# Image Classification and Change Detection of Water bodies in Satellite images using different Vegetation Indices

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*Abstract*— This paper presents an enhanced method for Change Detection and classification of water bodies in Satellite images based on Normalized Difference Water Index(NDWI) and Normalized Difference Vegetation Index (NDVI). These indices are applied on Remote sensing images taken by Resoursesat-2 LISS III sensor. The images are classified as water bodies, land area, clouds, and Vegetation area with four band combinations of the remote sensing images taken in the years 2009-2016. The pixel change detection between the images taken in different seasons such as monsoon, summer is compared for the changes in water levels. This will help to predict the natural disasters, flooding regions and disappearance of small water bodies, also aims to monitor drought in that area.

Keywords— NDWI, NDVI, Satellite Images, Change Detection, Classification

## I. INTRODUCTION

Water is the one of the essential natural resources for all living things. Water resources in Villages and cities are gradually reducing due to some encroachment. In rainy season the water levels will increase in ponds and lakes, and after that it gradually decreases. In summer many of the small ponds will disappear. Therefore it is an important task to monitor the water levels of the water resources.

Remote Sensing is an efficient technique for providing necessary information's about water resources, land area, vegetation area and building area and thus we can observe the earth's environment without coming into physical contact of these areas. Remote sensing can be classified as passive or active remote sensing. In passive remote sensing the energy will be directly available from sun, where as active remote sensing energy is generated and sent from the remote sensing platform towards the targets. The energy reflected back from the targets are recorded using sensors. Real sensors have fixed limits of spectral sensitivity and spatial resolution.

A normalized difference water index (NDWI) that uses two bands one green ( 0.52 to 0. 59 μm), and near-Infrared bands (0.77 to 0.85μm ) to find the water pixels present in the image [14]. This index is designed to maximize reflectance of water by using green wavelengths, minimize the low reflectance of NIR by water features and to take advantage of the high reflectance of NIR by vegetation and soil features[15]. As a result, water features have positive values and thus are enhanced, while vegetation and soil usually have zero or negative values [6]. However, the application of the NDWI in water regions with a built-up land background does not achieve its goal as expected. The extracted water information in those regions was often mixed with built-up land noise. This means that many built-up land features also have positive values in the NDWI image.

NDVI is calculated as a ratio difference between measured canopy reflectance in the red( 0.62 to 0.68 μm) and near infrared bands(0.77 to 0.85μm ) respectively [11]. NDVI is a common and widely used index [10]. It is an important vegetation index, widely applied in research on global environmental and climatic change [8].

The goal of this study was to develop an efficient procedure that would allow integrating remote sensing, and assessing its capability with a Geographic Information System of detecting surface features, spatially analyzing data, and identifying water bodies [13].

## II. STUDY AREA:

Satellite sensors store information as a grid. Sensors collect digital data from the area covered in the form of smallest area units, known as pixels. The size of the pixel is based on the sensor type and determines the resolution of the image. The Resolution of satellites varies from centimetres to kilometres. The LISS-III is a medium resolution sensor (5.8 m to 56 m) offering a Ground Sample Distance (GSD) of 23.5m with swath is 141 km with repeat cycle of 24 days. It operates in four spectral bands, three VNIR (Visible and Near Infrared and one SWIR (Short-wave Infrared). First spectral Band B2 ranges from 0.52 to 0. 59 μm, Second B3 Ranges from 0.62 to 0.68 μm, third spectral band B4 ranges from 0.77 to 0.85μm and the fourth spectral band B5 ranges from 1.55 to 1.70 μm. In this paper the first spectral Band B2 and third spectral Band B4 are used for detecting the changes in the water bodies.

The path is the descending orbit of the satellite and row is the scene centre. Each path number and row number combination describes a unique rectangular scene of satellite data.

The referencing scheme of LISS-III consists of 341 paths numbered from west to east. Each path consists of 149 rows. Consecutive paths are covered with a separation of five days. If Path 1 is covered on day one, Path 2 will be covered on day six. Each LISS-III scene covers an area of 142 Km x 141 Km. The side lap between two LISS-III scenes is 23.5 Km at the equator. The overlap between successive scenes in a path is 7 Km.

This data is received from Linear Imaging and Self Scanning Sensor (LISS) which operates in three spectral bands in VNIR and one band in SWIR with 23.5 metre spatial resolution and a swath of 141 km. The geographic location of the data is 79.75E, 13.25N, 80E, 13.25N ,80E, 13N ,9.75E, 13N with path/Row is 102 and 064.

## III. METHODOLOGY

The steps involved in proposed approach are i) data pre-processing of satellite images, ii) to correct for Radiometric errors in LISS III images, iii) Image classification using various Vegetation indices and iv) Change detection in different seasons in between the years 2009 and 2016.

The proposed approach for this method is

1.The image is pre-processed.
2.Median filter is applied for removing noise.
3.Histogram equalization is a technique for adjusting image intensities to enhance contrast.
4.Radiometric correction is performed in the image using the formula
RC=DN*gain + offset. [2]
5.RGB image is created from gray value image.
6.Normalized Difference Water Index value is calculated as the difference between green band and NIR band
NDWI=Green -NIR/(Green +NIR), the values lie between 0<NDWI>1
7.Normalized Difference Vegetation Index is calculated by the difference of red band and NIR band
NDVI=NIR-Red/NIR+Red, the values lie between 0<NDVI>1
8.LNDVI=Red/(Red+Green +NIR)
9.Cloud=(Green-NIR)+Red./(Green+NIR)-Red
10. $NDWI_{m,n} = NDWI_{m,n}(1) - NDWI_{m,n}(2)$

### *A. Data Pre-processing:*

The Satellite Image pre-processing is necessary to find the quality and characteristics of the data. Performing pre-processing on the satellite images will allow us to do something with the data and strengthen the satellite images for the purpose of further usage. One of the pre-processing technique is filtering which applies varies effects on the remote sensing image to reduce noise and enhance the quality of an image.

Median Filter is used for removing noise from an image, it replaces the value of a pixel by the median of the intensity levels in the neighbourhood of that pixel. The pattern of neighbours is called the "window", which slides, pixel by pixel over the entire image. The median is calculated by first sorting all the pixel values from the window into numerical order, and then replacing the pixel being considered with the mid pixel value.

An image histogram is a type of histogram which offers a graphical representation of the tonal distribution of the gray values in a digital image. A good histogram is that which covers all the possible values in the gray scale used. This type of histogram suggests that the
Image has good contrast and that details in the image may be observed more easily.

Histogram equalization formula

$$heq(i)=round\left(\frac{df(1)-dfmin}{mxn-dfmin}\right)*(L-1) \qquad (1)$$

where dfmin is the minimum value of the cumulative distribution function, m no of columns , n number of rows in the image and L is the number of gray levels.
We need to calculate the cumulative distribution function which is defined a

$$Cdf(x) = \sum_{i=0}^{x}(h(i)) \qquad (2)$$

Here x is a gray value and h is the image's histogram.

### *B. Radiometric Correction:*

Radiometric correction of remotely sensed data normally involves the processing of digital images to improve the fidelity of the brightness value magnitudes.. The main purpose for applying radiometric corrections is to reduce the influence of errors or inconsistencies in image brightness values that may limit one's ability to interpret or quantitatively process and analyze digital remotely sensed images.[4].
The radiometric resolution of an imaging system describes its ability to discriminate very slight differences in energy. This correction is to find the significant differences reflected energy or emitted energy. Radiometric correction is one of several corrections performed on satellite image data prior to the retrieval of land, atmosphere, and ocean information. Radiometric correction is done to reduce or correct errors in the digital numbers of images.
Radiometric resolution describes the ability of an imaging system to record many levels of brightness and to the effective bit-depth of the sensor that is the grayscale levels and is also expressed as 8-bit (0-255), 11-bit (0-2047), 12-bit (0-4095) or 16-bit (0-65,535) [5].
The formula for finding radiometric correction is

$$RC=DN*gain+offset \qquad (3)$$

Where gain=Lmax-Lmin, offset=Lmin and DN is the highest digital value of the image here the value is 255.
Lmin=Minimum radiance value, Lmax=maximum radiance value

TABLE I

LISS –III Data with radiometric resolution

| Band | Band Width µm | Lmin W/(m2. sr.um) | Lmax W/(m2. sr.um) | DN | Spatial Resolu-tion m | Radio metric Resolution |
|---|---|---|---|---|---|---|
| B2 | 0.52-0.59 | 0 | 12.064 | 255 | 23.5 | 0.04731 |
| B3 | 0.62-0.68 | 0 | 15.131 | 255 | 23.5 | 0.059337 |
| B4 | 0.77-0.86 | 0 | 15.757 | 255 | 23.5 | 0.061792 |
| B5 | 1.55-1.7 | 0 | 03.397 | 255 | 23.5 | 0.013322 |

*C. Image classification:*

Image classification is a vital component in remote sensing, image scrutiny and pattern identification. Classification of satellite imagery plays an important role in many application of remote sensing. Classification is a method by which labels or class identifiers are attached to the pixels making up remotely sensed image on the basis of their spectral characteristics. These characteristics are generally measurements of their spectral response in different bands.[3] .

Classification uses the spectral information represented by the digital numbers in one or more spectral bands and attempts to classify each individual pixel based on this spectral information. Vegetation indices computed from satellite images gives a good indication of the presence of vegetation. It is an indicator that describes the greenness, density and health of vegetation.

Vegetation indices (VI) enhances the spectral information and increases the separability of the regions of interest therefore it influences the quality of the information derived from the remotely sensed data.[3]. NDWI values range from -1 to 1. Water areas will generally yield high values because of their relatively high near-infrared reflectance and low visible reflectance. In contrast, water, clouds, and snow have larger visible reflectance than near-infrared reflectance. Thus, these features yield negative index values. Rock and bare soil areas have similar reflectance's in the two bands and result in vegetation indices near zero.

Normalized Difference Water Index (NDWI)[6] used to delineate open-water features combining the green (Green) and NIR bands. It can be written as

$$NDWI = Green - NIR / Green + NIR \quad (4)$$

Normalized Difference Vegetation Index (NDVI) [7].NDVI is one of the most widely adopted vegetation indexes, according to the red radiation absorption and NIR reflectance of vegetation in the photosynthetic processes. NDVI is defined as the normalized ratio of the NIR band and red (Red) band.

$$NDVI = NIR - Red / NIR + Red \quad (5)$$

*D. Change Detection:*

Change detection using satellite data is an important application of remote sensing science[12]. The satellite image change detection is based on the time in which the image is acquired using the sensor. Two types of change detection are pixel based change detection and object based change detection. Pixel based change detection carried out by changes in pixel by pixel , where as object based change detection involves comparison of two or more scenes consisting of many same objects.[1] . In this paper the water Body extraction is carried out at pixel level[1]. Change Detection is the extraction of information using two different dates. This method involves subtracting images of same bands taken in different dates. If the two bands have the same spectral resolution and identical radiometric characteristics then there will be no change in the result.

$$Img_{m,n,b} = Img2_{m,n,b} - Img2_{m,n,b} + C \quad (6)$$

Here $Img_{m,n,b}$ is change in pixel value, $Img1_{m,n,b}$ is brightness value on first image, $Img2_{m,n,b}$ is brightness value on second image, m, n stands for number of rows and columns , C is the constant value here the value of C is 127. B is a single band.

The NDWI values of two images taken in different time or different sensor is compared by subtracting the two NDWI computed images in two dates.[9].

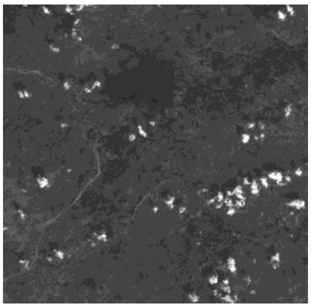
$$NDWI_{m,n} = NDWI_{m,n}(1) - NDWI_{m,n}(2) + C \quad (7)$$

Here m is number of columns, n is no of rows and C is constant.

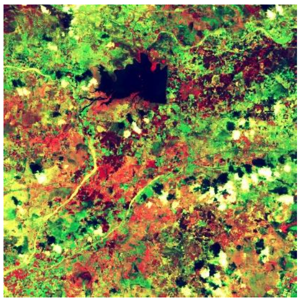
## IV. EXPERIMENTAL RESULTS AND DISCUSSION

Indian satellite Resource sat -2 LISS III imagery has been classified using various vegetation indexes such as NDWI, NDVI, LNDVI, CNDWI. NDWI has been widely used to
find the difference between images taken in different years of same period.

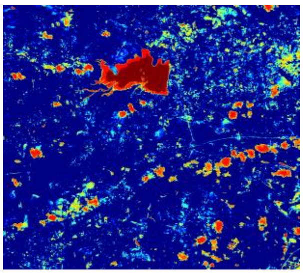
In this paper Fig.1 (a) represents the satellite image of covering Poondi lake alias Sathya Moorthy reservoir in Tiruvallur district of Tamil Nadu State that acts as the important water source for Chennai city which is 60 km away, and lies between longitude 79°42' to 79°54'36" and latitude 13°1'40.8" to 13°12'50.4". (b) represents the conversation of gray scale image to RGB image (c) represent the NDWI calculated image , (d) represent the NDVI calculated image, (e) represent the LNDVI calculated image, (f) represent the CNDWI calculated image.



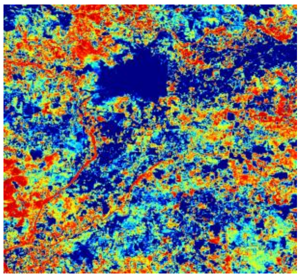
**(a)**



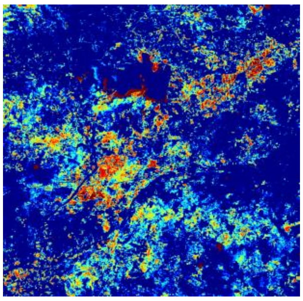
**(b)**



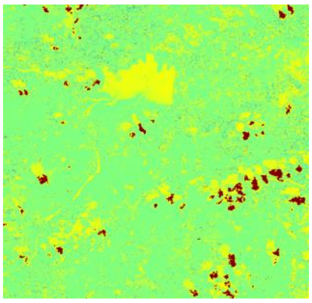
**( c )**



**(d)**



**(e)**



**(f)**

Fig 1: (a) original Tiff Image (b) RGB Image (c) NDWI Image (d) NDVI Image (e)LNDVI Image (f) CNDWI Image

TABLE II
Change Detection of Water bodies in Images taken in different years

| Year | Month | NDWI | | Difference |
|---|---|---|---|---|
| | | In Pixel | In KM$^2$ | |
| 2009 | Oct | 43232 | 38.91 | 9.38 |
| 2011 | Nov | 53659 | 48.29 | |
| 2012 | Mar | 71141 | 64.03 | 28.04 |
| 2013 | Mar | 39997 | 35.99 | |
| 2014 | Feb | 35496 | 31.95 | 56.63 |
| 2016 | Feb | 98423 | 88.58 | |

TABLE III
Classification of image using different Vegetation indexes

| Year &Month | Water bodies | | Vegetation | | Clouds | | Land Area | | Other areas | | Total area 1153 x1153 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | In Pixel | In KM$^2$ | In Pixel | In KM$^2$ | In Pixel | In KM$^2$ | In Pixel | In KM$^2$ | In Pixel | In KM$^2$ | In Pixel | In KM$^2$ |
| 2009 Oct | 43232 | 38.91 | 231871 | 208.68 | 25202 | 22.68 | 173680 | 156.31 | 855424 | 769.88 | 1329409 | 1196.47 |
| 2011 Nov | 53659 | 48.29 | 228091 | 205.28 | 25347 | 22.81 | 173575 | 156.21 | 848737 | 763.86 | 1329409 | 1196.47 |
| 2012 M ar | 71141 | 64.03 | 210026 | 189.02 | 26706 | 24.03 | 176022 | 158.41 | 845514 | 760.96 | 1329409 | 1196.47 |
| 2013 Mar | 39997 | 35.99 | 222977 | 200.67 | 19541 | 17.58 | 143825 | 129.44 | 903069 | 812.76 | 1329409 | 1196.47 |
| 2014 Feb | 35496 | 31.95 | 167271 | 150.54 | 33903 | 30.51 | 120931 | 108.83 | 971808 | 874.62 | 1329409 | 1196.47 |
| 2016 Feb | 98423 | 88.58 | 138322 | 124.48 | 27470 | 24.72 | 129371 | 116.43 | 924690 | 832.22 | 1324801 | 1192.32 |

In Table 2, The water bodies present in 2009 and 2011 varies by 9.38 KM$^2$ since the rain fall in October is 86mm and in 2011 November is 394 mm . Similarly for 2013 gets less rain fall than 2012. But in the year, 2016 February the level of water bodies in the satellite image is very high since the rainfall reached 995.6 mm in November and 419.3 mm in December in the year 2015. The Chennai district, Kancheepuram and Thiruvallur district get flooded due to heavy rain fall in November 2015.

In Table 3, The vegetation indices NDWI, NDVI, LNDVI, CNDWI are used to classify the images taken by LISS III sensor from the year 2009,2011,2012, 2013,2014 and 2016 . Using NDWI method water body pixels, by NDVI method vegetation pixels, by LNDVI method land area pixels and by CNDWI method cloud pixels are calculated. These pixels are converted to Kilometer square and compared with total area of the image.

CONCLUSION

In this paper an enhanced method is proposed for identification of water bodies in a Remote sensing image acquired by Resourcesat- 2 Liss III sensor in the period of 2009-2016. A set of vegetation indices NDWI, NDVI, LNDVI, CNDWI are used for pixel level extraction of water bodies, vegetation areas, Land area and clouds present in the image. The pixel change detection is used to predict the climate changes in that area for a certain periods.

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