (Green-MIR) − (0.25 × NIR + 2.75 × SWIR)	Water has positive value	[6]

IV. RESULT AND DISCUSSION

Water indices refers to mathematical models that raise the picture element of water signal at images obtained from optical remote sensing scanning sensors. Therefore, the performance of different satellite-derived indexes, including NDWI, MNDWI, WRI, NDVI, and AWEI was examined for the extraction of surface water from Landsat data.

MNDWI

MNDWI indices on pre-monsoon 4th April2014 OLI image we get water area 1052.64sqkm and land area 3351.532sqkm. We need the images of 26 th November1995 TM images, the water area 1370.455sqkm and the land area 3033.764sqkm. It is very much useful for different applications, like surface water mapping, land use/cover change analyses and ecological research.NDWI indices on premonsom 4april2014 OLI image we get water area 793.0152sqkm and land area 3611.157sqkm. We take the images of 26th November1995 TM images, the water area 1203.279sqkm and the land area 32008.59sqkm.

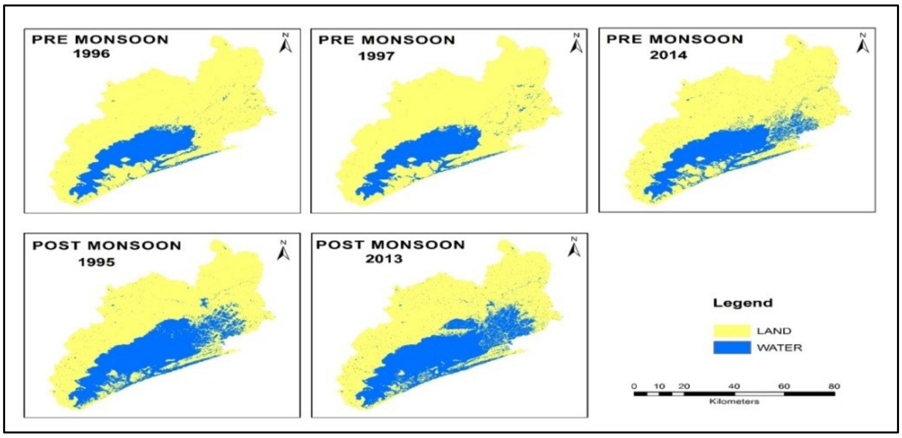


Figure 1

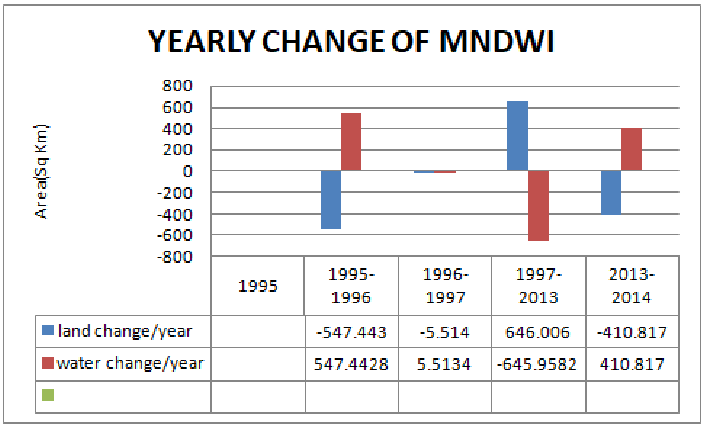


Figure 2

NDMI

Landsat imagery records spectral information reflected from the Earth's surface at a 30m spatial resolution across six different spectral bands.When we run NDMI indices on premonsoon 4april2014 OLI images we find the area of water is 1467.289sqkm and the area of land is 2936.822sqkm. We take the images of 26november1995 TM images we find the area of water is 1739.679sqkm and the area of land is 2664.54sqkm.

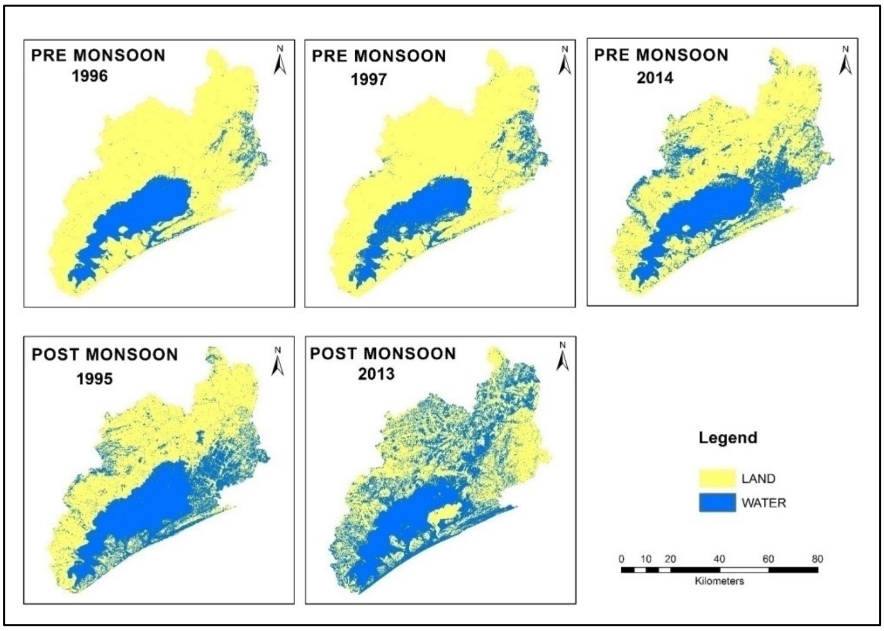


Figure 3

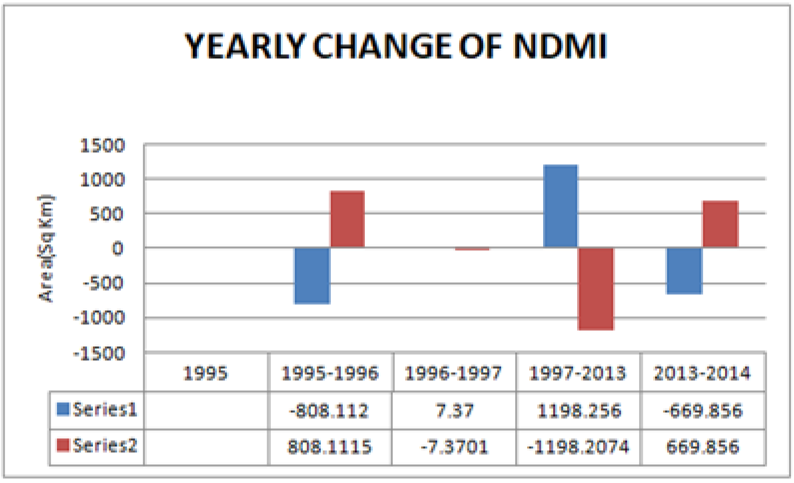


Figure 4

NDWI

NDWI index is applied to emphasize the reflectance of water by using green band, suppress the low reflectance of NIR by water features;

When we run NDWI indices on premonsom 4april2014 OLI image we get water area 793.0152sqkm and land area 3611.157sqkm. In 7may 1997 TM images we get water area 696.1905sqkm and land area 3708.029sqkm. In 18april 1996 TM images we get water area 764.6319sqkm and land area 3639.587sqkm. We take the images of 26november1995 TM images, the water area 1203.279sqkm and the land area 32008.59sqkm.

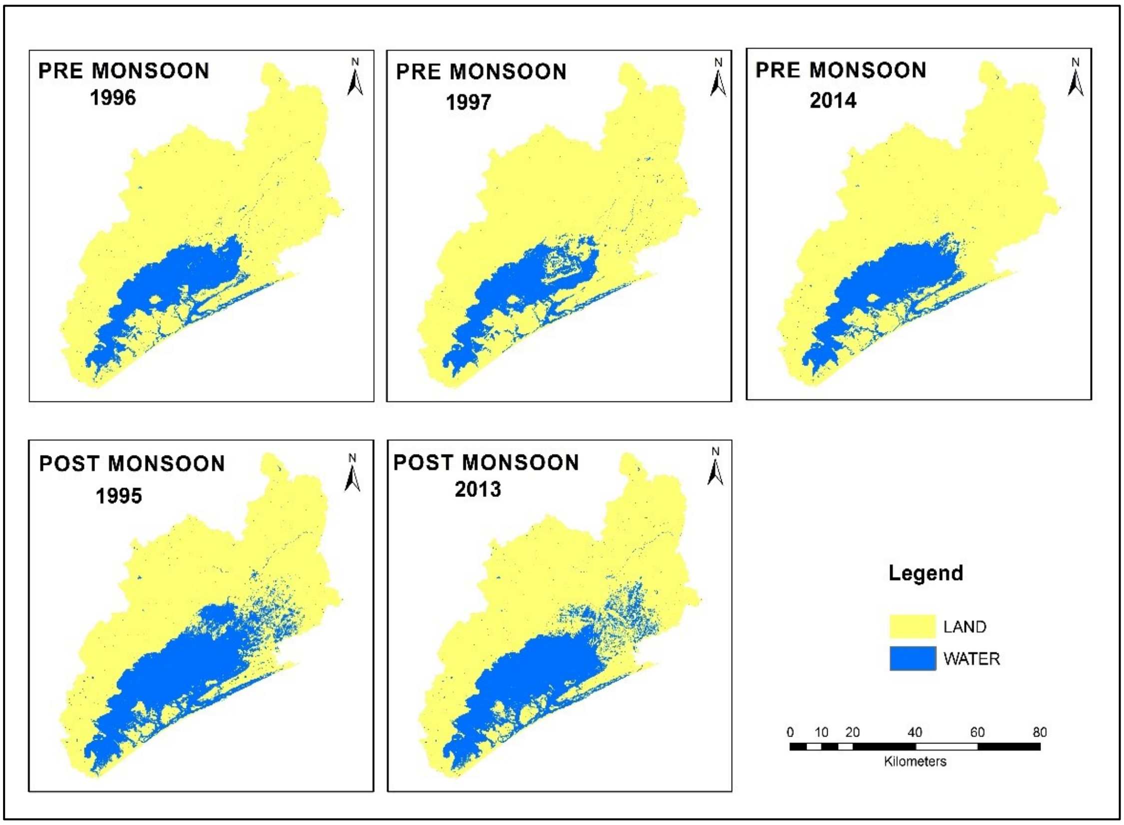


Figure 5

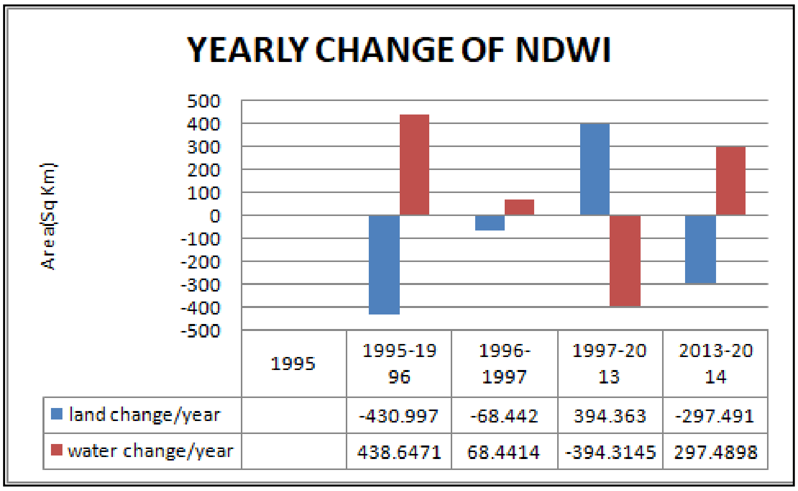


Figure 6

NDVI

But, it did perform well for surface water detection.NDVI indices on pre monsoon 4april2014 OLI images we get the area of water is 992.7198sqkm and the area of land is 3411.452sqkm. In 7may1997 TM images we find the area of water is 799.2036sqkm and the area of land is 3605.016sqkm. We take the images of 26november1995 TM images we find the area of water is 1185.989sqkm and the area of land is 3218.23sqkm.

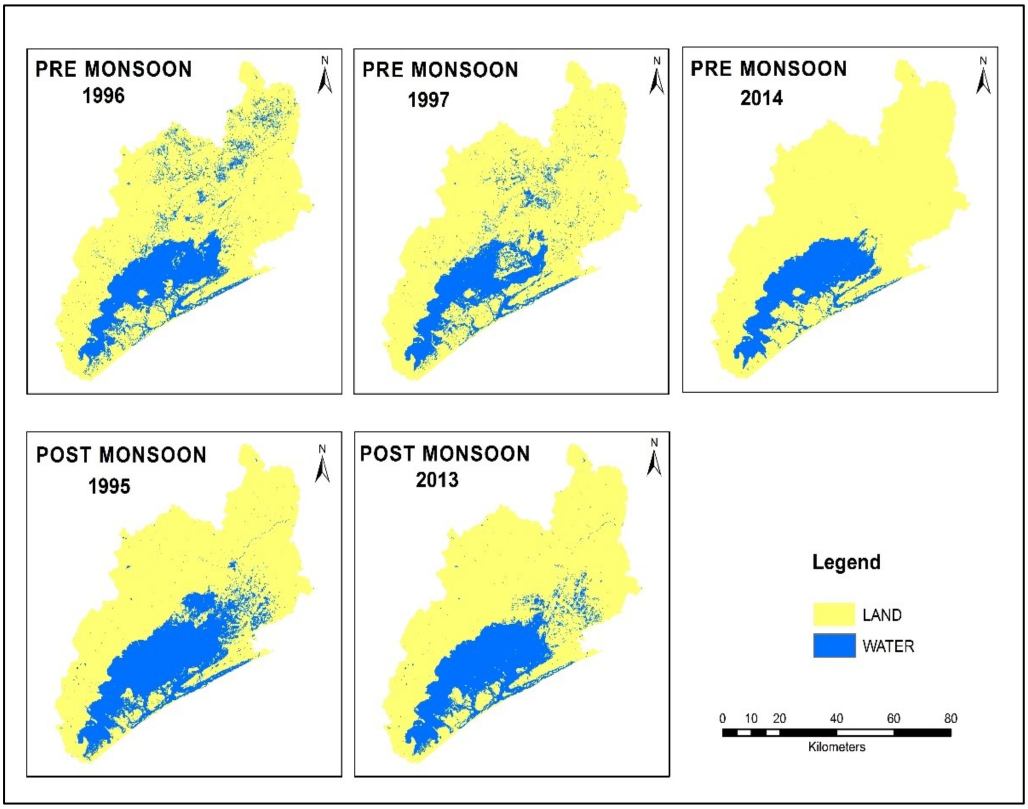


Figure 7

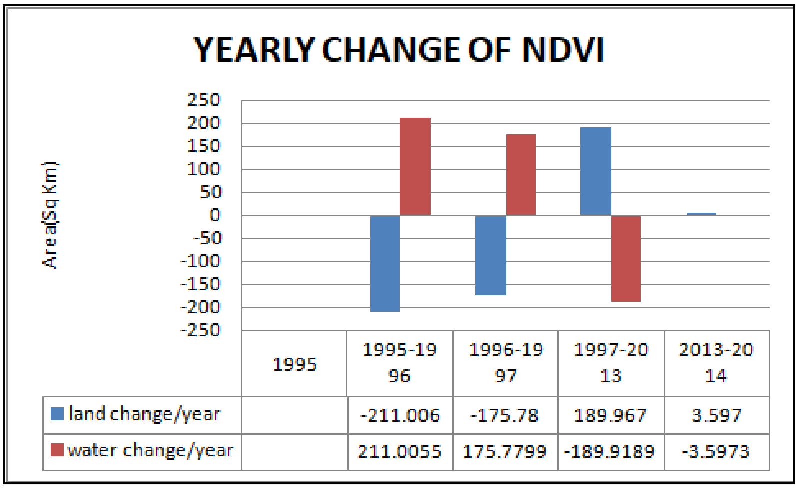


Figure 8

AWEI

The AWEI was used for extraction water in areas that include shadows and dark surfaces, formulated to effectively suppress shadow pixels and extract surface water with improved accuracy. The NDMI was developed for detection of vegetation moisture contents, and thus it is not suitable for extraction of water features in chilika.AWEIindicaes on premonsoon 4april2014 OLI images we find the area of water is 666.63sqkm and the area of land is 3737.542sqkm.

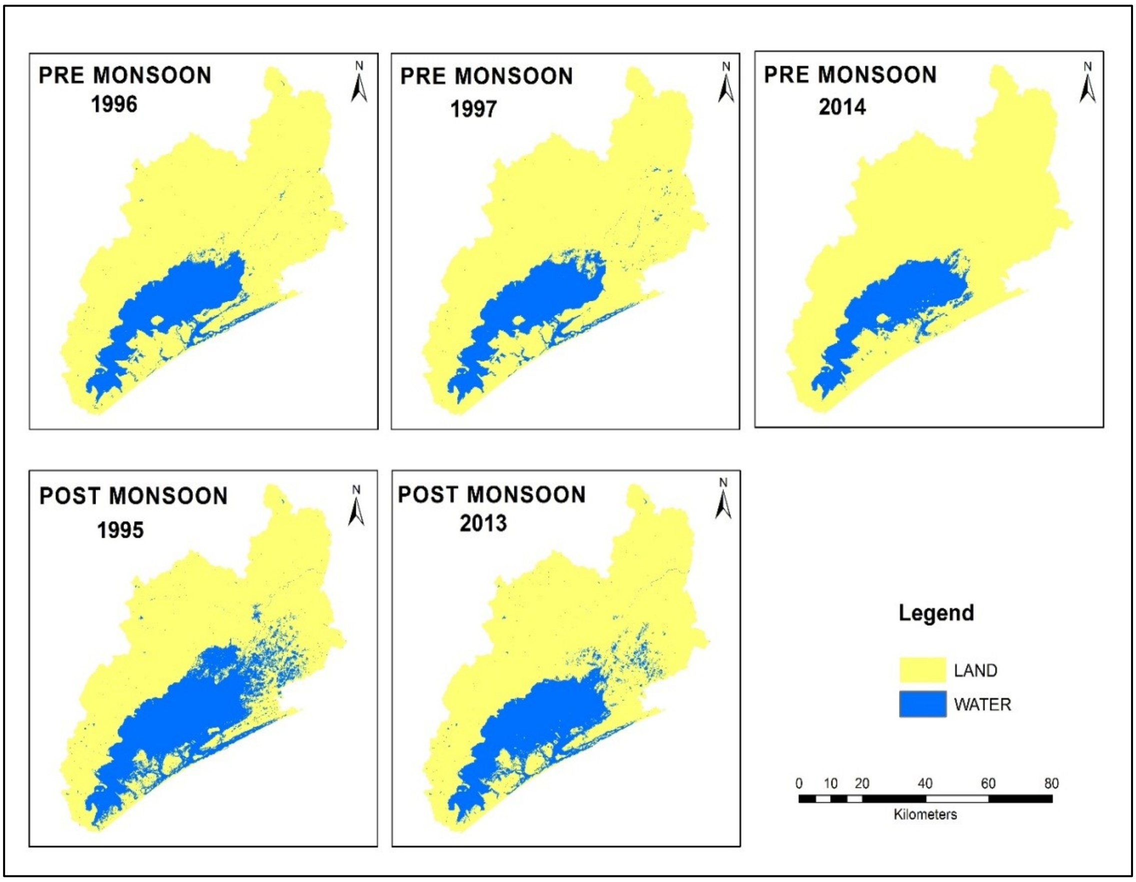


Figure 9

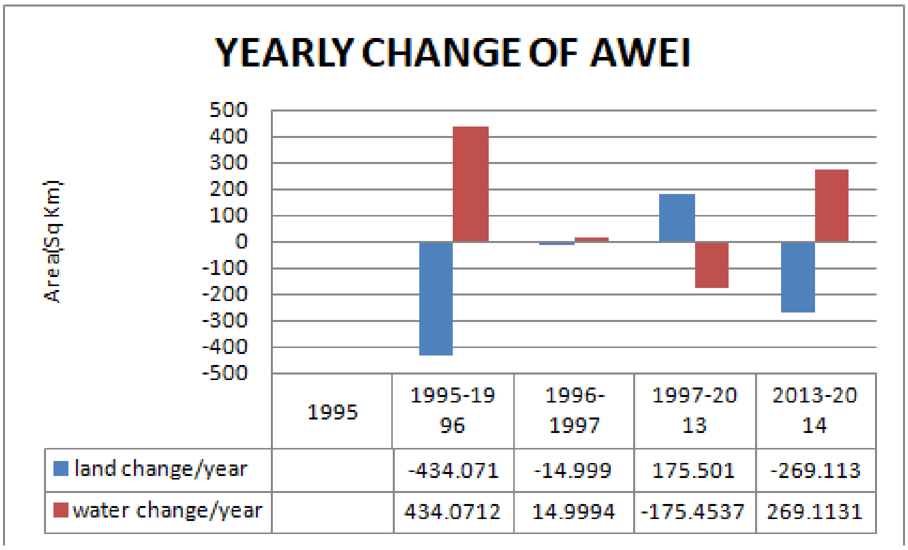


Figure 10

WRI

It can be proposed for the extraction water bodies only from those satellite imageries having the MIR band.WRI indices on premonsoon 4th April2014 OLI images we find the area of water is 848.3414sqkm and the area of land is3555.83sqkm. In 7May1997 TM images we find the area of water is 772.8984sqkm and the land area is 3631.321sqkm. We take the images of 26th November1995 TM images, the water area 920.2491sqkm and the land area 3483.97sqkm.

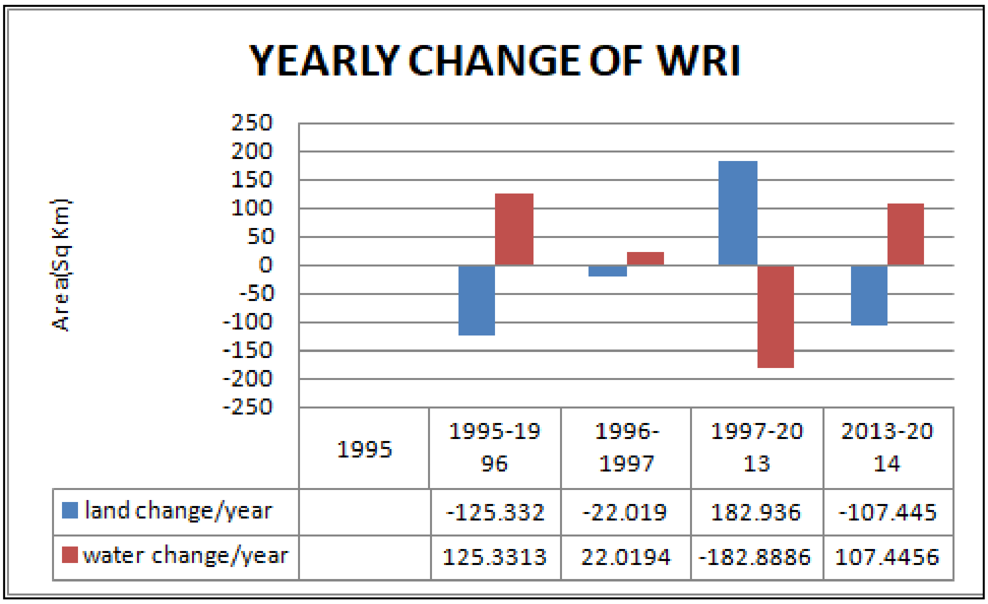


Figure 11

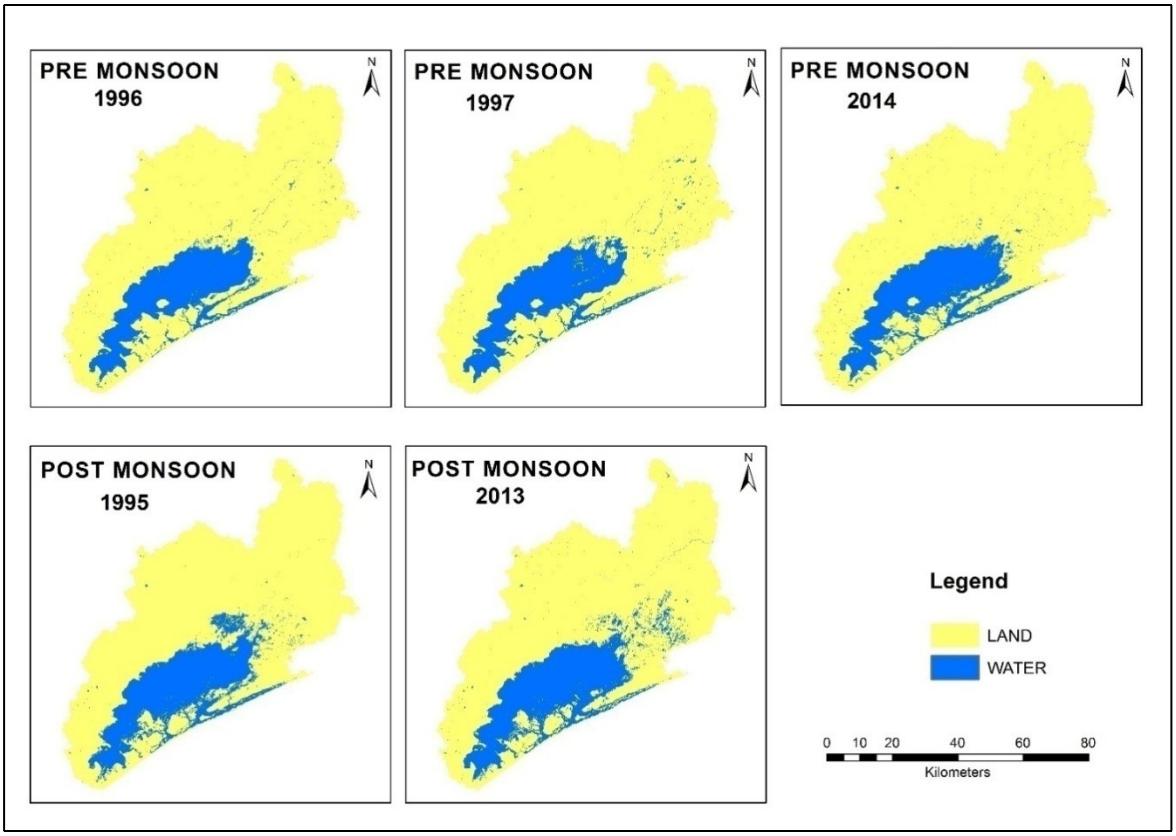
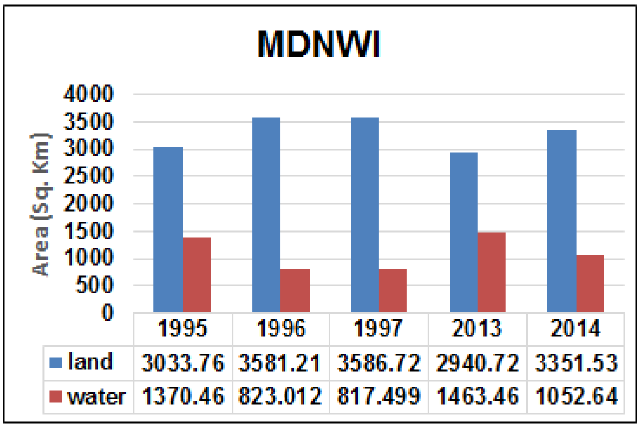


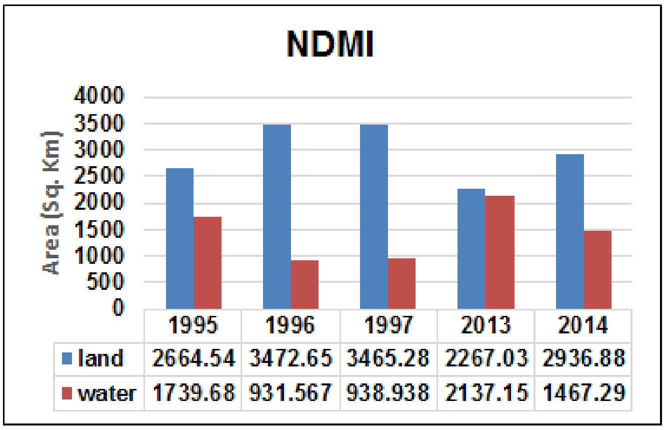
Figure 12

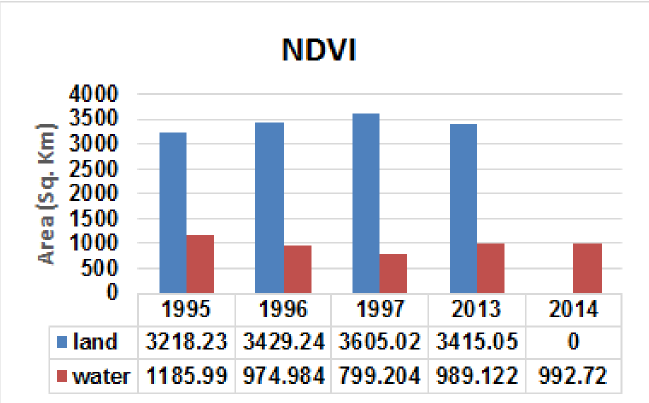
The water and land area of Chilika lake water shade was calculated by using the different types of water indices which are given below in the table.

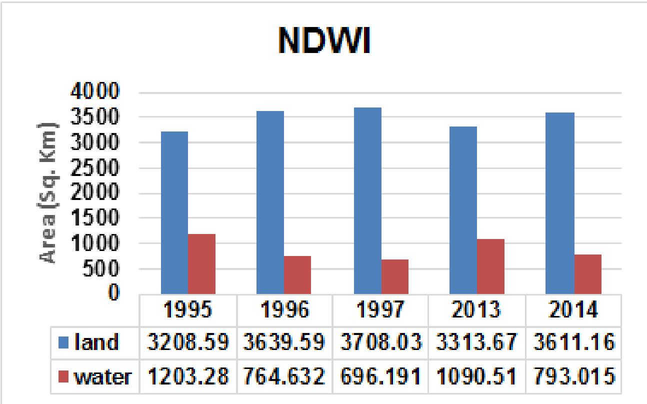
Table4. Area of water and land in square kilometres

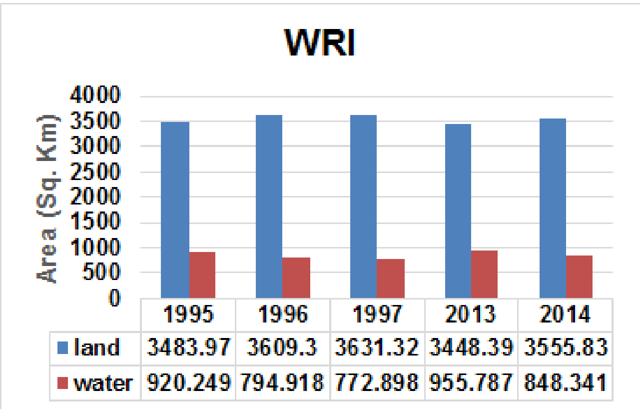
	AREA SQ KM	AREA SQ KM	AREA SQ KM	AREA SQ KM	AREA SQ KM	AREA SQ KM
pre monsoon	***MNDWI***	***NDMI***	***NDVI***	***NDWI***	***WRI***	***AWEI***
year	**2014**	**2014**	**2014**	**2014**	**2014**	**2014**
land	3351.532	2936.882	3411.452	3611.157	3555.83	3737.542
water	1052.64	1467.289	992.7198	793.0152	848.3414	666.63
year	**1997**	**1997**	**1997**	**1997**	**1997**	**1997**
land	3586.721	3465.282	3605.016	3708.029	3631.321	3643.93
water	817.4988	938.9376	799.2036	696.1905	772.8984	760.2894
year	**1996**	**1996**	**1996**	**1996**	**1996**	**1996**
land	3581.207	3472.652	3429.236	3639.587	3609.302	3628.931
water	823.0122	931.5675	974.9835	764.6319	794.9178	775.2888
Post monsoon	***MNDWI***	***NDMI***	***NDVI***	***NDWI***	***WRI***	***AWEI***
year	**1995**	**1995**	**1995**	**1995**	**1995**	**1995**
land	3033.764	2664.54	3218.23	32008.59	3483.97	3194.86
water	1370.455	1739.679	1185.989	1203.279	920.2491	1209.36
year	**2013**	**2013**	**2013**	**2013**	**2013**	**2013**
land	2940.715	2267.026	3415.049	3313.666	3448.385	3468.429
water	1463.457	2137.145	989.1225	1090.505	955.787	935.7431

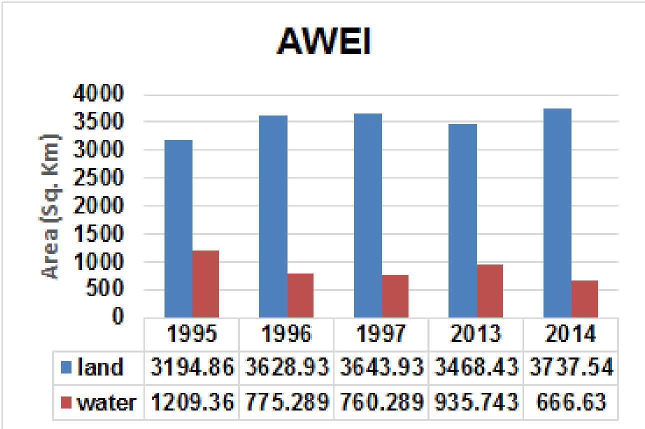












V. CONCLUSION

With remote sensing we can gather information on the relative variation of water quantity and quality parameters and make some qualitative comparisons. Multisensor satellite data such as Landsat TM/ETM+,MSS,OLI_TIRS,and we used Water Index (NDWI), Modified Normalized Difference Water Index (MNDWI), Normalized Difference Moisture Index (NDMI), Water Ratio Index (WRI), Normalized Difference Vegetation Index (NDVI) and Automated Water Extraction Index (AWEI) are the most common ones. These data are proved to be effective in extracting useful information regarding land cover change, and water clarity which serves as an indicator of water quality in a lake. Remotely sensed data contribute to a lake water quality assessment project through its ability to show spatial patterns of various environmental parameters.

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