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Forest Cover Changes and Distribution Pattern in the Sundarban Mangrove: Observation from MODIS Data

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Abstract

The Normalized Difference Vegetation Index (NDVI), an established remote sensing technique, is widely used as a surrogate to observe vegetation coverage in an area. Spatial and temporal changes in the vegetation coverage of the Sundarban mangrove forest for the period from 2001 to 2015 were observed and analysed using NDVI derived from MODIS (Moderate Resolution Imaging Spectroradiometer) data. Individual daily MODIS Level 1B band 1 and 2 image data, which has higher spatial and temporal resolution and lower spectral resolution at red and near-infrared spectral region, were processed and manipulated to convert reflectance products and NDVI values were derived from these reflectance products. Analysis of colour graded NDVI density maps, derived from the NDVI values, revealed that in 2001, the western and eastern parts of this forest had relatively higher vegetation growth compared to the central part. Though the eastern part was severely damaged due to the cyclone 'Sidr' in 15 November 2007, the NDVI map revealed that in 2015, the eastern part experienced more forest regrowth compared to other parts. The damage by the 'Sidr' was inferred in the vegetation coverage map of 2008, which indicated lower NDVI compared to the central and the western parts. Analysis of pixel data from the NDVI maps indicated that in January 2001 and 2008, relatively higher density NDVI (> 0.4) covered 66% and 53% of this forest, respectively. On the other hand, in January 2015, higher density NDVI was extended over 77% of the forest area. The image to image subtraction technique was applied to quantify temporal changes in NDVI density. The temporal changes indicated that over the last 14 years between 2001and 2015, the Sundarban mangrove experienced regrowth in the eastern part, which is in Bangladesh and deforestation in the western part, which is mostly in India and partly in Bangladesh. As a whole, 55% of the total Sundarban area experienced forest regrowth and 45% experienced deforestation over the period between 2001 and 2015.

Keywords: Sundarban mangrove forest, vegetation cover, MODIS, NDVI, forest regrowth and deforestation.

Introduction

The Sundarban mangrove, a World Heritage declared by UNESCO in 1997, is the world's largest contiguous mangrove forest located at the delta of the Ganges,

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Brahmaputra and Meghna river systems on the Bay of Bengal (Fig. 1) with total area of 10,200 km[2] (DUTTA *et al.* 2014). Roughly 62% of this forest extended over in Bangladesh and the remaining 38% is extended over in India (RANJAN *et al.* 2017). This forest is intersected by a complex network of tidal channels, mud flats, grass lands and dense mangrove forests.

Due to anthropogenic influences over several decades, different climatic variables are changing at an alarming rate (Intergovernmental Panel on Climate Change (IPCC) 5th Assessment Report (AR5) http://www.ipcc.ch). According to DANDA *et al.* (2011), the sea surface air temperature over the Bay of Bengal and sea level are rising at an alarming rate. It is triggering high intensity and frequency of cyclonic activities and salinity in the soil and water which damages vegetation in the Sundarban. GIRI *et al.* (2014) concluded that fresh sediment discharges by the upland rivers (the Ganges and its distributaries) and tidal channels help forest regrowth in Indian part of Sundarban. ISLAM *et al.* (1999) estimated that every year the Ganges and the Brahmaputra Rivers in Bangladesh discharge about 1000 million tons of suspended sediments. Half of these sediments pass through the Meghna estuary to the coastal sea off the Ganges-Brahmaputra delta. The eastern part of the Sundarban directly receives freshwater and suspended sediments through several distributaries (e.g. Balaswar, Bishkhali and Payr rivers) of the Meghna estuary (ISLAM *et al.* 2012).

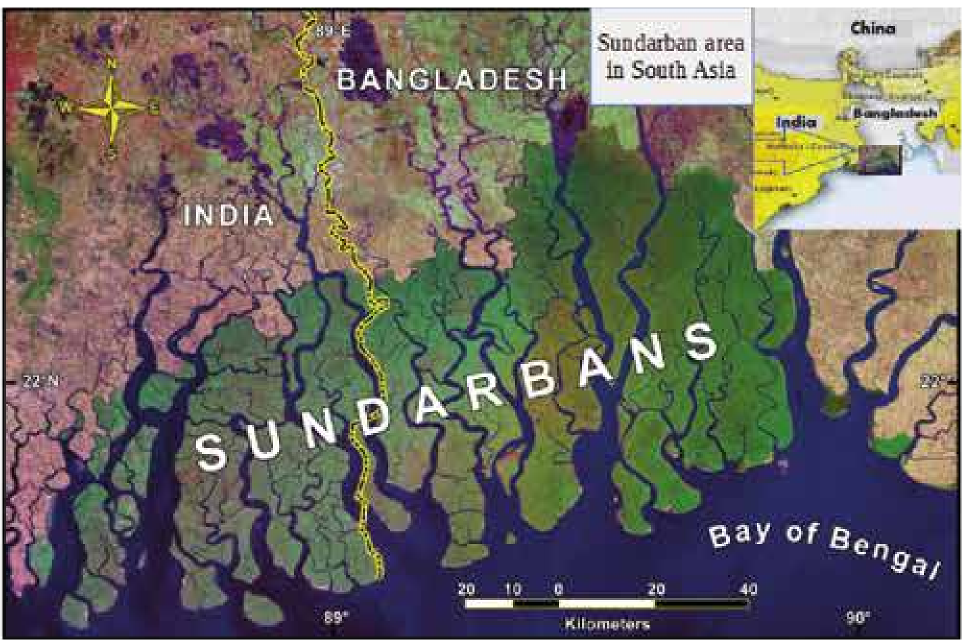

Fig. 1: Location map of the Sundarban Mangrove Forest.

Distribution of natural forest in Bangladesh is primarily a function of the climate and soil types (KAMALUDDIN and SHAMSUDDIN 1977). Climate change poses significant risks for Bangladesh, yet the core elements of its vulnerability are primarily contextual. Particularly, the coastal mangrove – the Sundarban – was identified as vulnerable to climate change (AGRAWALA *et al.* 2003). As in the other regions of the world (LI and KAFATOS 2000; ICHII 2002) observed that climate change has significant impact on forest area. Satellite remote sensing data and technology is an important tool because of its ability to provide timely and synoptic view of the study area. It has emerged as a powerful tool for mapping and quantifying mangrove forest cover (BLASCO *et al.* 1998). The multidate satellite data of similar resolution could be used effectively to find out the change in the areal extent and coverage, and vegetation health and biomass of mangroves (KRISHNAMOORTHY 1997; BEGUM *et al.* 2009). In recent years, several research works were carried out to study the Sundarban mangrove forest using MODIS images (e.g., SHIBLY and TAKEWAKA 2013; DUTTA *et al.* 2014). SHIBLY and TAKEWAKA (2013) used MODIS NDVI composite images to analyze the long-term variation in NDVI in the Sundarban mangrove forest in Bangladesh. DUTTA *et.al.* (2014) generated MODIS global disturbance index (MGDI) from MODIS time-series data for the assessment of the ecological disturbance in the mangrove ecosystem caused by three major cyclones developed over Bay of Bengal during last decade.

NDVI extracted from satellite images is widely used as an indicator for the measurement of biomass and vegetation coverage (CAMPBELL 1996). The higher the NDVI value, the higher the probability that the corresponding area on the ground has denser coverage of healthy green vegetation (i.e., higher NDVI values indicate higher vegetation canopy density) (JENSEN *et al.* 1991). Knowledge on the density of vegetation coverage and its changes over the period of time can decipher understanding of the impact of climate change and anthropogenic influences in the forest area. This type of study demanded great importance for better management and better planning for the Sundarban mangrove forest. Because mangrove ecosystems of this forest is highly susceptible to cumulative impact of climate change (AGRAWALA *et al.* 2003) and anthropogenic intervention (GUPTA and SHAW 2013).

Recent findings suggest that mangroves annually sequester two to four times more carbon compared to mature tropical forests, and store three to four times more carbon per equivalent area than tropic forests (MURDIVARSO *et al.* 2015). The Sundarban mangrove ecosystem also plays an important role by acting as bio-shield against storm surges by reducing the vulnerability to extreme climatic events like cyclones. The aim of this research work was (i) to explore the extraction technique of NDVI from Level 1B MODIS data of higher spatial and temporal resolution and lower spectral resolution, (ii) to measure the changes in vegetation density of the Sundarban Mangrove forest over decadal time scale and (iii) to study the whole Sundarban forest (in Bangladesh and India) captured in a single frame of image.

Data and Methodology

Satellite remote sensing data in mangrove forest study

Satellite imageries from numerous sensors such as ASTER (Advanced Space borne Thermal Emission and Reflection Radiometer), Landsat TM (Thematic Mapper) and ETM+ (Enhanced Thematic Mapper), AVHRR (Advanced Very High-Resolution Radiometer), MODIS (Moderate Resolution Imaging Spectroradiometer) have been employed for coastal and mangrove study applications. Spatial resolutions of ASTER and Landsat TM and ETM+ in optical bands (visible wave lengths) are 15m and 30m respectively. But temporal resolution of these images is 16 days. Due to relatively small swaths, any single frame of one of these images cannot cover the whole of the Sundarban. To cover the whole of the Sundarban, images of different frames are, therefore, needed to merge together. It influences the variation of reflectance due to satellite sensor calibration, changes in illumination and observation angle, atmospheric effects and difference in target reflectance over time which further affects NDVI (Du *et al.* 2002). The Terra MODIS may be a viable option with 1-2 days repeat cycle and spatial resolutions of 250 m for bands 1 and 2. One single frame of image can cover the whole of the Sundarban and make them likely to be useful for forest studies.

Acquisitions of MODIS Level 1B Data

Moderate Resolution Imaging Spectroradiometer (MODIS) is one of a number of instruments carried on board the Terra satellite platform, which was launched in December 1999. MODIS Level 1B data is still considered to be instrument data (Shao *et al.* 2009). These products do not directly contain images. Rather, they contain the calibrated data used for the construction of images. Individual daily MODIS scenes, Level 1B products, are not like composite images of Level 3 Vegetation index product (https://modis.gsfc.nasa.gov/data/dataprod/index.php) in terms of processing level and spatial and temporal resolution. Level 1B data can be obtained for any part of the earth, every day, since February 2000 (Level 1B Product User Guide 2009). Out of 36 spectral bands in MODIS image data, first two solar reflective bands (Bands 1 and 2) have relatively higher spatial resolution (250 m) and lower spectral resolution in the Red and Near-IR parts of the spectrum. These Level 1B data sets are stored as data granules in Hierarchal Data Format (HDF) known as MOD02QKM files. These files contain radiometrically calibrated 250 m band 1 and 2 geocoded image data, uncertainty index, metadata and geolocation data in one file.

MODIS data were readily available from the LAADS (Level 1B and Atmosphere Archive and Distribution System) website (https://ladsweb.nascom.nasa.gov/data/-search.html) which belongs to Goddard Space Flight Center, NASA. For this study, three MODIS Level 1B Bands 1 and 2 data sets captured on 27 January 2001, 24 January 2008 and 29 January 2015 were acquired from the archive. After careful examination of data quality, those three images were chosen from numerous MODIS images in the archive. All of these images were captured in the month of January, because during this month the sky usually remains clearer over this area. Moreover, January represents the season after the autumn and marks the beginning of the dry season. During the monsoon and autumn period, the Sundarban and its surrounding area experienced huge seasonal growth. To minimize this seasonal impact on the results obtained from this study, the month of January was selected. A time gap of several years between successive image capturing dates were selected so that inter- annual change in vegetation coverage and growth could be identified more confidently.

After downloading the MOD02QKM files, those data were processed and manipulated by ERDAS IMAGINE (Version 2015). As the full frame images are very big, the images over the Sundarban were extracted after subsetting the full frame images. Although the original expected geolocation accuracy of these images was 150 m, nowadays after several updates (use of parametric and nonparametric methods to eliminate bias and other sources of error) the accuracy of higher level products is 50 m. According to the MODIS web sources it could even be around 40 m. All image processing and pre-processing techniques including layer stacking of individual band in single image file, creation of False Colour Composite (FCC) image, extraction of the study area, calculation of reflectance and extraction of NDVI, creation of NDVI colour graded maps and acquiring of statistical values were done by ERDAS IMAGINE 2015 version.

Extractions of Reflectance Products from Image Data

The Level 1B data for the Reflective Solar bands (RSBs) are distributed as digital signals in 16-bit unsigned integer format. These data should be converted to radiance values, surface reflectance values, and/or brightness/temperature values before performing any analysis. Reflectance can be extracted using a pair of parameters called reflectance _scales and reflectance offset. These were derived from the calibration parameters that are input to Level 1B as look up tables and written as attributes to the reflective band Science Data Set (SDS). The reflectance product was calculated according to MODIS Level 1B Product User Guide (2009).

$$\rho \cos(\Theta)_{B,T,FS} = \text{reflectance\_scales}_B\,(SI_{B,T,FS} - \text{reflectance\_offsets}_B) \quad \text{Equation 1}$$

Where,

$\rho \cos(\Theta)$ is stands for the Earth View reflectance product, relative to the reflectance of a Lambertian reflecting surface,

ρ stands for the Bidirectional Reflectance factor of the Earth,

$\cos(\Theta)$stands for the cosine of the Solar incidence angle on the Earth View scene.

These data are written in 3-dimensional science data sets (SDSs) indexed by Band (B), Track (T) and Frame and Sample (FS), where Band is the least rapidly varying index and Frame and Sample is the most rapidly varying index. The scale and offset parameters are only band dependent (MODIS Level 1B Product User Guide 2009).

Extraction and mapping of NDVI

In this study, three NDVI maps were derived from the images captured on 27 January 2001, 24 January 2008 and 29 January 2015. There are several algorithms developed to calculate NDVI. Among them, the algorithm (Equation 2) developed by Tucker (1979) is widely used and was applied in this study.

$$NDVI = (NIR-RED)/(NIR+RED) \quad \text{Equation 2}$$

Where,

NIR stands for reflectance in Near Infra-Red band,

RED stands for reflectance in visible Red band.

In MODIS band 1 image data (wave length 620 to 670 nm) corresponds to the visible red band (RED) and band 2 (841 to 876 nm) corresponds to the near infra-red band (NIR). At first, band 1 and 2 Level 1B image data were converted to band 1 and 2 reflectance images following the procedure as shown in Equation 1. Those reflectance data were then converted to NDVI data for the respective dates by using equation 2.

The resultant NDVI maps contain dense mangrove, non-mangrove vegetated surface, water bodies, flood plains and barren land. It can be seen from the mathematical definition of the NDVI that an area containing a dense vegetation canopy will tend to have positive values (usually 0.3 to 0.8), while water bodies (including rivers, channels, water logged areas, ponds) and bare land have slightly negative to very low positive NDVI values (DONGLIAN *et al.* 2011). To minimize these influences, the NDVI values of these features were segregated from the lower end NDVI data. NDVI value of 0.1 was adopted as a threshold value after judging the distribution pattern of data histogram. After the segregation, three new NDVI density maps (Figs. 2a, 2b & 2c) were derived for 27 January 2001, 24 January 2008 and 29 January 2015 respectively.

Results and Discussion

Spatial variation of NDVI Density

Figs. 2a to 2c stand for colour graded NDVI density maps which represent the spatial distribution of NDVI values throughout the Sundarban at different years. These maps revealed that vegetation distribution was not smooth and contained patches as variation of NDVI value in different parts of the Sundarban observed over time. From Figs. 2a and 2b, it was found that NDVI ranged from 0.1 to 0.6. These NDVI values were relatively lower than the values of NDVI for 2015 (Fig. 2c). A small portion of the forest attained NDVI up to 0.7 in 29 January 2015.

Analysis of all the three NDVI density maps (Figs. 2a to 2c) revealed that in most cases, NDVI value ranged from 0.4 to 0.5. The quantitative analysis of NDVI values of the year 2001, 2008 and 2015 were presented in Table 1. It was inferred that between the years 2001 to 2015, only 4 to 5% area of the Sundarban had low vegetation coverage as in these area NDVI ranged from 0.1 to 0.2.

The areal distribution of dense mangrove (where NDVI is 0.4 or higher) was 65.75% in 2001. However, this significantly decreased to 53% in 2008 and again increased to 76.61% in 2015. This distribution pattern indicated that overall densely vegetated mangrove forest distribution increased by 10.26% in the last 14 years (from 2001 to 2015) whereas between 2001 and 2008, dense mangrove canopy coverage decreased by 12.75%. The decrease in distribution of dense mangrove in 2008 could be attributed to the effect of the cyclone 'Sidr' which hit the eastern part of the Sundarban in 15 November 2007. BHOWMIK and CABRAL (2013) mentioned that 22% of the total Sundarban was affected due to this cyclone.

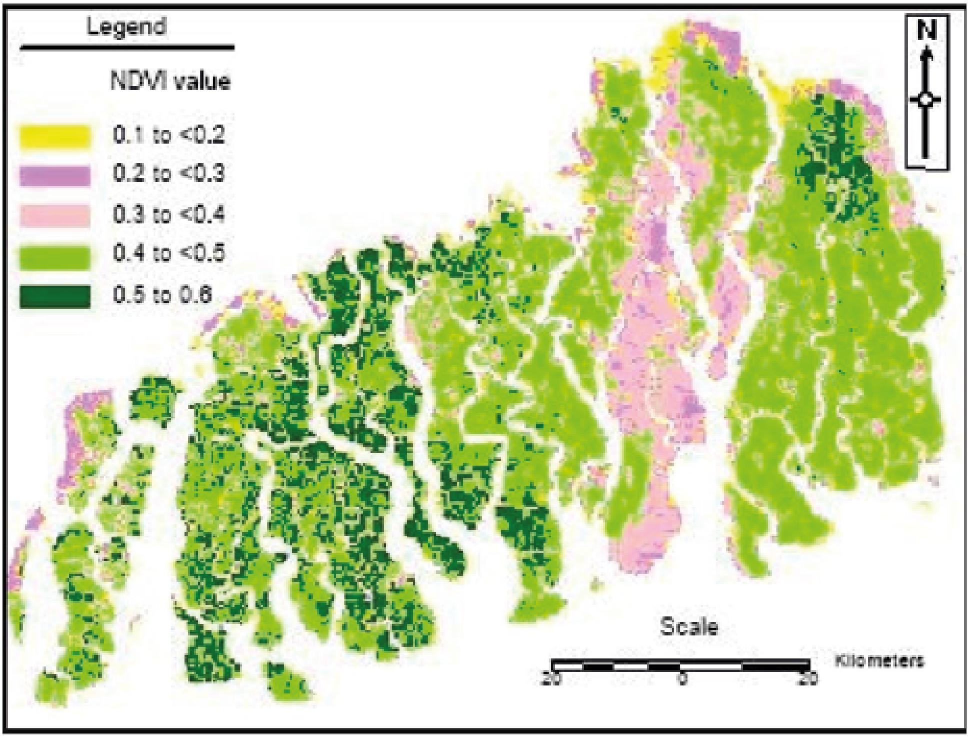

Fig. 2a: NDVI density map of the Sundarban mangrove forest derived from MODIS data captured on 27 January 2001. The colour coded scale indicates range of variations in NDVI through out the forest area.

Table 1: Comparison of NDVI values of the Sundarban Mangrove forest area on three different dates.

NDVI class	Area (%) 27.01.2001	Area (%) 24.01.2008	Area (%) 29.01.2015
0.1 to < 0.2	5.00	4.80	4.30
0.2 to < 0.3	8.20	8.60	6.60
0.3 to < 0.4	21.00	33.60	12.40
0.4 to < 0.5	52.00	52.40	61.80
0.5 to < 0.6	13.80	0.60	14.80
0.6 to 0.7			0.10

Fig. 2a revealed that in 2001 NDVI was relatively higher (0.4 to 0.6) in the western part of the forest. Geographically, this area corresponds to the Indian part and the western part of the Sundarban forest in Bangladesh (Fig. 1). Though the distribution pattern was not smooth, it was observed that a south-west to north-east elongated shaped patch of forest in Bangladesh has lower NDVI (dominantly varies from 0.2 to 0.3).

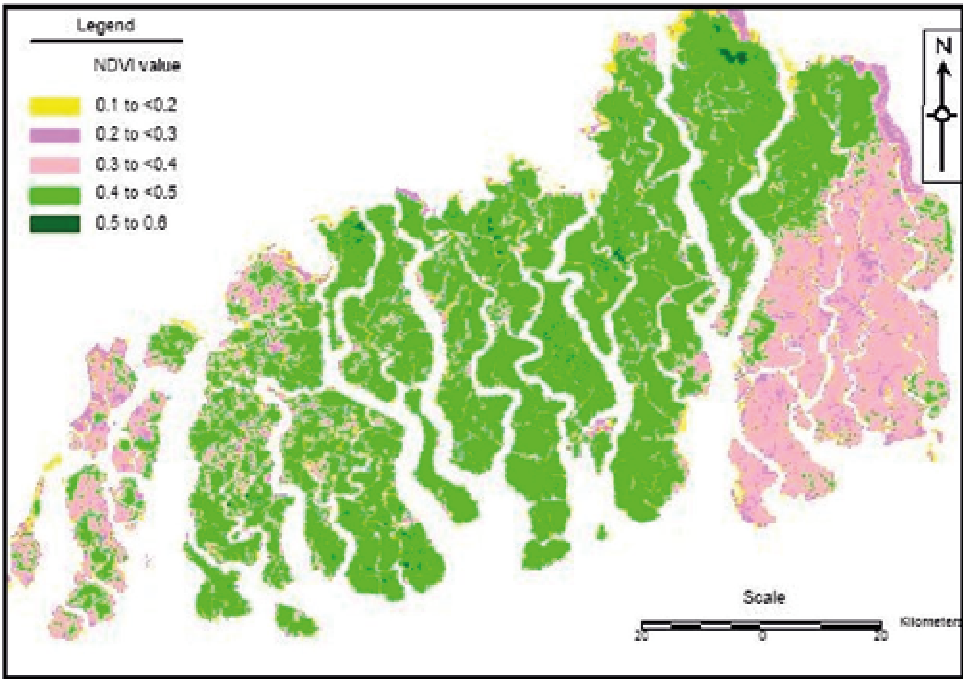

Fig. 2b: NDVI density map of the Sundarban mangrove derived from MODIS data captured on 24 January 2008. The colour coded scale indicates range of variations in NDVI throughout the forest area.

The distribution pattern of vegetation canopy and variation in quantity in January 24, 2008 was depicted in Fig. 2b. From this figure, it was inferred that the pattern of distribution of NDVI was shifted. Higher vegetation canopy (usually NDVI is 0.4 or above) can be found in the central part of the Sundarban. The western part did not show a smooth pattern in distribution. Around this region NDVI predominantly ranges from 0.3 to 0.4. However, significant changes in distribution pattern, both quantitative and qualitative, were revealed in the eastern part. Here NDVI predominantly ranges from 0.2 to 0.3. As already mentioned, this image was captured around two months after the cyclone 'Sidr' which hit the eastern part of the Sundarban in Bangladesh on 15 November 2007. Its impact on vegetation canopy was clearly inferred from the magnitude and distribution pattern of NDVI (Fig. 2b).

After Seven years of cyclone 'Sidr', an opposite scenario was inferred from the quantity and distribution pattern on the NDVI density map of 29 January 2015 (Fig. 2c); relatively higher NDVI (dominantly ranges from 0.4 to 0.6) was observed in the eastern part compared to the western and central part of the Sundarban. Particularly, the region which was mostly affected by the cyclone 'Sidr' in 2007 had higher vegetation density in 2015. Analysis of these results indicated, as a whole, in the period between 2001 and 2015, the pattern of vegetation canopy distribution was shifted over the time and the eastern part of the Sundarban in Bangladesh experienced more

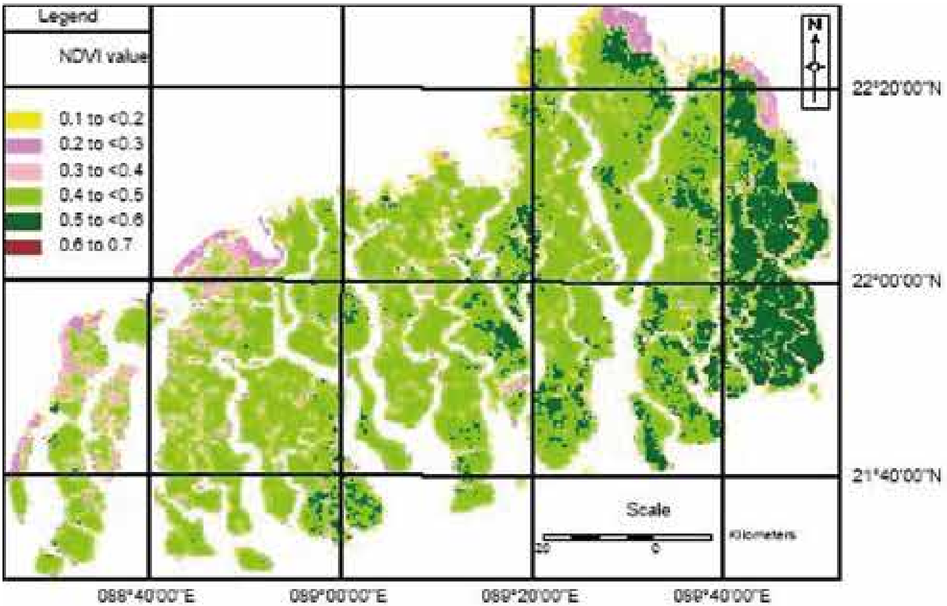

Fig. 2c: NDVI map of the Sundarban mangrove derived from MODIS data captured on 29 January 2015. The colour coded scale indicates range of variations in NDVI throughout the forest area.

forest regrowth compared to the western part in India. However, the central part did not reveal any significant dynamics in the changes of distribution pattern of vegetation canopy over the decades.

Change detection in NDVI Density

To quantify the change detection over the decadal time scale and to prepare a colour coded change detection map (Fig. 3), the NDVI map of 2001 (Fig. 2a) was subtracted from that of 2015 (Fig. 2c) as both satellite images had the same spatial (250 m) and spectral resolutions in red and infra-red bands and both of these two images were captured in the last week of January (27 January and 29 January, respectively). Fig. 3 indicated the resultant changes in NDVI over the period between 2001 and 2015. The changes accompanied by green part (i.e., positive) indicated increment in NDVI and hence increment in vegetation canopy, and by yellow part (i.e., negative) indicated decrease in NDVI and hence decrease in vegetation canopy. Positive and negative NDVI indicated forest regrowth and deforestation respectively. From Fig. 3, it was found that most of the eastern part of the Sundarban, except for a few patches, experienced forest regrowth and the western part of the forest area experienced deforestation. Analysis of data histogram indicated that, 55% of the total Sundarban area experienced forest regrowth and 45% experienced deforestation over the period between 2001 and 2015. It was seen that difference in NDVI values increased up to 0.5 and decreased up to -0.5. However, increases or decreases in NDVI value did not occur in the same magnitude throughout the Sundarban.

BEGUM *et al.* (2009) analyzed high-resolution ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) and Landsat TM data over the Sundarban mangrove forest in Bangladesh and reached in the similar conclusion. GIRI *et al.* (2014) also mentioned that, as a whole, the Sundarban mangrove has been experiencing forest regrowth. Though RANJAN *et al.* (2017) observed that Indian part of the Sundarban mangroves were diminished at the rate of 0.37% which is 9.84 km^2 due to various climatic and anthropogenic factors, it also experienced increased in mangrove productivity over this period. Their observation was based on the study of Landsat TM and ETM+ data from 1990 to 2016 of equal intervals of ten years.

SHIBLY and TAKEWAKA (2013) analysed AVHRR (Advanced Very High Resolution Radiometer) GIMMS (Global Inventory Modeling and Mapping Studies) and MODIS NDVI (Normalized Difference Vegetation Index) data (composite) sets for the period 1985-2006 and 2005-2010 respectively to monitor the long term variation of NDVI for the segments covered with mangroves in Bangladesh part. They concluded that NDVI variation of the Sundarban near shore showed that NDVI had decreasing trends in the period of 1995-2000 and 2005-2010 and increasing from 2000-2005.

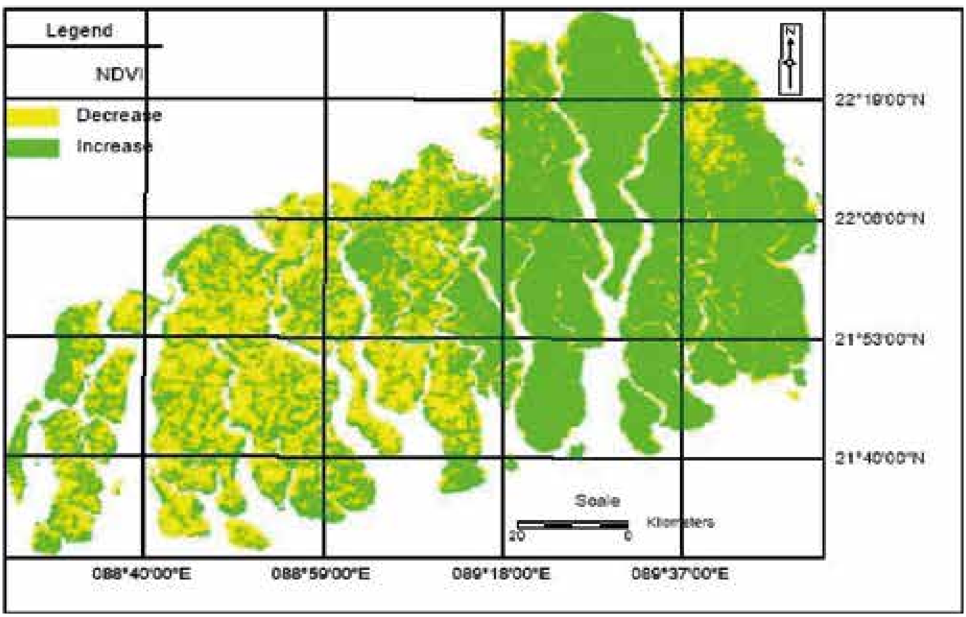

Fig. 3: NDVI density change detection map of the Sundarban for the period between 27 January 2001and 29 January 2015. The colour 'green' indicates the areas experienced with forest regrowth and colour 'yellow' indicates the areas suffered with deforestation.

It is noteworthy that the Sundarban Mangrove is not the only forest which was experiencing forest regrowth over time. KAWABATA *et al.* (2001) concluded that the global mapping of NDVI trend revealed a general increase in NDVI in the northern mid and high latitude areas and equatorial regions, a decrease in the semiarid regions of the Southern Hemisphere. The Sundarban mangrove forest falls within the equatorial region. Analysis of satellite-based time-series data for 30 years by ICHII *et al.* (2013) indicated that increase in NDVI were dominant in the sub-continental regions of Siberia, East Asia, and India.

Conclusions

To observe the spatial and temporal changes and distribution pattern in the vegetation coverage of the Sundarban mangrove forest over the decadal time scale, NDVI density maps were derived from individual daily MODIS Level 1B band 1 and 2 imageries captured on 27 January 2001, 24 January 2008 and 29 January 2015. The data have higher spatial and temporal resolution and lower spectral resolution at red and near-infrared spectral region and can cover the whole of the Sundarban within one single frame of image which make useful for forest studies. All image processing and pre-processing techniques including layer stacking of individual band in single image file, creation of False Colour Composite (FCC) image, extraction of the study area, calculation of reflectance and extraction of NDVI, creation of NDVI colour graded maps, acquiring of statistical values and image to image subtraction modelling were done by ERDAS IMAGINE version 2015.

Analysis of the NDVI density maps revealed that in 2001, the western part of this forest had relatively higher vegetation coverage compared to the eastern and central parts. On the other hand, in 2015 the eastern proximity of this forest in Bangladesh experienced more forest regrowth than the other parts. However, the central part did not show any significant variation over the decades.

Analysis also revealed that in 2008, relatively lower NDVI values (i.e., lower vegetation coverage) were mostly concentrated in the eastern part of the forest, which corresponds to the area affected by cyclone ‘Sidr’ on 15 November 2007. However, relatively higher NDVI was inferred in the eastern part of the forest in 2015. That means the region, which was affected most by the cyclone ‘Sidr’ in 15 November 2007, had lower vegetation density in 2008 but higher in 2015. The discrepancy depicted both in the NDVI magnitude and the distribution pattern of the vegetation density could be attributed to the effect of the cyclone ‘Sidr’.

The comparison between the index values depicted in NDVI maps revealed that, compare to the NDVI scenario of 2001, overall densely vegetated mangrove forest coverage (where NDVI value > 0.4) was decreased by 12.75% in the year 2008. Whereas, a net increase in dense vegetation coverage by 10.26% was inferred in 2015 for the period of 14 years when the NDVI maps of 2001 are compared with that of 2015.

The image to image subtraction technique was applied to quantify the temporal changes in NDVI over the decade. It was found that, most of the eastern part of the Sundarban mangrove experienced regrowth and the western part experienced deforestation. As a whole, 55% of the total Sundarban area experienced forest regrowth and 45% experienced deforestation over the period between 2001 and 2015. As the colour graded NDVI density maps of different years reveal various condition of forest coverage, the outcome deciphered from this research could be useful for better planning, development and management of the mangrove forest.

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সুন্দরবন ম্যানগ্রোভ বনের বনজ আচ্ছাদনের পরিবর্তন এবং এর বিস্তৃতির বিন্যাস: মডিস চিত্র উপাত্ত থেকে পর্যবেক্ষণ

সৈয়দা ফাহলিজা বেগম, মোহাম্মদ রেজওয়ানুল ইসলাম, রবীন্দ্র জয়ারত্নে ও মার্টিন জে ম্যারিয়ট

সারসংক্ষেপ

টেরা কৃত্রিম উপগ্রহে সংযোজিত মডিস (মডারেট রেজুলিউশন ইমেজিং স্পেকট্রোরেডিওমিটার) সেন্সর দ্বারা ধারণকৃত চিত্র উপাত্ত থেকে প্রস্তুতকৃত স্তর-৩ এর ৮/১৬ দিনের কম্পোজিট এনডিভিআই (নরমালাইজড ডিফারেন্স ভেজিটেশন ইনডেক্স) উপাত্ত বনজ আচ্ছাদনের ও বৃক্ষরাজির বিস্তৃতির সার্বিক অবস্থা পর্যবেক্ষণের জন্য বৈজ্ঞানিক গবেষণায় ব্যবহৃত হয়ে আসছে। কিন্তু মডিস স্তর ১বি চিত্র উপাত্তর লাল ও অবলোহিত তরঙ্গ দৈর্ঘ্যে উচ্চতর স্থানিক ও সময়গত ঘনত্ব রয়েছে যা বিস্তারিত এবং সুনির্দিষ্ট পর্যবেক্ষণের জন্য সুবিধাজনক। বর্তমান গবেষনায় এই সুবিধা কাজে লাগানোর জন্য মডিস স্তর ১বি চিত্র উপাত্ত প্রক্রিয়া ও ক্যালিব্রেট করে সমগ্র সুন্দরবন (যা বাংলাদেশ ও ভারতের অংশ বিশেষ নিয়ে বিস্তৃত) ম্যানগ্রোভ বনের এনডিভিআই চিত্র তৈরী, পর্যবেক্ষণ ও বিশ্লেষণ করা হয়েছে। যেহেতু মডিস একটি একক ফ্রেমের মাধ্যমে প্রায় ২০০০ বর্গ কিমি এলাকা জুড়ে চিত্র ধারণ করতে পারে, সেইজন্য এই অধ্যয়নে কোন চিত্র মোজাইকিং পদ্ধতির আশ্রয় নিতে হয় নাই।

এক দশকের বেশী সময়কাল জুড়ে সুন্দরবনের বনজ আচ্ছাদন এবং এর আকৃতির ও বিস্তৃতির বিন্যাসে কি ধরনের পরিবর্তন হয়েছে তা পর্যবেক্ষণের জন্য ২৭/০১/২০০১, ২৪/০১/২০০৮ এবং ২৯/০১/২০১৫ তারিখে ধারণকৃত ৩টি চিত্র নাসার আর্কাইভ থেকে বাছাই করা হয়েছে। সংগৃহীত চিত্রগুলোতে মেঘাচ্ছন্ন আকাশ এবং চিত্র বিকৃতির পরিমান নিম্ন মাত্রার কিনা তা বিবেচনা করে বাছাইপর্ব সম্পন্ন করা হয়েছে।

সংগৃহীত চিত্রগুলো মডিস স্তর ১বি উপাত্ত ব্যবহারের গাইড (২০০৯) অনুসরণ করে এই চিত্রগুলো থেকে প্রতিফলন বের করা হয়েছে। টাকার (১৯৯৩) এর সূত্র ব্যবহার করে প্রতিফলন থেকে এনডিভিআই সূচক বের করা হয়েছে। "এরডাস ইমাজিন" (২০১৫ সংস্করন) ব্যবহার করে এনডিভিআই ঘনত্বের মানচিত্রে রূপান্তর করা হয়েছে। এই প্রক্রিয়ায় প্রতিফলন চিত্রগুলোকে প্রথমে এনডিভিআই চিত্র ও পরে এনডিভিআই ঘনত্বের মানচিত্রে রূপান্তর করা হয়েছে।

এই রং-শ্রেণীর (কালার গ্রেডেড) মানচিত্রগুলো থেকে প্রাপ্ত এনডিভিআই বিশ্লেষণ করে ২০০১ সাল থেকে ২০১৫ পর্যন্ত সুন্দরবনের বনজ আচ্ছাদনের পরিবর্তন পর্যবেক্ষণ করা হয়েছে। বিশ্লেষণে অনুধাবন করা যায় যে, ২০০১ সালে সুন্দরবনের পশ্চিমাংশে ও পূর্বাংশে বৃক্ষরাজির ঘনত্বের পরিমাণ মধ্যাঞ্চল থেকে বেশী। অন্যদিক ২০১৫ সালে বনের পূর্বাংশে বৃক্ষরাজির ঘনত্বের পরিমাণ বৃদ্ধি পেয়েছে বাকি অংশগুলোর তুলনায় বেশী। পরিবর্তনটা বেশী স্পষ্ট হয় যখন ২০০৮ এবং ২০১৫ সালের মানচিত্র ২টির তুলনা করা হয়। ২০০৮ সালে বনের পূর্ব অংশে ঘনত্বের পরিমাণ অনেক কম কিন্তু ২০১৫ সালে এটা অনেক বেশী। ২০০৮ সালের নিম্ন মাত্রার ঘনত্বের জন্য ২০০৭ সালের ১৫ই নভেম্বরে সুন্দরবনের পূর্বাংশে আঘাত করা 'সিড্‌র' ঘূর্ণিঝড়কে কারণ হিসাবে চিহ্নিত করা যায়।

ঘনত্বের সময়গত পরিবর্তনের পার্থক্য পর্যবেক্ষণের জন্য চিত্র থেকে চিত্র বিয়োগকরণ কৌশল প্রয়োগ করা হয়েছে। প্রাপ্ত সময়গত পরিবর্তন নির্দেশ করে যে, গত ১৪ বছরে সুন্দরবনের পূর্বাংশে বনের ঘনত্ব বৃদ্ধি পেয়েছে এবং পশ্চিমাংশে হ্রাস পেয়েছে। প্রাপ্ত সূচকের বিশ্লেষণে দেখা যায় যে, উচ্চতর এনডিভিআই সূচক (>০.৪) ২০০১ সালে সমগ্র বনের ৬৬%, ২০০৮ সালে ৫৩% এবং ২০১৫ সালে বনের ৭৭% অংশ জুড়ে বিদ্যমান। এই বিশ্লেষণ থেকে সিদ্ধান্তে পৌছানো যায় যে, গত ১৪ বছরে সুন্দরবনের সামগ্রিক বনজ আচ্ছাদন এলাকা বৃদ্ধি পেয়েছে প্রায় ১০%।