APPLICATION OF SUPERVISED ENHANCEMENT TECHNIQUE IN MONITORING THE MANGROVE FOREST COVER DYNAMICS – A CASE STUDY ON AJMALMARI RESERVE FOREST, SUNDARBAN, WEST BENGAL

Abstract

The enhancement technique is basically done for the betterment of image interpretability and analysis. This may be statistical or object oriented. For the study like change detection or object dynamics, object oriented enhancement should be given importance. The object oriented enhancement can be said as supervised enhancement which like the point operation, is the combination of spectral bands using algebraic operation from mathematical or algebraic functions by which selected target spectral features can be enhanced. In this present study a new object oriented enhancement algorithm has been proposed to monitor the mangrove forest cover of the Ajmalmari reserve forest of Indian Sunderban deltaic environment and has been applied on temporal digital database to get the changing scenario of mangrove forest cover. Finally it has been experienced that the vegetation nature in terms of chlorophyll ‘a’ and vegetation density in zonal aspect have altered noticeably.

Key words: Supervised Enhancement, MAVI (Modified Advance Vegetation Index), VD (Vegetation Density), Object oriented Enhancement, Mangrove Forest,

Introduction

Low sensitivity of the detectors, weak signal of the objects and the environmental conditions at the time of recording are the major causes of low contrast. Besides sometimes human eye acts poorly at discriminating the small radiometric or spectral differences, that may characterize the features. The main aim of the digital image enhancement is to amplify these least differences for better clarity of the scene. This means the digital image enhancement increases the separability between the nearly classes or features. It is basically a mathematical operation applied to the digital image to improve the visual appearance for better interpretability and subsequent digital analysis (Lillesand & Kifer, 1999) [1].

In remote sensing image processing, different kinds of digital enhancement algorithms are used like, contrast stretching, filtering, ratioing, PCA, linear combinations, spectral band combination etc. Out of them some are statistical where the original histograms of the images are directly modified or some are object oriented where spectral band combinations are done using algebraic operations from mathematical and algebraic functions by which selected target spectral features can be enhanced. In the context of the present study, the object oriented enhancement algebraically can be considered as supervised enhancement as it is done on the basis of the prior spectral designations. By this objects’ internal characteristics can be expressed as well as the separability can be recognized from the nearly spectral objects. In this present study this kind of enhancement algorithm seems very fruitful.

Mangrove forests, found in the inter-tidal zone in the tropics and subtropics, play an important role in stabilizing shorelines and in helping reduce the devastating impact of natural disasters such as tsunamis, and hurricanes [2]. They also provide important ecological and societal goods and services including breeding and nursing grounds for marine and pelagic species, food, medicine, fuel, and building materials for local communities. These forests, however, are declining at an alarming rate, perhaps even more rapidly than inland tropical forests, and much of what remains is in degraded condition (Wilkie and Fortune, 2003)[3]. The rate and causes of such changes are not fully known. And, the remaining mangrove forests are under immense pressure from clear cutting, encroachment, hydrological alterations, chemical spills, and climate change (Blasco et al., 2001; McKee, 2005)[4]. The Sundarbans offers coastal protection to millions of people in Bangladesh and India. The forests lie in a zone of cyclonic storms and tidal bores that originate in the Bay of Bengal and periodically devastate coastal areas.
At the beginning of the colonial era (1757 to 1947) in India, the Sundarbans mangrove forest occupied approximately twice its current extent (Islam et al., 1997) [5]. Currently, the Sundarbans covers approximately 10,000 km², 40% of which is in India and the rest is in Bangladesh (WCMC, 2005) [6]. Periodic forest inventories have been taken, recording the volume and condition of the timber resources of the Sundarbans at intervals of approximately 15 to 20 years. Through the 1900s inventories and management plans became more sophisticated and accurate, but remained focused on maximizing timber yield (Chaudhuri and Choudhury, 1994) [7]. However, in Bangladesh, for example, it has been 20 years since the Department for International Development of United Kingdom (formerly, Overseas Development Administration) conducted the last detailed inventory (Chaffey et al., 1985) [8]. Availability to up-to-date information on the status and conditions of this important ecosystem is critical for managing mangrove resources in a sustainable manner.

Remote sensing could play an important and effective role in the assessment and monitoring of mangrove forest cover dynamics. While remote-sensing data analysis does not replace field inventory, it provides supplementary information quickly and efficiently. The use of remotely sensed data offers many advantages including synoptic coverage, availability of low-cost or free satellite data, availability of historical satellite data, and repeated coverage. In addition, recent advances in the hardware and software used for processing a large volume of satellite data has helped increase the usefulness of remotely sensed data. Moreover, it is extremely difficult to get into vast swamps of mangrove forests, and conducting field inventory is time consuming and costly. A number of studies conducted in the Sundarbans have begun to develop and apply remote-sensing techniques mainly for mapping purposes (Islam et al., 1997; Dwivedi et al., 1999; Blasco et al., 2001; Nayak et al., 2001) [9]. These studies were conducted either in Bangladesh or Indian parts of the Sundarbans at different times; thus, they lacked a holistic view of the whole Sundarbans mangrove forests. Monitoring of this important ecosystem in terms of both deforestation and forest degradation was urgently needed.

In this paper, we examine the forest cover dynamics in terms of chlorophyll ‘a’ and vegetation density in zonal perspective of the Ajmalmari reserve forest developed at Matla estuarine complex of Indian Sundarbans deltaic environments using multi-temporal Landsat data at the intervals of ten years between the 2000s and 2010s. Our specific objectives are to assess the current status of the remaining forest and the changing patterns.

The study area

In this present study mangrove dominated Ajmalmari island groups have been selected for the application (fig.1). These are the part of Buffer zone of the Sundarban Biosphere Reserve (SBR). These are located at the upper section of Matla estuary. The co-ordinate location of these island groups is 21°47’9” N to 21°59’59” N and 88°33’ E to 88°40’ E. Both of overlapping and non-overlapping nature of mangroves is noticeable over here. The Sonneratia sp. maintains a unique identity of its own by its appearance in the lowest intertidal zone and it exhibits a distinct non-overlapping character from the major cluster of other mangroves. Species diversity occurs in different parts of the islands, Excoecaria-Avicennia- Phoenix combination in the upper section of the island, Avicennia – Aegialitis- Rhizophora in the middle section and Avicennia- Ceriops- Rhizophora combination in the lower section of the islands.

Materials and Methodology

In this present study LANDSAT ETM+ and TM digital data (P/R 138/40) of the year of 2000 and 2010 respectively has been used and has been processed in the TNT mips Pro environment.

The use of multi-temporal satellite data at a large scale using TM and ETM+ possesses a number of challenges including geometric correction error, noise arising from atmospheric effect, errors arising from changing illumination geometry, and instrument errors (Homer et al., 2004). Such
errors can introduce biases in mangrove forest classification and change analysis.

To reduce the noise due to influence of the atmospheric and illumination geometry, we used the techniques developed for the National Land Cover Database of the United States (Homer et al., 2004) [10]. Each image was normalized for variation in solar angle and Earth-sun distance by converting the digital number values to the top of the atmosphere reflectance (Chander and Markham, 2003) [11]. Considering the relative uncertainty of algorithms currently available, atmospheric correction was not performed. Only first-order normalization conversion to at-satellite reflectance was performed. This conversion algorithm is “physically based, automated, and does not introduce significant errors to the data” (Huang et al., 2002) [12]. Finally, mosaics were created for each decade with no further radiometric normalization.

In an image, for vegetation pixel due to chlorophyll content there is significant difference in both absorption and reflectance of electromagnetic radiation in Green, Red and Near infrared region. In vegetation pixel reflectance of Near infrared band always will be greater than Red band. Based on this properties various multispectral indices or band ratioings have already been developed which can enhance the vegetation internal characteristics like health, vigour, moisture content etc.

In this present study, after all the preprocessing techniques, to assess the mangrove forest cover dynamics, an object oriented enhancement algorithm has been designed using mathematical operators, which is supervised in nature and expressing the characteristics of plant chlorophyll ‘a’.

Two considerations have been taken in this respect like, pixel value having chlorophyll influence will be greater in near-infrared band than red band and pixel value having no chlorophyll influence will be greater in red band than near-infrared band. On the basis of these considerations following supervised enhancement algorithm has been developed and is named as Modified Advance Vegetation Index (MAVI). That can be calculated as –

\[
\left(\frac{(\rho_{NIR}+L) \cdot (256-\rho_{RED}) \cdot (\rho_{NIR}-\rho_{RED})^{1/3}}{(\rho_{NIR}+L) \cdot (256-\rho_{RED}) \cdot (\rho_{NIR}-\rho_{RED})^{1/3}}\right)
\]

(Where, \(\rho_{RED}\), Reflectance value of Red band of TM5 Sensor, \(\rho_{NIR}\), Reflectance value of Near-infrared band of TM5 Sensor, \(L\) = Coefficient, varies with the vegetation cover, Here \(L=2\).)

It differs from NDVI in the perspective of physiognomic vegetation classes though there is almost positive relationship between these two. It is more sensitive than NDVI as it is using the power degree of Infrared response. This algorithm has been applied both of the images of year 2000 and 2010 and after this a Combination function has been used between the two rasters to get the changing scenario of vegetation health status.

In the second phase the vegetation density (VD) has been calculated for both of images of year 2000 and 2010 by synthesizing the equation 1 and bareness index (BI) on Principle Component (PCA) basis and it is level sliced into 5 density zones having distinct areal extent. The bareness index (BI) is calculated as -

\[
\frac{(\text{Band5+Band3})-(\text{Band} 4+\text{Band1})/(\text{Band} 5+\text{Band} 3)+\text{Band} 4+\text{Band} 1)}{(\text{Band} 5+\text{Band} 3)}
\]

Result and Discussion

From different literature it has already been proved that Sunderban mangrove forest cover is changing temporarily either in terms of areal extent or canopy closure. The species dynamics are also relevant over here. In this present study it is seen that along with the aforesaid factors, dynamics in vegetation health and density are so significant.

From the MAVI outputs (figure 2) derived from satellite digital data (for the year of 2000 and 2010), where the NIR response has been enhanced using the equation 1, the dynamics of vegetation health in terms of chlorophyll ‘a’ temporarily can be identified.

![Figure 2. MAVI of the forest cover](image)

If the vegetation nature wise compartments, derived from the sliced MAVI rasters are compared (Table 1 and figure 3), the deteriorating status of vegetation health will be experienced.
Table 1. MAVI values according to zone

<table>
<thead>
<tr>
<th>Zone</th>
<th>Year 2000</th>
<th>Year 2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very low</td>
<td>0.00 – 48.25</td>
<td>0.00 – 49.13</td>
</tr>
<tr>
<td>Low</td>
<td>48.25 – 54.44</td>
<td>49.13 – 51.73</td>
</tr>
<tr>
<td>Moderate</td>
<td>54.44 – 58.73</td>
<td>51.73 – 53.32</td>
</tr>
<tr>
<td>High</td>
<td>58.73 – 63.03</td>
<td>53.32 – 54.56</td>
</tr>
<tr>
<td>Very high</td>
<td>63.03 – 74.41</td>
<td>54.56 – 60.14</td>
</tr>
</tbody>
</table>

Figure 3. Vegetation status from year 2000 to 2010

This dynamicity in the vegetation health between year 2000 and 2010 will be visualized from figure 4. It is very interesting, though vegetation nature is deteriorating, 7% vegetal area of the study area has been upgraded to class 5 health status which is most fair and only 0.9% area has been deteriorated to class 1 health status which is most non healthy.

In case of vegetation density (figure 5), the dynamicity also is relevant. The areas (table 2 & figure 6/) of each vegetation density zones are temporarily compared, it will be seen that the area of the highest vegetation density zone (noted as zone 5) is increased considerably for the year of 2010, which is 20% of the total area and rate of this increment for the zone with respect to the year of 2000 is approximately 2%. On the other hand, in case of zone 3 a considerable decrease in area is seen for the year of 2010 in compare to year of 2000. For this zone the rate of change is approximately 2.5%.

Figure 4. Vegetation change detection map on perspective of health status

Figure 5. Vegetation Density map

It is noteworthy that there is a positive relationship between vegetation density and vegetation health. If the MAVI and vegetation density (VD) rasters are compared, most healthy
vegetation will seen to be concentrated within the high density zones.

Table 2. Areas of different density zones

<table>
<thead>
<tr>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Very low</td>
<td>2958100</td>
<td>21929400</td>
</tr>
<tr>
<td>Low</td>
<td>29231100</td>
<td>29788200</td>
</tr>
<tr>
<td>Moderate</td>
<td>32892300</td>
<td>30710700</td>
</tr>
<tr>
<td>High</td>
<td>31274100</td>
<td>30200400</td>
</tr>
<tr>
<td>Very high</td>
<td>25605000</td>
<td>29274300</td>
</tr>
</tbody>
</table>

Figure 6. Areal dynamics of density zones

A chemical compound in leaves called chlorophyll strongly absorbs radiation in the red and blue wavelengths but reflects green wavelengths. The internal structure of healthy leaves act as excellent diffuse reflectors of near-infrared (IR) wavelengths. If our eyes were sensitive to near-infrared, trees would appear extremely bright to us at these wavelengths. In fact, measuring and monitoring the near-IR reflectance is one way that scientists can determine how healthy (or unhealthy) vegetation may be. Higher is the NIR response, better will be the vegetation health. On the basis of this physiognomic nature of vegetation, in this present study to monitor the vegetation health status, NIR response has been tried to enhance using equation 1 which is in turn generated MAVI raster and is seen that the healthy vegetation zone corresponds to the higher NIR value. The MAVI and NIR rasters are correlated with the co-efficient value of 0.97. Besides this, the high standard deviation of MAVI raster than the Red band (Table 3) modulated the NIR response vis-à-vis vegetation nature in such a way that an interpreter can get a clear visualization.

Table 3. Standered deviation values of the rasters

<table>
<thead>
<tr>
<th>Year</th>
<th>Rasters</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>MAVI</td>
<td>9.30</td>
</tr>
<tr>
<td></td>
<td>Red</td>
<td>1.88</td>
</tr>
<tr>
<td></td>
<td>Infra Red</td>
<td>4.81</td>
</tr>
<tr>
<td>2010</td>
<td>MAVI</td>
<td>6.17</td>
</tr>
<tr>
<td></td>
<td>Red</td>
<td>3.37</td>
</tr>
<tr>
<td></td>
<td>Infra Red</td>
<td>5.56</td>
</tr>
</tbody>
</table>

Conclusion

After overall analysis and discussion, it can be concluded that for the environmental mapping and monitoring supervised enhancement can play an important role. Ample combinations of algebraic operations can be derived from basic arithmetic operations and algebraic functions. But aimless combinations of algebraic operations and arithmetic functions can not provide any satisfactory result though that may be visually impressive. So using the knowledge of the spectral properties of the target features, an effective and meaningful band combination algebraically can be designed to truly enhance the particular target. These kinds of algebraic band combination having supervised nature can also suppress image radiometric flaws and atmospheric scattering effects. In this present study by formulating a spectral index named as MAVI, based on the NIR and Red spectral property of vegetation, the health status as well as the density nature becomes so interpretable, that an environmentalist can undertake some effective decision for environmental sustainability.

References


Biography

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