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TEMPORAL VARIATION OF BIOMASS CONCENTRATION IN THE BANGLADESH SUNDARBANS USING REMOTE SENSING TECHNIQUES

Ahsan Azhar Shopan[1*], G.M. Tarekul Islam[1], A.K.M. Saiful Islam[1], Md. Munsur Rahman[1], Attila N. Lázár[2] & Craig Hutton[3]

[1] *Institute of Water and Flood Management, Bangladesh University of Engineering and Technology, Dhaka-1000, Bangladesh.*
[2] *Faculty of Engineering and the Environment, University of Southampton, Southampton, United Kingdom.*
[3] *GeoData Institute, University of Southampton, Southampton, United Kingdom.*
**Corresponding Author, <ahsan.shopan@gmail.com>*

ABSTRACT

The Sundarbans is the largest deltaic mangrove forest in the world. Formed at estuarine phase of the Ganges-Brahmaputra river system, the forest covers approximately 10,000 km2, of which about 6,000 km2 are in Bangladesh and the rest are in India. It plays an important role in the national economy and the demand of its resources is increasing rapidly along with the population. This paper assesses the change in biomass concentration of the Sundarbans in Bangladesh from 1980 to 2009. The biomass concentration was assessed by estimating the normalized differential vegetation index (NDVI) as there is a correlation between biomass concentration and the NDVI. The study used four Landsat satellite images covering the entire Bangladesh Sundarbans, all acquired in the month of January in 1980, 1989, 2000 and 2009 respectively. It has been found that the mean NDVI value of the mangrove forest increased continuously during 1980-2000 from 0.31 to 0.56. However, in 2009, the mean NDVI value dropped to 0.52. The top 5% of NDVI values ranged between 0.39-0.43, 0.57-0.59, 0.69-0.72 and 0.59-0.61 in 1980, 1989, 2000 and 2009 respectively. Again, the bottom 5% of NDVI values ranged between 0.10-0.20, 0.17-0.35, 0.03-0.32 and 0.16-0.34 in the respective years. These results indicate that till 2000 the biomass concentration of the Sundarbans was increasing continuously but during 2000-2009 the concentration reduced most likely due to massive deforestation. Such deforestation may cause an imbalance in the mangrove ecosystem resulting to the extinction of endangered species of the Sundarbans.

Keywords: Sundarbans, Biomass Concentration, NDVI, Landsat, Remote Sensing

INTRODUCTION

Mangrove ecosystems dominate the coastal wetlands of tropical and subtropical regions throughout the world. They provide various ecological and economical ecosystem services. At the same time, mangroves belong to the most threatened and vulnerable ecosystems worldwide and experienced a dramatic decline during the last half century. International programs, such as the Ramsar Convention on Wetlands or the Kyoto Protocol, underscore the importance of immediate protection measures and conservation activities to prevent the further loss of mangroves (Kuenzer et al., 2011).

The *Sundarbans* is the largest deltaic mangrove forest in the world. Formed at estuarine phase of the Ganges-Brahmaputra river system, the forest covers approximately 10,000 km^2, of which about 6,000 km^2 are in Bangladesh and the rest are in India. The *Sundarbans* is a complex ecosystem intersected by a complex network of tidal waterways, mudflats and small islands of salt-tolerant mangrove forests (Hussain and Acharya, 1994). It plays an important role in the economy of the south-western region of Bangladesh as well as in the national economy. In addition to traditional forest produce like timber, fuel wood, pulpwood etc., large scale harvest of non-wood forest products such as thatching materials, honey, bees-wax, fish, crustacean and mollusc resources of the forest takes place regularly (FAO, 1995). The vegetated tidal lands of the *Sundarbans* also function as an essential habitat, produce nutrients and purify water. The forest also traps nutrient and sediment, acts as a storm barrier, shore stabilizer and energy storage unit. However, the demand of its resources is increasing rapidly along with the population and thus, as other mangroves, the *Sundarbans*, is also under threat.

The trophic relationships between mangroves and coastal ecosystem can be characterized by the biomass and productivity of the mangrove forests (Hess et al., 1990). Biomass is biological material derived from living, or recently living organisms. In the context of biomass for energy this is often used to mean plant based material. However, biomass and productivity data of mangrove forests are scarce, mainly because of the difficulties associated with field measurements. In this context, remote-sensing techniques have demonstrated a high potential to detect, identify, map, and monitor mangrove conditions and changes, which is reflected by the large number of scientific papers published on this topic.

Remote sensing from satellites is economically competitive with other forms of data collection, such as aerial photography, especially where low or moderate resolutions are adequate. Broad swath widths and the advent of high-resolution systems enable frequent repeat coverage of targets. Systems can also collect data over denied or hazardous areas without interruption. Satellite sensors not only observe the earth in visible light, but also in the infrared region and with microwaves. Spatial resolution ranges from more than one kilometer to less than one meter (Karmaker, 2006).

This paper assesses the change in biomass concentration of the *Sundarbans* in Bangladesh from 1980 to 2009 using remote sensing techniques. The scope of the study is limited to the Bangladesh part of the *Sundarbans* only, which is situated between 21^{o}40’00’’N to 22^{o}30’00’’N and 89^{o}00’00”E to 89^{o}50’00”E. It mainly belongs to 3 districts of the Khulna division of Bangladesh namely: Satkhira, Khulna and Bagerhat. Howerver, a minor part of it also belongs to the Barguna district of Barisal division.

METHODOLOGY

In this study, the biomass concentration was assessed by estimating the normalized differential vegetation index (NDVI) as there is a correlation between biomass concentration and the NDVI. NDVI is an index of plant “greenness” or photosynthetic activity, and is one of the most commonly used vegetation indices. By taking the ratio of red and near infrared bands from a remotely-sensed image, an index of vegetation “greenness” can be defined. Vegetation indices are based on the observation that different surfaces reflect different types of light differently. Photosynthetically active vegetation, in particular, absorbs most of the red light that hits it while reflecting much of the near infrared light. Vegetation that is dead or stressed reflects more red light and less near infrared light. Likewise, non-vegetated surfaces have a much more even reflectance across the light spectrum. NDVI is calculated on a per-pixel basis as the normalized difference between the red and near infrared bands from an image using the following equation:

$$NDVI = \frac{(NIR - RED)}{(NIR + RED)} \qquad (1)$$

Where, NIR is the near infrared band value for a cell and RED is the red band value for the cell. Many factors affect NDVI values like plant photosynthetic activity, total plant cover, biomass, plant and soil moisture, and plant stress. Because of this, NDVI is correlated with many ecosystem attributes. Also, because it is a ratio of two bands, NDVI helps compensate for differences both in illumination within an image due to slope and aspect, and differences between images due things like time of day or season when the images were acquired. Thus, vegetation indices like NDVI make it possible to compare images over time to look for ecologically significant changes.

The study used four Landsat satellite images covering the entire Bangladesh *Sundarbans*, acquired in 1980, 1989, 2000 and 2009 respectively. The images have been downloaded from webpage of United

States Geological Survey (www.earthexplorer.usgs.gov). These images are taken at four tiles: Path of 137 with Row of 44, Path of 137 with Row of 45, Path of 138 with Row of 44 and Path of 138 with Row of 45, which cover the entire study area. The images represent dry season of Bangladesh as all of them have been captured in the month of January. It is assumed that temporal changes of water bodies remain insignificant over this period.

Properties of the images are presented in Table 1. It should be mentioned that the TM (Thematic Mapper) sensor has a spatial resolution of 30 m for the visible, near-IR, and mid-IR wavelengths and a spatial resolution of 120 m for the thermal-IR band. The ETM+ (Enhanced Thematic Mapper Plus) has spectral bands which are similar to those of TM, except that the thermal band (band 6) has an improved resolution of 60 m. However, all TM/ETM+ images are now resampled to 30 m resolution by the production system. On the other hand, the downloaded MSS images had a spatial resolution of 60 m which were resampled to 30 m during analysis for convenience of the study.

Table 1: Properties of Landsat satellite images

Image No.	Acquisition Date	Satellite	Sensor	Spatial Resolution (m)
1	January, 1980	Landsat 3	MSS	60
2	January, 1989	Landsat 4	TM	30
3	January, 2000	Landsat 7	ETM+	30
4	January, 2009	Landsat 5	TM	30

The images were analyzed using open-source remote sensing software ILWIS 3.4. Firstly, the images were manually digitized along the border of the *Sundarbans* to separate it from the whole image. It was then classified into several categories such as mangroves, mudflats, and waterways using maximum likelihood classification. The waterways and mudflats were then excluded from the images and the mangroves area was further analyzed to determine the changes in biomass concentration of the *Sundarbans* over the period of 29 years by preparing NDVI maps of the *Sundarbans* for 1980, 1989, 2000 and 2009 and compare them to determine the intensity of deforestation at different parts of the Bangladesh *Sundarbans*.

RESULTS AND DISCUSSIONS

The NDVI maps of the *Sundarbans* at different years are presented below (Figure 1). Minimum, maximum, mean, median and mode values of NDVI are compared in Figure 2. Table 2 also shows the standard deviation, range and skewness of the distribution of the NDVI values. It has been found that the mean NDVI value of the mangrove forest increased continuously during 1980-2000 from 0.31 to 0.56. However, in 2009, the mean NDVI value dropped to 0.52. Again, the maximum NDVI value increased from 0.43 to 0.72 over the period of 1980-2000 but reduced to 0.61 in 2009. However, the minimum NDVI value changed inconsistently throughout the period. These results indicate that till 2000 the biomass concentration of the *Sundarbans* was increasing continuously but during 2000-2009 the concentration reduced most likely due to massive deforestation. From the comparative spatial analysis of the NDVI maps of 2000 and 2009, it has been found that the southwest region of the Bangladesh *Sundarbans* is affected the most in terms of biomass degradation. Figure 3 shows the areas where NDVI value has decreased by more than 0.15 from 2000 to 2009.

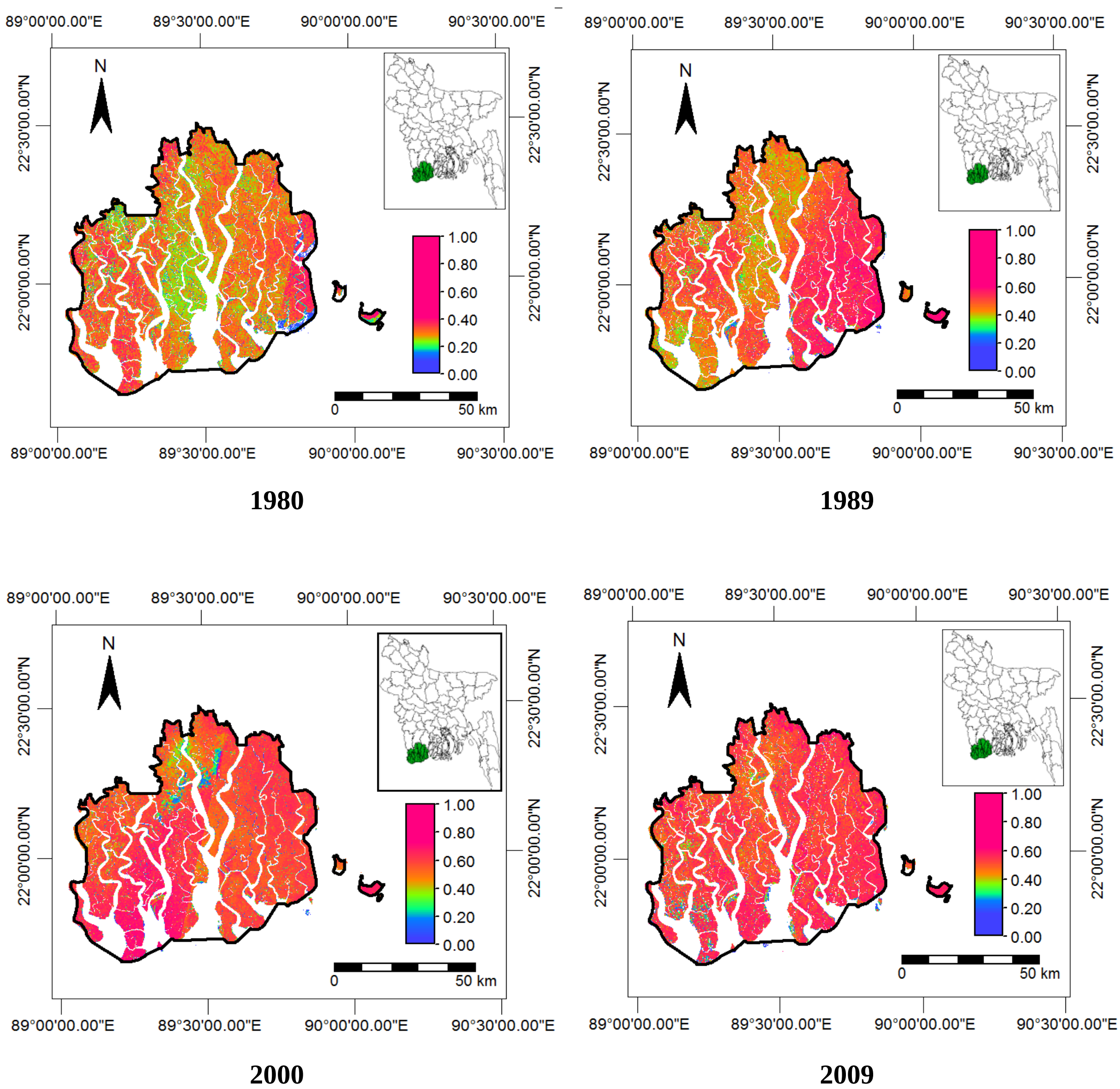

Figure 1: NDVI maps of the *Sundarbans* at different years

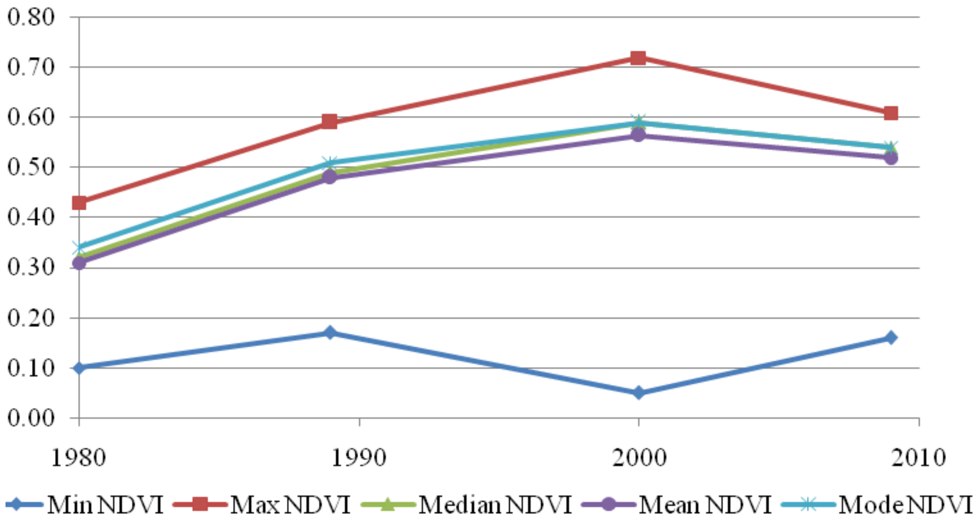

Figure 2: Comparison of NDVI values at different years

Table 2: NDVI value properties at different years

NDVI	1980	1989	2000	2009
Min	0.10	0.17	0.05	0.16
Max	0.43	0.59	0.72	0.61
Median	0.32	0.49	0.59	0.54
Mean	0.31	0.48	0.56	0.52
Mode	0.34	0.51	0.59	0.54
Std Dev	0.01	0.01	0.01	0.02
Range	0.33	0.42	0.67	0.45
Skewness	Negative	Negative	Negative	Negative

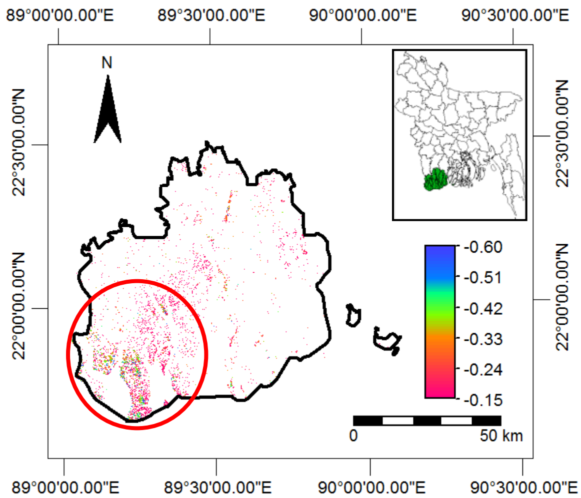

Figure 3: Biomass degradation at the Bangladesh *Sundarbans* during 2000-2009

CONCLUSION

Forest degradation has become a serious issue, especially in developing countries. In 2000, the total area of degraded forest in 77 countries was estimated at 800 million hectares (ha), 500 million ha of which had changed from primary to secondary vegetation (ITTO, 2002). Among other impacts, the process of forest degradation represents a significant proportion of greenhouse gas emissions. Thus, there is an urgent need to measure and analyze it, in order to design action to reverse the process. NDVI, despite of its limitations has been proved to be very useful to measure forest degradation. This study clearly indicates that the biomass concentration at the Bangladesh *Sundarbans* has decreased significantly since 2000 most likely due to massive deforestation. Such deforestation may cause an imbalance in the mangrove ecosystem resulting to the extinction of endangered species of the *Sundarbans*. Thus, extensive studies must be carried out to determine the exact causes of biomass degradation at the *Sundarbans* as this study does not focus on this subject. Moreover, latest images can be analyzed to further verify the findings of the study.

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