JOURNAL OF AGROFORESTRY AND ENVIRONMENT
ISSN 1995 - 6983
journal homepage : www.jaebd.com

ENVIRONMENTAL AND SOCIO-ECONOMIC DISASTER DUE TO FARAKKA BARRAGE IN BANGLADESH- A REMOTE SENSING AND GIS EVALUATION

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Abstract: Bangladesh is the deltaic country lies on the largest delta of Ganga-Brahmaputra basin in the South Asian region. The country has 54 transboundary rivers and 80 percent of the country's surface water comes through the basin that originated from the Himalayas. India installed Farakka barrage over the Ganges river 14 km from Bangladesh near Chapainababgonj boarder in 1974 to divert water from it. Since the commission of the barrage, the rivers in the western part of Bangladesh are silting up and few of them have already dried up resulting shrinkage or waterways to 7,000 kilometers from about 24,000 kilometers. Landsat TM/ETM images of 1990 and 2000, were utilized to develop false colour composite (FCC) images with the bands 347 (RGB) for visual analysis of the effect of Farakka barrage. The normalized vegetation index (NDVI) and unsupervised classification were also done to discriminate the vegetation level, extent of water and bare land, and to see the land use pattern in the region. The image analysis reveals that the land use pattern has changed significantly in the region over the time. The water flow in the rivers in 2000 image has reduced comparing to 1990 image, drastic change in the quality and availability of water, invasion of salt water into upstream rivers and underground aquifers, as well as the related changes in the soil. It is also revealed that with the recession of freshwater flow from upstream, saline water intrudes into the south-western rivers, increasing significant number of shrimp ponds without proper planning which posing threats to the overall ecology, agriculture, forestry, fisheries, industry, coastal erosion and infrastructure. The world's largest mangrove forest, the Sunderban is under threat, has already shown dying out effect due to increase in salinity level in the estuarine rivers flowing through it. On the other hand, the barrage has been causing desertification in northern part of the Ganges river catchments.

Keywords: Farakka barrage, Mangrove forest, Water diversion, Landsat image, NDVI, Unsupervised image classification, False colour composite

Introduction

Bangladesh is a lower riparian country located within the flood plains of three large river systems – the Ganges, the Brahmaputra, and the Meghna. The river systems drain an area of 1.72 millions sq kilometers within Bangladesh, India, Nepal, and Bhutan. About 8 percent of the catchments area lies within Bangladesh (Alam and Kabir, 2004). Most of the water comes as an inflow from upper riparian countries over which Bangladesh has no control. Bangladesh is an agrarian country with its economy entirely dependent on water. Water withdrawals in upstream countries create serious adverse effect on socioeconomic sustainability and growth, the environment, and the ecology of Bangladesh. The country is experiencing floods and river erosion every year due to its geographical location and upstream abstraction of water. The massive inter-basin water transfer project of India emerges as a serious threat to the ecology of the region and survival of Bangladesh as an economically sustainable nation (Bandyopadhyay and Perveen, 2002). The entire economic system of Bangladesh could be paralyzed from lack of water adversely affecting agricultural production, fishery, forestry, navigation, and freshwater need for municipality and industry. Unilateral water withdrawal would also cause salinization of coastal belt and degradation of the world largest continuous mangrove forest and overall the ecosystems in the region.

Satellite remote sensing data is usually the most accurate and up-to-date "map" available for the developing countries (Pellikka, 2004). Remote Sensing technology provides multiple, repetitive, and update physical information for round the year. Space-born remote sensing has a good potential for change detection and good data availability and is therefore, well suited for the monitoring of land use change over a time period. Satellite images can show large areas as a satellite regularly passes over the same area capturing new data every time, shows a change in the land use and condition can be routinely monitored. Multitemporal measurements are particularly important because monitoring efforts by remote sensing data to assess plant biophysical characteristics and changes in land use/land cover (LULC) are often confounded by spectral patterns that change with climate from season-to-season and year-to-year (Kavin *et al*., 2001).

Therefore, the objective of this study was to apply remote sensing technology to detect and evaluate the state of vegetation, land use and land cover changes, estimation of rice cultivation area and the state of water in the region after commissioning of Farraka barrage using multi-temporal Landsat TM/ETM images data obtained in mid November 1990 and 2000.

Materials and Methods

Study area: The study area is located between 24^{0}00´ north latitude and 90^{0}00´ east longitude. The area covers the Ganges River catchments which have been mostly affected by the Ganges barrage installation (Fig. 1). The river Gorai, Modhumati, Arialkha, Ichhamoti, Kumar and Kapotaskha are the branches flowing through the study area which receive water from the Ganges in the upstream flowing towards the Bay of Bengal. On the other hand, Baleshar, Pasur, Rupsa, Raimongal and Hariabhaga are estuarine rivers connected to the land and the sources of saline water flowing towards the land. Climatically the area has less rain fall than the other parts of the country (Kam, 2007) where irrigated rice, winter vegetation, fruits, and orchards are the main crops produced in the area. Water based activities mostly dominated freshwater fin fish culture in the upstream and shrimp, prawn, crab and marine fin fish culture in the down stream of the river catchments area. Some people are also engaged in fish harvesting from the natural water bodies for their livelihood.

The methodology of this study is based on Remote Sensing image interpretation which is supported by the secondary data collected from a range of sources like field visit, literature review, internet search and consultation with the relevant reports. The overall methodology for this study is presented in Fig. 2 and the details are as follows: Multi-temporal Thematic Mapper image data obtained from Landsat-5 and Landsat-7 launched by NASA, USA was used (Table 1). Landsat TM/ETM image has 7 bands with 3 visible and 4 infrared channels including one thermal band. The spatial resolution of one pixel of TM image is 30m by 30m except thermal band with 120m by 120m.

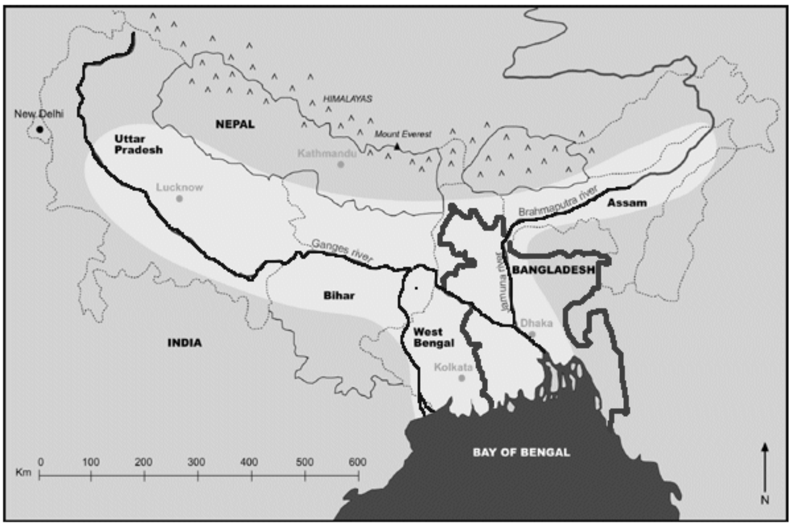

Fig 1. The Ganges-Brahmaputra basin and their catchments area.

Table 1. Landsat TM/ETM image information used in the study.

Image Data	Date of satellite over pass	Path -Row	Season	Remarks
Landsat TM	14 November 1990	138-44	Post monsoon	Image acquired sixteen years after the Ganges barrage installation
Landsat ETM	17 November 2000	138-44	Post monsoon	Image acquired twenty six years after the Ganges barrage installation

Satellite Image Data: The Landsat TM/ETM images were down loaded from the Global Land Cover Facility of Earth Science Data Interface web site of Maryland University, USA. Table 1 describes the details of the data down loaded and used in the study.

Image Enhancements: The images were subjected to preliminary digital enhancements in order to enable their visual interpretation. False colour composite (FCC) using the Landsat TM/ ETM bands 3, 4 and 7 (visible red, near infrared and infrared respectively) were found to give a clear visual discrimination of the vegetation, water and water-bare land boundary (Gray ***et al.*** 1990; Trolier and Philipson, 1986). An associated contrast stretch of 5% was also applied to give a better visual representation.

Normalized Difference Vegetation Index: The Normalized Difference Vegetation Index (NDVI), invented by Rouse *et al*. (1974), were applied to calculate the state of vegetation on the land surface for each image from the RED and NIR bands of the satellite data using equation 1. NDVI expresses vegetated ground and the vegetation condition and is closely related to the leaf area index (LAI). The land use changes between different years can be studied by NDVI ratios. Dense vegetation shows up very strongly in the imagery, and areas with little or no vegetation are also clearly identified. NDVI also identifies water and bare lands clearly. NDVI takes values between -1 to 1, the value 0.5 indicating dense vegetation and value <0 indicating no vegetation. Produced NDVI maps were reclassified in to six land use categories depending on the DN values as deep water, shallow water, bare land, very low vegetation, moderate vegetation and high vegetation types.

$$\text{NDVI} = \frac{\text{Near } NIR \text{ (Band 4)} - Red \text{ (Band}}{\text{Near } NIR \text{ (Band 4)} - Red \text{ (Band 3)}}$$

Where, NIR is the DN in the near infrared band and RED is the DN in the red band in the Landsat TM/ETM images.

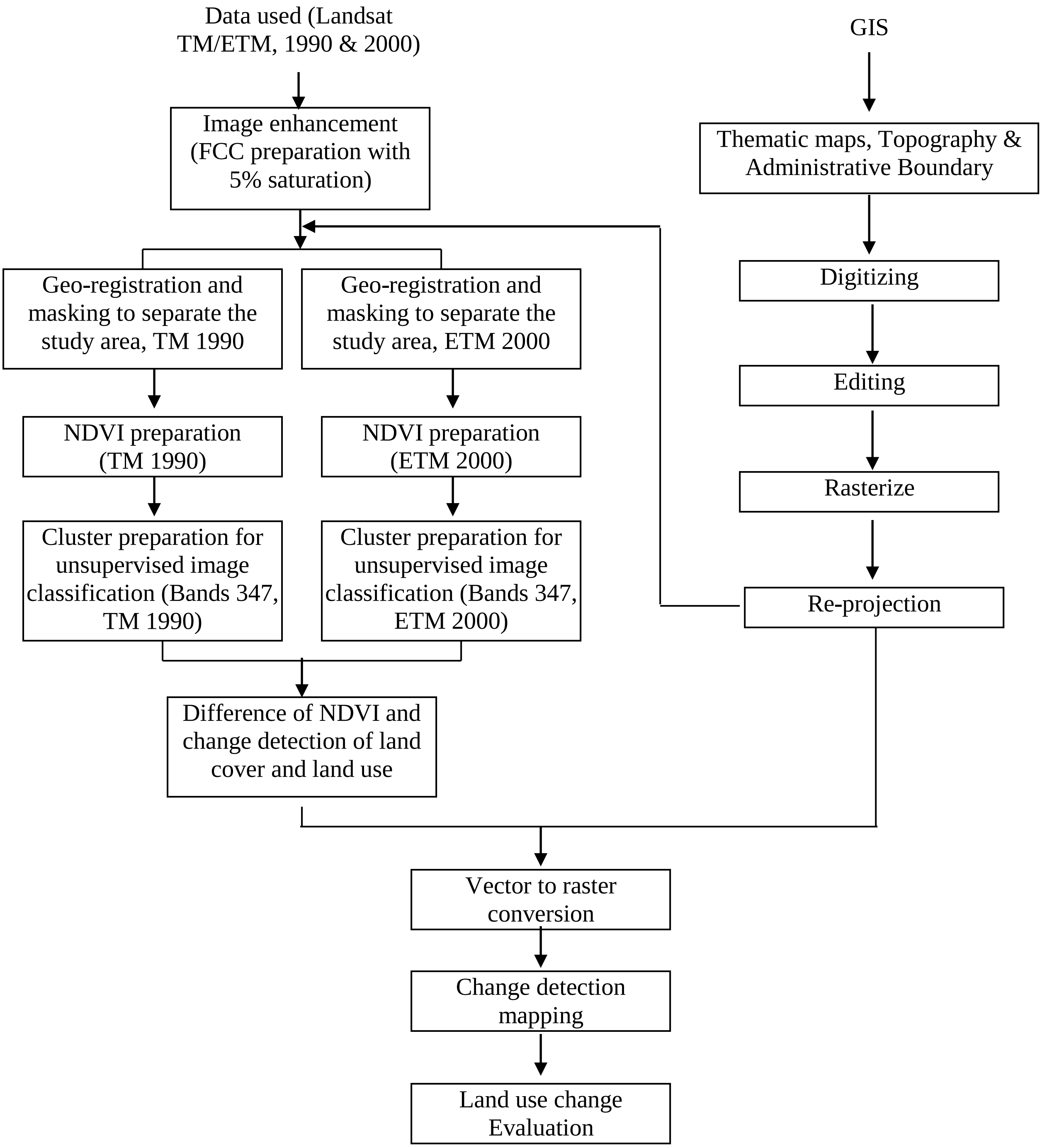

Fig. 2. Schematic diagram of the major steps of research methodology adopted in the study.

Unsupervised image classification: The logic by which unsupervised classification works is known as cluster analysis and this is provided in IDRISI KILIMANJARO by the CLUSTER module. This module groups together features with similar reflectance patterns. The module was used to produce an unsupervised classification from the image bands of 3, 4 and 7 and this provides an interpretation of the number of spectral classes in the raw data. This was conducted in several steps. Cluster was used with the option of user selecting the number of classes for the final images. The module then classifies the images into discrete categories. This process was conducted using 15 fine clusters. Following the cluster, a 3 x 3 mode FILTER was carried out to eliminate small clusters with less than 9 pixels. The clusters were then identified and further reclassified into five land cover classes based on the colour composite Landsat TM image and field visit data.

Results and Discussion

False Colour composite images of 347 bands from mid November for 1990 and 2000 were obtained (Fig. 3), which was used to guide the land use and land cover classification and NDVI image interpretation. In the FCC image of 1990, blue and black represent the water colour, by contrast the water colour is reddish to brown in 2000 FCC image which is the indication of turbid water. The other colours in both the images represented the same land use phenomenon. Detailed vegetation index maps of south west Bangladesh were also produced (Fig. 4) and reclassified in to six land use categories (Fig. 5) and total area in various land use classes was calculated. The NDVI images interpretation showed that the deep water, shallow water, bare land and low vegetation are higher in 2000 image than in the 1990 image (Fig. 6). This is because extent of brackish water shrimp *ghers* and freshwater prawn and fish farms has increased a lot during the years between the dates the images were acquired. The interesting thing is that the gradual increase in water bodies in the southern part and decrease tendency in the northern part is noticed. According to the MOFL (1997), coastal aquaculture increased from 20,000 ha in 1994/1995 to 135,000 ha in 1996/1997 period. On the other hand, moderate and high vegetation areas are much higher in 1990 image than the image of 2000 (Fig. 5). It is also noticed that the occurrence of moderate and high vegetation is comparatively higher in northern part in 1990 image than in 2000 image due to scarcity of water in the region. The other reason behind the thin vegetation present in 2000 image in southern part is to expansion of saline water shrimp *ghers* in the area. Karim (2006) mentioned that the cropping intensity was 113% in 1973 which reduced to 105% in 1985 in the area that has further reduced to 100% in 1999 which is much lower than the national average (151%). The drastic fall in water level of the Ganges River during the post-Farakka years seriously reduced the soil moisture, increase soil salinity, and non-availability of surface and groundwater that affected the agricultural productivity in southwestern region. He also mentioned that the brackish water shrimp cultivation and less water flow in the rivers is the main reason for decrease in cropping intensity in southwestern part of Bangladesh. NDVI values were between -0.94 to 0.75 and -0.93 to 0.69 in 1990 and 2000 images respectively, that means the state of vegetation were higher in 1990 image than in the image of 2000 which quantify the result mentioned by Karim (2006) and unsupervised out come of the present study. In addition, the global worming and future sea level rise would incresed the cyclone intensity and the storms could reach further inland, causing the loss of the world's largest mangrove forest (the Sundarbans), river bank and shoreline erosion, salinity intrusion into aquifers and upstream rivers and the devastating flood could damage the infrastructures, crop failure, fisheries destruction, loss of biodiversity, and dispersal the people far from their homes (Larson, 2003).

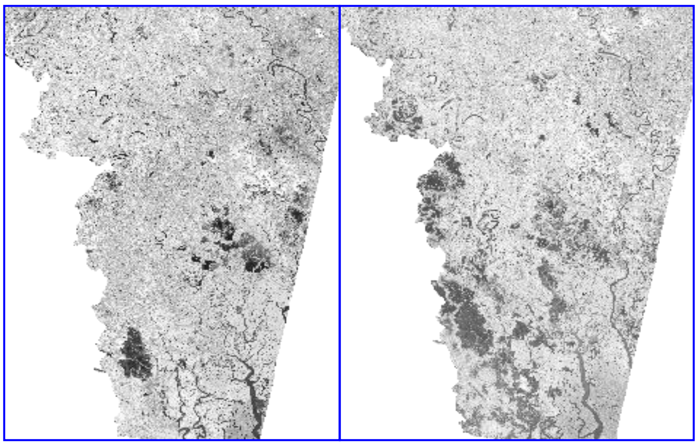

Fig. 3. False colour composite (FCC) images of bands 3, 4 and 7 of 1990 and 2000.

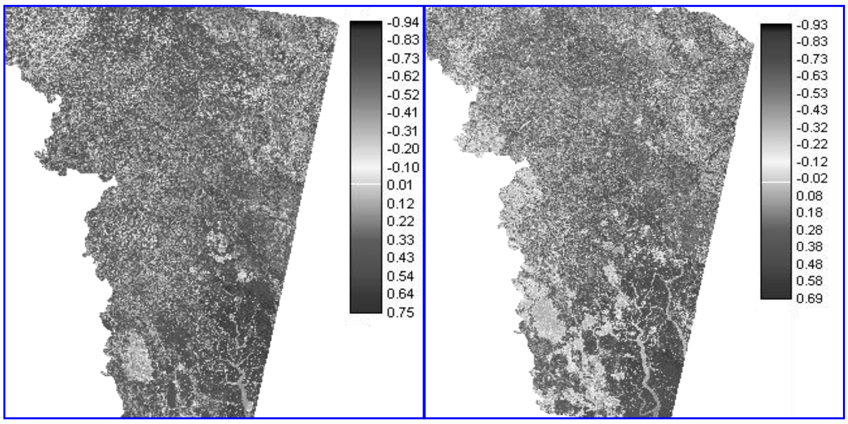

Fig. 4. Normalized Vegetation Index (NDVI) images of red band 3 and near infrared band 4 of 1990 and 2000.

Produced cluster images were reclassified into five distinct land use categories looking at the topographic map and FCC images such as water bodies (i.e. shrimp *ghers*, ponds, rivers, canals and other form of water bodies), homestead trees, aman rice, bare land and agricultural crops (Fig. 7). The results obtained through unsupervised classification of the two date images showed similar trend as NDVI images.

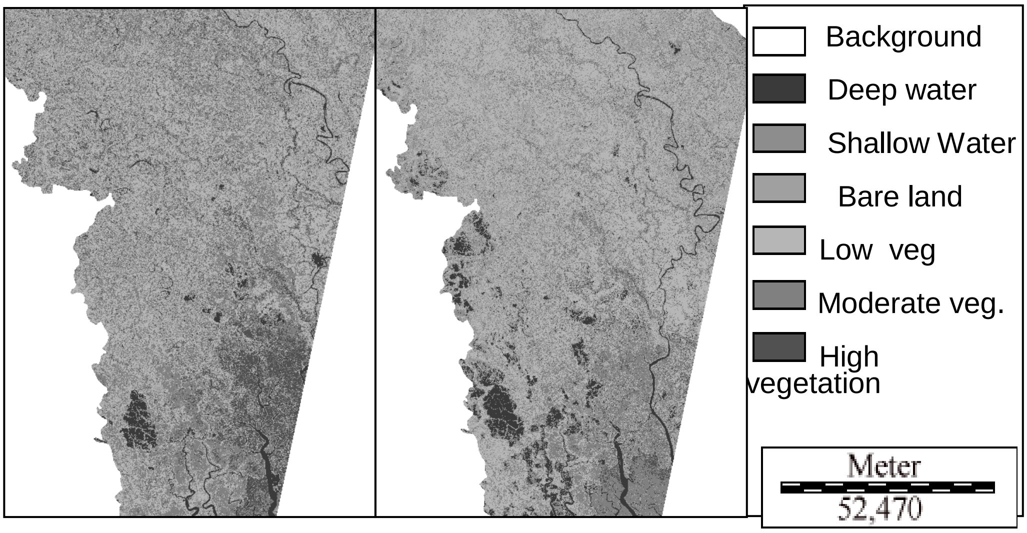

Fig. 5. NDVI images classified into six distinct land use categories of 1990 and 2000 image.

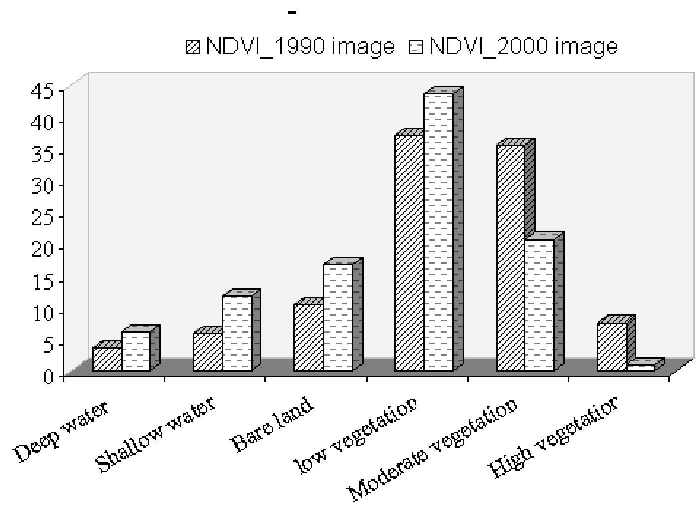

Fig. 6. Land use changes in two different dates NDVI reclassified images of 1990 and 2000.

From the unsupervised image classification, it is clear that the water area has increased in 3.07% and bare land increased 12.38% in 2000 image than the image of 1990. By contrast, the other land use categories like homestead trees, aman rice and agricultural crops areas has decreased 6.83, 2.75 and 5.86%, respectively in 2000 image than the image of 1990 (Fig. 8). This is due to the freshwater flow has declined almost 60% since 1973 in the Sibsa and Pasur river systems which are the major rivers in the area (Mirza, 2002). The possible reasons of water area and bare land increased and homestead trees, aman rice and agricultural crops area decreased could be the reduction in freshwater flow from the upstream and brackish water intrusion in the down stream (Sarker *et al*., 1999). Mirza (2002) also mentioned that the construction of the Farakka Barrage in 1973 on the Ganges River by neighbouring country has silted up most of its southbound distributaries in Bangladesh leading to the Sibsa and Pasur river systems and impacted the carrying capacities of these rivers. As a result the dry season as well as the wet season flow in many of these rivers is either cut off or substantially reduced, lowering the ground water level causing ecological devastation, as well as desertification in northern part, while southern region is getting more and more salinization as in the dry season tidal water pushed further inland during the high tide.

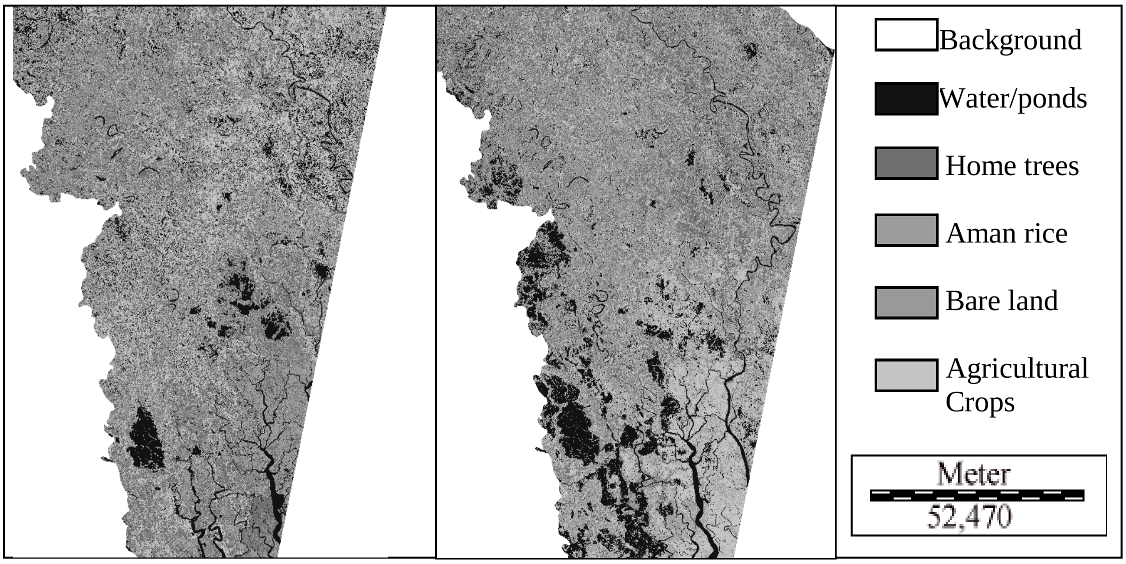

Fig. 7. Unsupervised land use classification of 1990 and 2000 images.

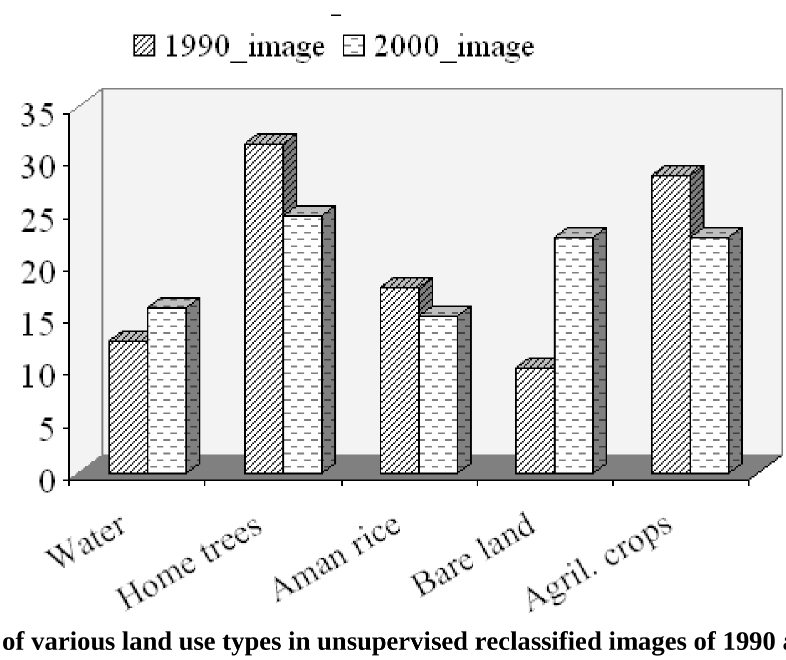

Fig. 8. Comparison of various land use types in unsupervised reclassified images of 1990 and 2000.

The heavily silted river beds frequently produce devastating floods and river erosion which prolongs the suffering of the people living in low lying areas making them vulnerable to food insecurity, indebtedness, gender discrimination, unemployment, least access to health and education and other government services.

Conclusion

The study showed that the bare land area has increased sharply as most of the rivers in south-western Bangladesh are being silted up and a few of them have already been dried up in the last few years mainly due to the unilateral regulation of the Ganges water by upper riparian neighbour country. The rivers now have very lean flows during the dry season that make them practically difficult for navigation and irrigation of the agricultural hinterlands and in the wet season, the heavily silted river beds frequently produce devastating floods and increased the intensity of river bank erosion. With the recession of water flow, saline water intrudes into the south-western rivers posing threats to the overall ecology, agriculture, forestry, fishery and the source of drinking water. Direct damage caused to Bangladesh in these sectors amounted to about $3 billion since the barrage installation. If indirect losses are taken into account, the amount would increase significantly (ASB, 2006). According to the

Bangladesh Water Development Board (BWDB), at least 20 rivers in south-western Bangladesh are being silted up while four have already been dried up and the riverbeds are under cultivation. Eventually, floods are occurring in the region in the recent years mainly during the rainy season (Das, 2005 and Rahman, 2004).

On the other hand, the result of the study also showed that the agricultural crops and homestead tress has decreased remarkably which means the grazing land for cattle has reduced. Moreover, the brackish water shrimp faming area has increased dramatically allowing saline water in further inland areas which also reduced the grazing land as well as agricultural crop cultivation.

Bangladesh and India has signed the Ganges water-sharing treaty in December 1996. Both the countries were agreed to share the dry season (January-May) discharge of the Ganges River at Farakka point, West Bengal, India (Mirza, 2002). The sharing season is divided into fifteen 10-day cycles. The treaty is based on the discharge of the Ganges at Farakka over the period 1949-1988, taking the average discharge values of the periods 1949-1973 (pre- Farakka) and 1975-1988 (post-Farakka). Since 1975, however, the dry season discharge of the Ganges at Farakka point has declined due to increased upstream uses for agriculture and other purposes. Therefore, the likelihood of occurrence of the 1949-1988 discharge values has reduced. The results indicate that reductions in the discharge due to withdrawals upstream of Farakka put Bangladesh at risk of non-availability of the shared discharge agreed in the treaty. Failure of the sharing arrangement in two out of five years (1997-2001) since the enforcement of the treaty supports the results of the analysis. Due to the sharing arrangement of the treaty, Bangladesh may be at a greater risk than India in future if more water is withdrawn in the upstream of Farakka (Mirza, 2002).

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