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CAPABILITY OF NDVI TECHNIQUE IN DETECTING MANGROVE VEGETATION

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ABSTRACT

The Normalized Difference Vegetation Index (NDVI) is a numerical indicator that uses the visible red and near-infrared bands of the electromagnetic spectrum, and is adopted to analyze remote sensing techniques and assess whether the target being observed contains live green vegetation or not. Generally, healthy vegetation will absorb most of the visible red lights, and reflects a large portion of the near-infrared light. Contrary to this, unhealthy or sparse vegetation reflects more visible red light and less near-infrared light. If the difference is big then there has to be more vegetation. A part of Hugli estuary has been selected as a study area where mangrove vegetation is found in a large scale along with other vegetation due to high tidal activities. Normally, the reflectance value of mangrove vegetation in near-infrared band is more than the other types of vegetation. Hence, the main objective of this study is to distinguish mangrove vegetation from other vegetation by applying NDVI. After NDVI generation, overall accuracy has been computed which is 88.75% and 86.25% in 1989 and 2010 Landsat TM5 satellite images, and overall kappa statistics of 0.81% and 0.76% for both the images respectively for 80 sample points. It is examined that NDVI technique provides quite satisfactory result in distinguishing various types of vegetation coverage.

KEYWORDS: NDVI, mangrove, accuracy assessment, Landsat TM5, kappa statistics.

INTRODUCTION

Land use/land cover change is a very important natural and manmade phenomenon. For sustainable development this changes of land use/land cover has to be identified and observed continuously. Remote Sensing and GIS techniques are extremely effective in identifying these changes. Hugli estuary is considered as an ever-changing landform because of its dynamic nature due to tidal effects. Major part of this area has changed through erosional and depositional activities in very recent past. To get a feasible result regarding the major alteration in this area, Landsat TM5 data of 1989 and 2010 have been used. The main objective of this study is to classify two images and to apply Normalized Difference Vegetation Index technique to detect changes in mangrove vegetation and other vegetation. NDVI technique is a very suitable technique to detect the vegetation, to identify the difference between vegetation of two different types. Spatial and temporal differences of vegetated areas are well demarcated through this NDVI technique. This index values can range from -1.0 to 1.0, but vegetation values typically range between 0.1 and 0.7. Higher index values are associated with higher levels of healthy vegetation cover, whereas clouds and snow will cause index values near zero, making it appear that the vegetation is less green. For Landsat TM 5 data, band 3 (0.63-0.69 µm) and band 4 (0.76-0.90 µm) are required for generating NDVI.

NDVI can be used as an indicator of relative biomass and greenness (Boone *et al*., 2000). If sufficient ground data is available, the NDVI can be used to calculate and predict primary production, dominant species, and grazing impact and stocking rates (Ricotta *et al*., 1999, Oesterheld *et al*., 1998, Paruelo *et al*., 1997, Peters *et al*., 1997). It is also highly correlated with climatic variables, such as the El Niño Southern Oscillation (ENSO) (Li and Kafatos, 2000, Boone *et al*., 2000) and precipitation (Schmidt and Karnieli, 2000). Wang and Tenhunen (2004) applied NDVI in vegetation mapping along the North Eastern China Transect to differentiate various characteristic features of vegetation for different seasons. They applied supervised minimum distance classification and unsupervised "k-means" classification and both the methods achieved similar accuracy. Beck (2006) showed a completely new method to monitor the activity of vegetation in high altitude by using MODIS NDVI that estimate the NDVI of winter vegetation and applied double logistics function. Maselli (2004) of Italy tried to monitor the forest conditions in a protected Mediterranean coastal area by multilayer NDVI data analysis. He produced NDVI data series of coniferous and broad-leaved forests. Moreover, Kross (2011) examined the effect of the temporal resolution of NDVI data on season onset dates and trends across Canadian broadleaf forests. Thus, NDVI was one of the most successful of many attempts to simplify and quickly identify vegetated areas and their "condition," and it remains the most well-known and mostly used index to detect live green plant canopies in multi-spectral remote sensing data. Once the possibility to detect vegetation had been demonstrated, users tended to use the NDVI to quantify the photosynthetic capacity of plant canopies.

LOCATION OF THE STUDY AREA

A part of Hugli estuary has been considered as a study area. It covers an area of 4794.35 km^2 of Gangetic delta in West Bengal, India. Nayachara, Sagar, Balari and Ghoramara islands are some eminent islands in this area. This study area has extremely dynamic and complex landscape because of its tidal nature. The area extends from $87^0$55'01"N to $88^0$48'04"N latitude and $21^0$29'02"E to $22^0$09'00"E longitude, is a world-class example of mangrove vegetation. The inhabitants of this area are involved in mainly primary activities such as fishing, forestry and to some extent agriculture. The area is under the influence of subtropical monsoon climate. Most of the rainfall occurred in the rainy season (June to September) with an average of 150-200 cm. Some severe cyclonic storms like Nor'wester suddenly causing local depression due to nearness to sea are among the special features of weather phenomena of this region. The location map of the study area is given in Fig. 1. Topographically the study area is considered as a deltaic plain where the process of development is still going on. Large amount of river sediments are responsible for the expanded nature of this land. The nature of soil is mainly saline throughout the area due to tidal activities. This area is specially noted for the large accumulation of mangrove vegetation like *sundari, garan, hogla, golpata* etc. Recently it is seen that for many reason the nature of vegetation has changed.

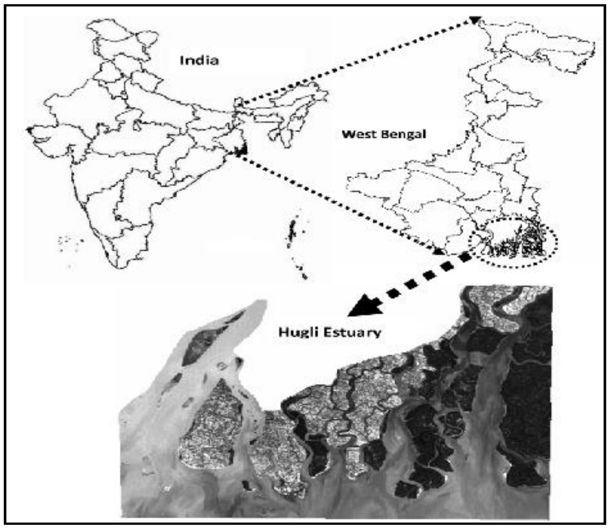

FIGURE 1: Study area along with Landsat TM5 Satellite Image

MATERIALS AND METHODS

For getting classified images with landuse/ landcover change the interval between the dates should be large. Hence, in order to fulfill this criteria two cloud free Landsat TM5 images of 19th January, 1989 and 21st January, 2010 have been selected. A description of the characteristic features of these satellite images is given in the following Table-1. Here, specific description with respect to minimum/maximum radiance and DN value is needed more for band-3 and band-4 of Landsat TM5 images to get an accurate result in generating normalized difference vegetation index.

TABLE 1: Characteristics of Landsat TM5 Satellite Images

Data Type	Acquisition Date	Path/Row	Sun Azimuth (°)	Sun Elevation (°)	Resolution (m)
LANDSAT TM5	19/1/1989	138/45	140.009792	36.905332	30
LANDSAT TM5	21/1/2010	138/45	143.935974	39.7974968	30
Minimum/Maximum Radiance and DN Value Table					
Date	Band No.	($L\max_a$)	($L\min_a$)	DN (Maximum)	DN (Minimum)
19/1/1989	Band 3	254	-1.17	255	0
19/1/1989	Band 4	221	-1.51	255	0
21/1/2010	Band 3	244	-1.17	255	0
21/1/2010	Band 4	221	-1.51	255	0

Pre-processing of images

Pre-processing of satellite images include geometric correction and radiometric calibration procedures to facilitate comparison between dates. The 1989 image was geometrically registered to 1:50,000 scale topographic maps; and 2010 image were geometrically registered to the 1989 base image. Root mean square errors of registration were maintained at 1 pixel (<30m) only. After getting the geometrically corrected image the radiometric calibration and image rectification processes are applied.

At the first stage, DN value is converted into spectral radiance (L_a) after checking the gain value using the official NASA approved ranges of $L\max_a$ and $L\min_a$ by the following formula:

$$L_{TOA} = (\frac{L\max_{\lambda} - L\min_{\lambda}}{QCAL\max - QCAL\min}) * (DN - QCAL\min) + L\min_{\lambda} \quad (1)$$

Where, $L\max_{\lambda}$ = maximum radiance (in $Wm^{-2}sr^{-1}\mu m^{-1}$); $L\min_{\lambda}$ = minimum radiance (in $Wm^{-2}sr^{-1}\mu m^{-1}$); $QCAL\max$ = maximum DN value possible (255); $QCAL\min$ = minimum DN value possible (0 or 1).

Radiance value is converted into reflectance using following equation:

$$\rho = \frac{L_{TOA} \pi d^2}{ESUN_{\lambda} \cos\theta_z} \quad (2)$$

Where, ρ = Reflectance; d^2 = Earth sun distance (AU); $ESUN_{\lambda}$ = Band dependent exoatmospheric irradiance $(Wm^{-2} \mu m^{-1})$; θ_z = Solar zenith angle (degree).

$$d = 1.001672 * \sin(\frac{2\pi (J - 93.5)}{356}) \quad (3)$$

Where, J = Julian day.

Different approaches are given in the literature for estimating emissivity from satellite imagery, viz.*Valor & Caselles, 1996* and *Van de Griend & Owe, 1993*. The NDVI Threshold method has been used to estimate the emissivity from the NDVI.

$$NDVI = \frac{\rho_{NIR} - \rho_{RED}}{\rho_{NIR} + \rho_{RED}} \quad (4)$$

Where ρ_{NIR} and ρ_{RED} are the spectral reflectance of near-infrared and red respectively in the LANDSAT TM5 satellite data (*Yongnian et al, 2010*)

Classification of the images

Threshold method is applied here for the delineation of different landuse categories. Density slicing or threshold signifies the division of the histogram in to two or more parts with each range or slice having a specific class like forest or no forest. The threshold value for Mangrove for the year 1989 ranges from 0.325 to 0.15 and for other forest, upper range value is 0.15 to -0.125 and other landuses exist outside these ranges. For 2010, mangrove forest threshold value is from 0.46 to 0.275 and for other forest it ranges from 0.275 to 0.025. After getting the classified images of two dates, accuracy of these images has been assessed through error matrix. On the basis of producer accuracy, user accuracy, overall accuracy and kappa statistics the whole process of accuracy assessment has been done.

Accuracy Assessment

Two types of accuracy are found in an error matrix – producer accuracy and user accuracy. Producer accuracy is related to omission errors and user accuracy is related to commission errors. The overall accuracy is calculated by dividing the total number of correctly classified pixels by the total number of reference pixels.

Kappa Coefficient

In the present study, Kappa coefficient has been applied for accuracy assessment, which is a discrete multivariate technique. Kappa analysis yields *Khat statistic* that indicates the measure of agreement of accuracy. The *Khat statistic* computed has been given below: -

$$Khat = \frac{N \sum_{i=1}^{r} X_{ii} - \sum_{i=1}^{r} (X_{i+} \times X_{+i})}{N^2 - \sum_{i=1}^{r} (X_{i+} \times X_{+i})} \quad (5)$$

Where, r = the number of rows in the error matrix; X_{ii} = the number of observations in row 'i' and column 'i' (on the major diagonal); X_{i+} = total of observations in row 'i' (shown as marginal total to right of the matrix); X_{+i} = total of observations in column 'i' (shown as marginal total at bottom of the matrix); N = the total number of observations included in matrix.

RESULTS & DISCUSSION

TABLE 2: Basic Statistics of NDVI

Landuse/ Land Cover Type	Minimum	Maximum	Mean	Median	Mode	Standard Deviation
Mangrove Forest (1989)	0.15	0.325	0.259	0.263	0.285	0.085
Other Forest (1989)	-0.125	0.15	0.080	0.075	0.009	0.070
Mangrove Forest (2010)	0.275	0.46	0.367	0.392	0.429	0.092
Other Forest (2010)	0.025	0.275	0.162	0.155	0.143	0.078
Entire Image (1989)	-0.491	0.325	-0.094	-0.001	-0.001	0.229
Entire Image (2010)	-0.481	0.46	-0.600	-0.002	-0.002	0.260

Table-2 shows the basic statistics of the NDVI map of 1989 and 2010. The minimum value of mangrove forest in 1989 and 2010 is 0.15 and 0.275 respectively. Maximum values are 0.325 and 0.46 for 1989 and 2010 respectively. If the standard deviation values are taken then the difference will be only 0.007 (0.085 for 1989 and 0.092 for 2010). The range of standard deviation values of other forest will be 0.008 (0.070 in 1989 and 0.078 in 2010). The minimum values of other forest in 1989 and 2010 are -0.125 and 0.025 while the maximum values are 0.15 and 0.275 respectively.

For accuracy assessment, a total of 80 sample points are randomly taken from each images covering different classes. The error or confusion matrices of 1989 and 2010 NDVI images have been given in Table-3 and Table-4 respectively. From the tables of error matrix the values of producer accuracy and user accuracy are obtained and on the basis of these values the values of overall accuracy and kappa coefficient have also been determined.

TABLE 3: Error Matrix (1989)

Class Name	Reference Total	Classified Total	Number of Correct Points	Producer Accuracy (%)	Omission Error (%)	User Accuracy (%)	Commission Error (%)
Mangrove Forest	18	16	14	77.78	22.22	87.50	12.50
Other Forest	13	12	11	84.62	15.38	91.67	8.33
Others	49	52	46	93.88	6.12	88.47	11.53
Total	80	80	71	-	-	-	-

Table-3 includes the confusion matrices for the NDVI based land cover map for the year 1989. It reveals that producer accuracy and user accuracy are 77.78% and 87.50% for mangrove forest respectively while for other forests producer and user accuracies are 84.62% and 91.67%. These producers and users accuracies are 93.88% and 88.47% respectively for other land covers. If we observe the error matrix then we will see that out of 80 sample points 71 are correctly classified. It indicates a very good result.

TABLE 4: Error Matrix (2010)

Class Name	Reference Total	Classified Total	Number of Correct Points	Producer Accuracy (%)	Omission Error (%)	User Accuracy (%)	Commission Error (%)
Mangrove Forest	18	17	13	72.22	27.78	76.47	23.53
Other Forest	12	12	10	83.33	16.67	83.33	16.67
Others	50	51	46	92.00	8.00	90.20	9.80
Total	80	80	69	-	-	-	-

Table-4 includes the error matrices for 2010 NDVI classified image. It indicates the range of producer and user accuracy, which is from 72.22% to 92.00% and 76.47% to 90.20% respectively. Moreover, producers and users both types of accuracies are equal (83.33%) for other forests classification. In 2010 NDVI classified image 69 points are correctly classified out of 80 points which also depicts a good result.

TABLE 5: Comparison of Kappa Statistics for Mangrove and Other Forest (1989 & 2010)

Year	Individual Kappa Statistics			Overall kappa Statistics and Accuracy	
	Mangrove Forest	Other Forest	Others	Overall kappa Statistics	Overall Accuracy (%)
1989	0.88	0.84	0.76	0.81	88.75
2010	0.77	0.80	0.74	0.76	86.25

In Table-5, values of individual kappa statistics, overall kappa statistics and overall accuracy are given. Overall kappa statistics and overall accuracy is 0.81 and 88.75%. Individual kappa statistics of mangrove forest and other forest are 0.88 and 0.84 respectively. If these values are compared with 2010 accuracy value then it can be observed that the overall kappa statistics and overall accuracy is 0.76 and 86.25%. Individual kappa statistics of mangrove forest and other forests are 0.77 and 0.80 respectively. These values of overall kappa statistics and overall accuracy reflect a very accurate result.

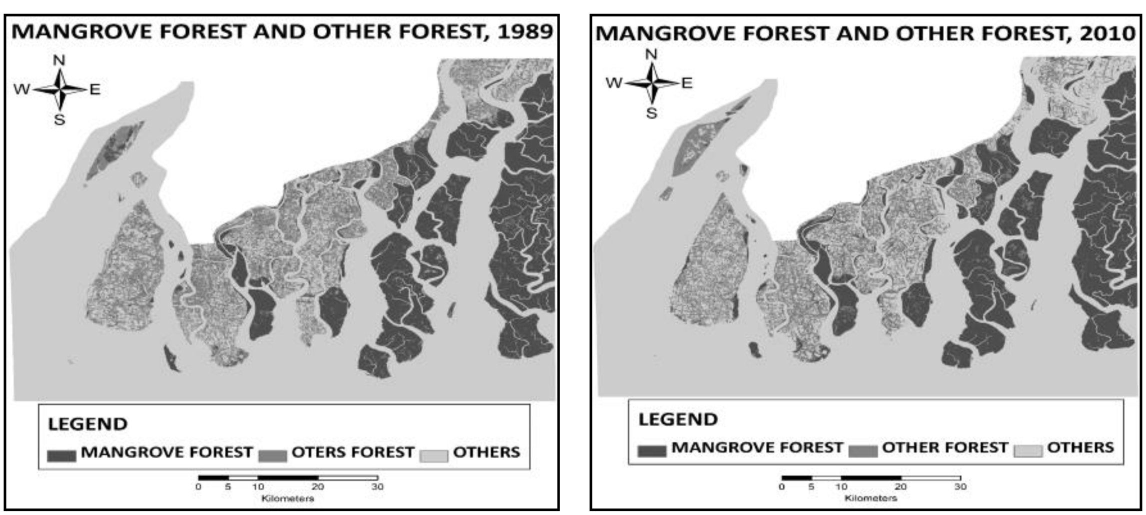

FIGURE 2: NDVI (1989 & 2010 image) showing the area of mangrove forest and other forest

TABLE 6: Area Statistics of Land use/Land Cover

Year	Mangrove Forest (km^2)	Mangrove Forest (%)	Other Forest (km^2)	Other Forest (%)	Others (km^2)	Others (%)
1989	968.76	20.11	620.71	12.88	3228.51	67.01
2010	993.40	20.62	514.32	10.67	3310.26	68.71
Difference	24.64	0.51	-106.39	-2.21	81.75	1.70

Table-6 vividly reflects the statistics of land use/land cover of the study area. Area under mangrove forest has been increased from 968.76 km^2 in 1989 to 993.40 km^2 in 2010. If we consider about other forests, then it will be reduced from 620.71 km^2 to 514.32 km^2**.** 0.51% area under mangrove forest has been added from 1989 to 2010 image whereas 2.21% area under other forest has been reduced in this time span (Fig. 2).

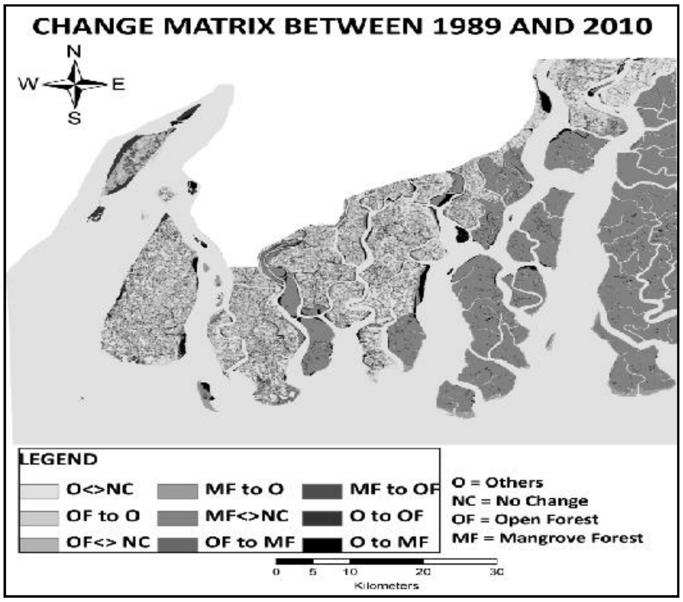

FIGURE 3: Change Matrix showing the area of Landuse/Land Cover Change in the Study Area

TABLE 7: Area Statistics of Land use/Land Cover Change

1989	2010	Area (Km^2)	1989	2010	Area (Km^2)
Other land class	Other land class	3009.513	Other Forest	Mangrove Forest	50.7285
Other Forest	Other land class	236.2221	Mangrove Forest	Other Forest	49.8366
Other Forest	Other Forest	334.143	Other land class	Other Forest	130.6665
Mangrove Forest	Other land class	64.3509	Other land class	Mangrove Forest	88.1397
Mangrove Forest	Mangrove Forest	854.3799			

Table-7 indicates the changing scenario of land use/land cover in the last two decades (1989 – 2010). 49.84 km^2 area of mangrove forest is converted into other forest while 50.73 km^2 areas have been converted from other forest to mangrove. Conversion of area from mangrove forest to other land is 64.3509 km^2 and 88.1397 km^2 vice-versa. Besides, 130.6665 km^2 areas under other land has also been converted into other than mangrove forest while the vice-versa conversion has been taken place in 236.2221 km^2 area (Fig.3). This type of conversion indicates that erosion and deposition have taken place simultaneously in this study area. This area signifies a newly built area, which is characterized by constant deposition and erosional activities are operating in natural way. Tidal impact is deeply significant in this region.

CONCLUSION

In this paper, emphasis is given over the NDVI technique, which has been applied to classify satellite images. Basically, through NDVI technique mangrove vegetation can easily be differentiated from other forest due to its different reflectance value. Landsat TM5 satellite images of 1989 and 2010 have been applied to assess the decadal landuse/ land cover changes in the study area. 80 sample points are taken for accuracy assessment. With an overall accuracy of 88.75% for 1989 image and 86.25% for 2010 images, and overall kappa coefficient of 0.81 and 0.76, it can be concluded that this technique is quite appropriate. Evaluation of basic statistics of NDVI also supports this result (Table-2). From Table-7, it is clear that both types of land conversion (mangrove to other forest and other forest to mangrove forest) have taken place simultaneously without affecting the basic nature of the study area. It is also evident that accumulation of mangrove forest is mainly confined in the eastern parts of the study area whereas other forests are seen in the western delta and mainland region. This is mainly due to less human interference in the eastern portion of Hugli estuary.

Finally, it can be said that the entire study area is a land of constant erosional and depositional activities where tidal vegetation are trying to endure with their full characteristics. One can examine the accuracy level of other vegetation indices in the same study area. Moreover, the effectiveness of NDVI technique may also be evaluated for different types of vegetation characteristics.

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