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DETECTING FRAGMENTED MANGROVES IN THE SUNDARBANS, BANGLADESH USING OPTICAL AND RADAR SATELLITE IMAGES

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ABSTRACTS: This study shows that Landsat TM, JERS-VNIR (optical) and JERS-SAR (radar) data can be used for detecting edges of fragmented mangrove in the Sundarbans, Bangladesh. The classification JERS-SAR image gives highest overall classification accuracy of 85.53% and per class accuracy of 86.49% in detecting high contrast edges. Whereas overall classification accuracy of Landsat TM and JERS-VNIR image are 80.52% and 82.27% respectively. Mapping of high contrast edges can be done through producing segment map from on screen digitising of class high contrast edges on classification map of all three sensors mentioned above. It is believed that the high contrast edges, with their specific spatial characteristics and pattern (e.g., linear feature shape and network like pattern) can be detected spatially on remotely sensed data.

1. INTRODUCTION

A mangrove is a plant or plants community, which lives between the sea and the land in areas, which are inundated by tides in tropical and subtropical regions. Mangrove plants live in muddy and wet soils. Mangroves embody two concepts: first it is an ecological group of evergreen plant species belonging to several families but possessing marked similarity in their physiological characteristics and structural adaptation to similar habitat performance; second it is a complex plant communities fringing the sheltered tropical shores, such communities usually have trees associated with shrubs growing in the zone of tidal influence both on the sheltered coast itself and inland lining the bank of estuaries and rivers.

A significant part of population in the developing countries is directly or indirectly lives on mangroves. Tremendous pressure for different products from mangrove is ever increasing. These pressures include clearing for settlements, illicit felling, over exploitation, conversion for shrimp farming, damming the rivers and harbor facilities.

The Sundarbans, being a home of complex and varied vegetation structure, is conducive to the growth of diverse floral and faunal elements. Seemingly, it is under pressure of economic activities of the people living in the vicinity of the forest, notably the gathering of forest products that destroys the habitats and important species need to be clearly understood. In the process of degradation of the habitat, vegetation cover has changed and becomes more and more perforated and fragmented. Edges of fragments appearing throughout the Sundarbans mangroves. There has been increasing concern about the degradation of Sundarbans mangroves in Bangladesh for last the two decades. Edge is said to be one of the indicators of forest fragmentation and its effects. The distance, which edge and its effects penetrate into forest remnants, is a common measure used to indicate the intensity of habitat fragmentation (Dale and Pearson, 1997). The size, shape and age of forest remnants or fragments will often interact to determine the importance of edge effects. Various studies show remote sensing techniques proved to be useful in many management applications for the area. None of the above mentioned efforts had been to study or map the edges of fragments in the Sundarbans mangroves. The objectives of this study wee to develop a method for mapping edges of fragments in the Sundarbans mangroves of Bangladesh using remotely sensed data and to evaluate optical and microwave sensor data for detecting edges of fragments in the Sundarbans mangroves of Bangladesh.

2. MATERIALS AND METHODS

2.1 Study Area

The Sundarbans is found west of the main outflow of the three mighty rivers Ganges, Brahmaputra and Meghna. The Sundarbans covering 10,000 Sq. km. of land and water is part of the world's largest delta (80,000 Sq. km.) formed from sediments deposited by these rivers as they converge on the Bengal Basin (Seidensticker and Hai, 1983).

The Sundarbans comprise a complex network of tidal waterways, mud flats and small islands. These salt-tolerant mangrove forests present an excellent example of dynamic ecological processes, displaying the effects of monsoon heavy downpours, delta formation, tidal action, plant colonization and successional developments. The Sundarbans is dependent on discharge from the Ganges but suffers from low flows during the dry season (December to April). The environmental effect of which is very serious in terms of salt-water intrusion in the Sundarbans. Despite much rhetoric to define the reasons behind the increasing degradation of the Sundarbans mangroves there has been very little progress in research to confirm the underlying factors.

The Sundarbans mangrove is divided into five management units called Forest Range. The study area is part of management unit namely Shatkhira Forest Range. The study area is located in the western part of the Sundarbans and falls in Shatkhira districts. 89^0 03' to 89^0 15'E longitudes and 21^0 55' to 22009' N latitudes. The study area is generally low-lying deltaic tidal forest. It is mainly flat to slightly rolling, most of which flooded during the high tide and the monsoons. The area is bounded by rivers and webbed by many small channels or streams. Elevation ranges below mean sea level to 1m above sea level.

2.2 Data and Materials

In this research different satellite images were acquired and used. Beside image data, other ancillary data such as forest cover types maps, information from published and unpublished documents of Bangladesh Forest Department were also used. Two optical images of Landsat TM and JERS-VNIR of 27th February 1999 and 22nd January 1996 respectively were used because of their availability and they are the closest dates to the time of fieldwork. JERS-1 SAR image of 1997 was latest Radar L-band image available, since the satellite stopped collecting data in October 1998.

2.3 General Methodology

Methodology of this research is generally explained in Figure 1. The following was the strategy applied in the research: Improving data quality or removing different noises from optical images and speckle reduction from radar images; Visual interpretation and spectral signature analysis; Classification of land cover types and mangroves delineation; Accuracy assessment image classification and detection of "high contrast edges"; Digitizing of "high contrast edges"; Accuracy assessment of digitized map of "high contrast edges" and Preparation of the final map of "high contrast edges".

2.4 Field Work

Fieldwork was done in the month of August and September 2000. Fieldwork activities can be divided into two phases. In the first phase a reconnaissance survey was done to get the idea regarding distribution of degraded mangroves and high contrast edges as mapped in the classified Landsat TM image of February 1999. In locating sample plot in the field, maps produced in previous part with random sample plots were used. With the help of Sundarbans Forest Range maps, classified image with correct geo reference and co-ordinates, and GPS receiver "map sample plots" were located in the field.

2.4.1 Fragmented Mangrove Edge Detection

Ranking the edges was done to quantify different aspects of edges. In the Table 1 detail description of how the edges were raked is given. Firstly vegetation along both side of edges were compared in to aspects. Those aspects are vegetation composition and vegetation structure. Vegetation composition deals with how many species are in the vegetation. On the other hand vegetation structure deals with average vegetation height and crown closure percentage. So each edge was assigned with two ranks, one rank for vegetation composition (rank A) and the other one for vegetation structure (rank B) (Kramer, 1997). For each identified edge both ranks were multiplied to get the "edge index". If edge index found to be between six to nine was classified as medium contrast edge. If edge index found to be above nine was classified as "high contrast edges". These can be expressed as follows:

High Contrast Edges (HCE)= (Rank in A * rank in B)>9
Medium Contrast Edges (MCE)= (Rank in A * rank in B) >6<9
Low Contrast Edges (LCE)= (Rank in A * rank in B)>0<6

Table 1. Edge contrast index (Physiognomy * species composition)

Vegetation structure (A)	Height differential: virtually none <25%	Height differential: 25% - 100%	Height differential: 100%-200%	Height differential: > 300%
Ranks assigned	1	2	3	4
Vegetation composition (B)	No major change in dominant species between edges >75% shared dominants	24% - 74% shared dominants	1%-24% shared dominants	No dominants shared by either side
Ranks assigned	1	2	3	4

High Contrast Edges (HCE)= (Rank in A * rank in B)>9
Medium Contrast Edges (MCE)= (Rank in A * rank in B) >6<9
Low Contrast Edges (LCE)= (Rank in A * rank in B)>0<6

Maximum Likelihood Classification algorithm was used in supervised classification.. The nature of the mangrove here is a network of numerous creeks and rivers. That means many field site boundaries will be close to boundaries between mangroves, degraded mangroves and water bodies. But for research purpose rivers or creeks and natural boundaries will be disregarded as edge. Edge enhancement can give better result in identifying which features are associated with which features (Green, *et al.,* 1998).

Supervised classification was done using all available bands of optical (Landsat TM and JERS-VNIR) and radar (JERS-SAR) images (e.g., seven bands of TM, three bands of VNIR). Point map produced with plot center co-ordinates was overlaid on the images. Training sample sets were carefully collected based on the ground truth data gathered during fieldwork. For every images two sample set were collected. One sample set was used as training samples for supervised classification of the images. The other ones were used as test sample sets for accuracy assessment of classification.

From the results of supervised classification the class of "high contrast edges" appeared as a linear feature as it was expected along with some scattered single pixels. It is believed that the high contrast edges, with their specific spatial characteristics and pattern (e.g., linear feature shape and network like pattern) can be detected spatially on remotely sensed data. Since there is hardly any software that can detect spatial features and classify them like any classification techniques, it was decided to try to manually screen digitize high contrast edges from classification maps of the three sensors. After accuracy assessment done through generating confusion matrix for all classification maps "high contrast edges" were digitized on the classification maps of all images.

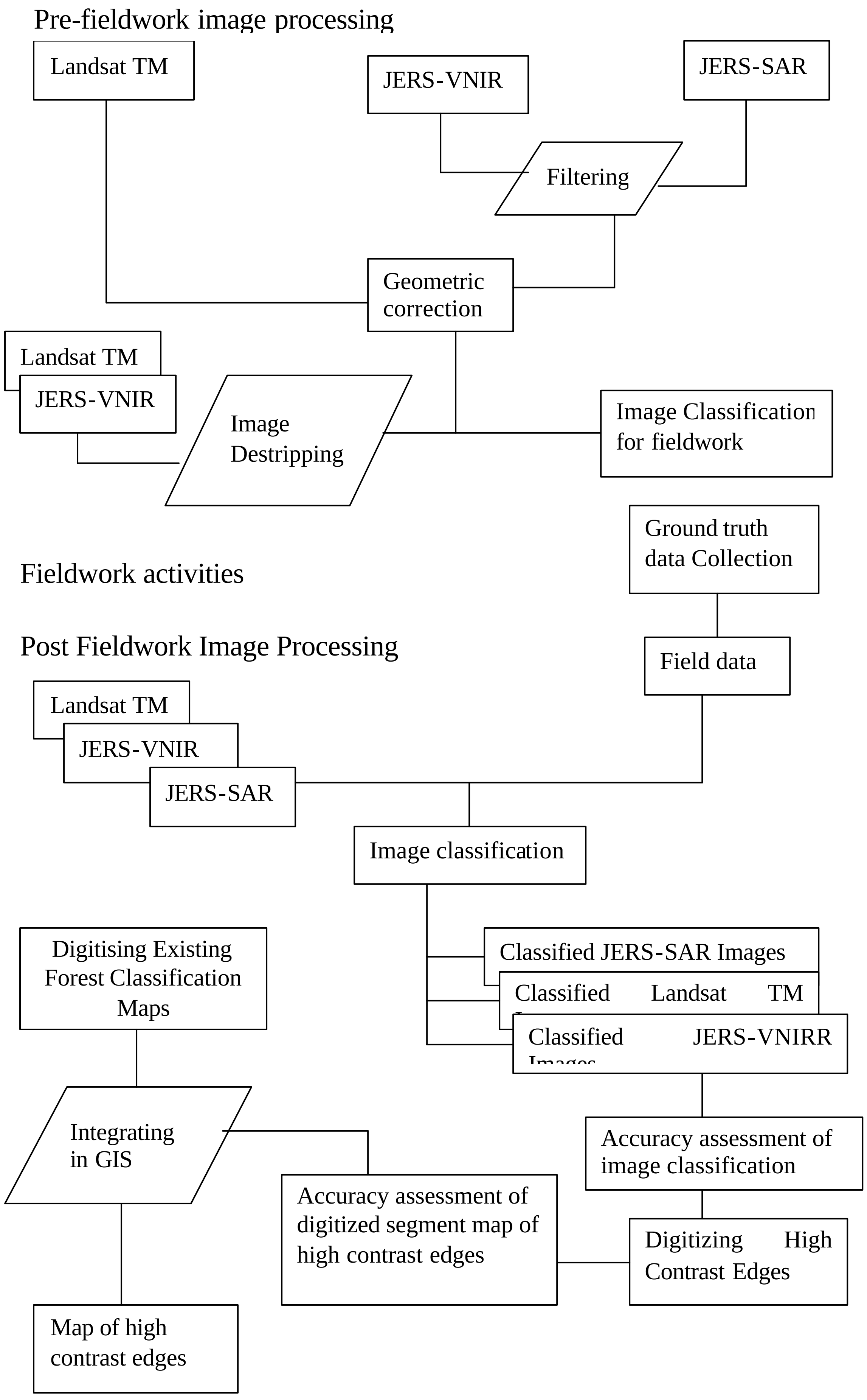

Figure 1. Flowchart showing methods adopted in the research

4. RESULTS AND CONCLUSIONS

Spectral signature analysis was done to check the separability or to evaluate the spectral separation between land cover classes. Figure 2 shows an example of the spectral reflectance of different cover types in different spectral bands of VNIR of JERS-1 image.

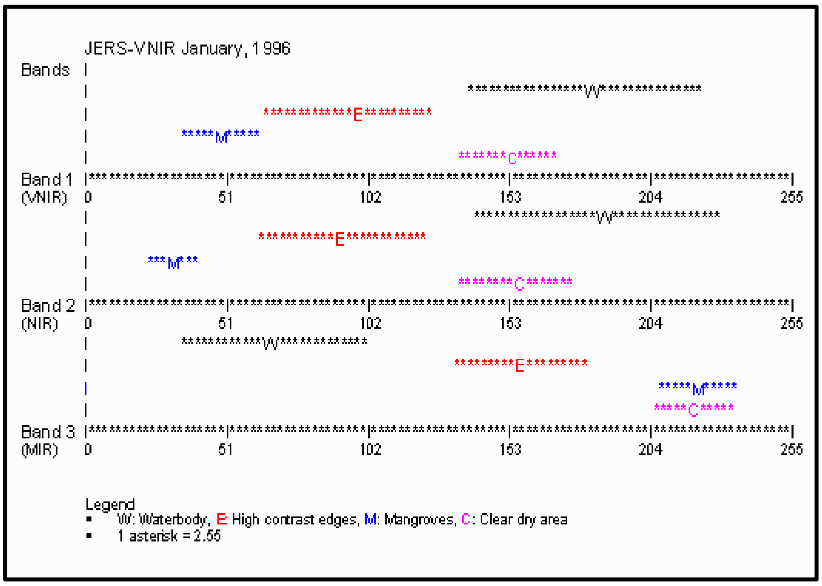

Figure 2. Coincidence scatter plot of VNIR-JERS-1

The overall accuracy of Landsat TM image classification is lower compared to those of both JERS-VNIR and JERS-SAR (Figure 3). The overall classification accuracy and accuracy in correctly classifying "high contrast edges" are higher in the classification map of JERS-SAR image than the other two optical data.

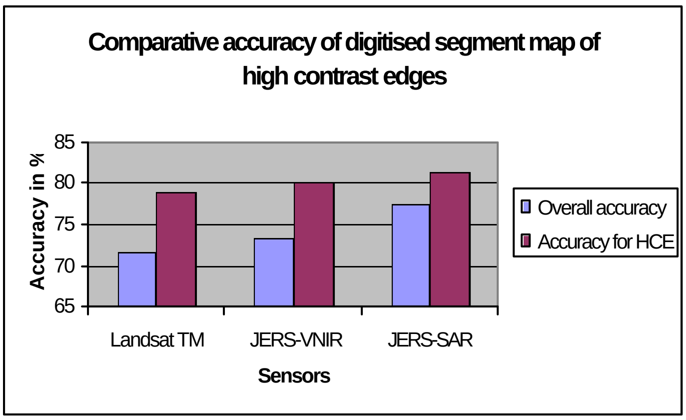

Figure 3. Comparison of accuracy of High Contrast Edge detection using different sensors.

4.1 Results and concluding remarks

Fieldwork data analysis revealed that three contrast edge classes were found. These are high contrast edges, medium contrast edges and low contrast edges. Using optical remotely sensed data used in this research, it was possible to detect only one contrast edge class, which is the high contrast edge. Therefore, using both optical and radar remotely sensed data used in this research, detection or classification of subclasses of contrast edges can not be accomplished.

High contrast edges can be separated using spectral signatures of Landsat TM image. In this study color composite 432 in RGB appeared as the best combination. For separating high contrast edges from other land cover types Landsat TM band seven (MIR) gave best separability. Spectral reflectance of high contrast edges in this band is distinct and its (high contrast edges) position on the scatter-plot is free from any overlapping with other classes. However, high contrast edges can also be separated with Landsat TM bands 1,2 and 3 respectively blue, green and red. In these three bands high contrast edges have many overlaps with the class of degraded mangroves.

All seven bands of Landsat TM image were used for supervised classification with maximum likelihood classifier. In classification Landsat TM image four training classes were given. The classes are intact mangroves, high contrast edges, degraded mangroves and water body.

In the case of JERS-VNIR, high contrast edges can be separated using spectral signatures. Color composite of 321 in RGB has given the best results for both visual interpretation and supervised classification. Four classes (e.g., clear and dry area, mangroves, high contrast edges and water body) were given in supervised classification with maximum likelihood classifier.

For separating high contrast edges from other classes all three bands gave distinct appearance of class high contrast edges in the coincidence scatter-plot of JERS-VNIR reflectance of four training classes. However, detection of sub classes of edges can not be accomplished for both the images of Landsat TM and JERS-VNIR optical sensors. Spatial pattern of high contrast edges detected by Landsat TM and JERS-VNIR is as linear feature. High contrast edges can be mapped by on screen manual digitizing from both the classification maps of Landsat TM and JERS-VNIR images.

High contrast edges can be detected. The detection of sub classes of edges can not be accomplished from JERS-SAR image. Qualitatively high contrast edges detected by L-band HH polarisation JERS-SAR was more in number and spatial pattern of high contrast edges is a linear feature. High contrast edges can be mapped by on screen manual digitizing from the classification map of JERS-SAR images. Manual onscreen digitizing of high contrast edges and production of segment map of high contrast edges from JERS-SAR image can be done.

High contrast edges can be detected using Landsat TM, JERS-VNIR and JERS-SAR with accuracy of 80.52%, 82.27% and 85.58% respectively. Reliability of class high contrast edges for three sensors, Landsat TM, JERS-VNIR and JERS-SAR are 73.68%, 79.23% and 86.49% respectively. Onscreen manual digitizing of high contrast edges from the classification map of JERS-SAR image gives reasonably higher accuracy (81.25%) compared to those of Landsat TM (78.84%) and JERS-VNIR (80.08%).

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