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CHANGE DETECTION OF SHRIMP FARMS UNDER SEMI-SALINE COASTAL AREAS OF BANGLADESH: AN RS AND GIS INTEGRATED APPROACH

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Abstract: Remote sensing and GIS are the modern techniques for change detection of land features. These techniques have been used for the analysis of coastal land use and land cover transformation in a semi-saline area. The Debhata Upazila was selected as the study area. Landsat MSS, TM, IRS image and other vector GIS data are used for change detection of shrimp farms development for a time span of two decades, 1973-97. The visual and digital interpretation methods and statistical summarisation techniques are used for identifying different types of land uses, mainly shrimp farming areas from the satellite data. The result reveals that the significant amount of wetland and traditional paddy cum gazing lands have been transformed into shrimp farm between the years 1973 to 1990. The vegetation covers of both highland and lowlands have disappeared due to the expansion of shrimp farms. Besides the gradual expansion of settlements has taken up considerable amount of agricultural lands as well. The RS and GIS integrated approach for change detection in coastal areas appears to be a promising tool to adopt.

Key words: remote sensing, change detection, shrimp farm, coastal area, geographical information system (GIS), land use, land cover.

BACKGROUND

Change Detection

Change detection is a technique mainly used for identifying the transformation/ modification occurred in a feature. In traditional spatial feature change detection of two time periods may be easily done through photographic or any other form of graphical portrait/map comparison, provided suitable past photo mosaics or graphical/map records are available. In satellite remote sensing, such change detection techniques primarily rely upon the differences on the digital number (DN) values between corresponding pixels in the two or more images acquiring at different times over the same area (Spiropoulous & Granger 1993). These differences in DN values are related to the changes in spectral reflectance of the corresponding features in the two or more images and consequently reflect changes in the feature characteristics (Alam and Hossain 1998). These change

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detection techniques when customised in a GIS format become a powerful tool for analysing the evolving nature of a spatial feature.

Application of Change Detection Techniques in Coastal Land use Applications

The RS and GIS change detection techniques have been used widely in analysing land use transformation in the coastal areas both in the developed and developing countries (Thant et al 1988, Maniakshi et al 1999, Pramanik and Jabbar 1990 and Shahid et al 1992). Remotely sensed data being rich in geographical information and available on a timely fashion are capable of providing the essential database, especially the spatial data e.g. land use and land cover. Besides recent developments of change detection software in GIS have enhanced the capability to derive change statistics. Geoscientists are using RS and GIS to identify the appropriate land sites for a particular use e.g. shrimp pond siting in the coastal area (Shahid 1989); evaluating site environments for aquaculture development (Ramesh and Rajkumar 1996). Remotely sensed data are also undertaken for identification of detectable changes of coastal land and monitoring natural and manmade changes (Klemas 1975). The available research work on coastal areas of Bangladesh using satellite data are mostly based on manual interpretation, virtually no study is available through RS and GIS data integration (Saifuzzaman 2000). The advantages of such data integration technique over traditional manual intrepretation includes:

- Rapid automated interpretation of imagery using optical and digital enhancement techniques;
- Being integrated with GIS, database statistics, and a wide range accurate thematic map may be generated very quickly. Besides, a wide range of ancillary data may be digitally compared with remote sensing data, which helps in enhanced feature discrimination and decision making in a well-informed condition.

Given this background, the present study aims at using RS and GIS together for understanding the changes occurred in coastal shrimp farming lands of the semi-saline areas in Bangladesh.

OBJECTIVES

The study concentrated on the Debhata Thana/Upazila of Satkhira District. Specific objectives of the research efforts include:

1. To identify and detect the overall land use and land cover changes occurred in the coastal areas;
2. To analyse multi-data remote sensing data, methods and techniques for identifying spatio-temporal change for expansion of shrimp farm occurred in the coastal areas;
3. To examine the relative advantages of the various sensors **(LANDSAT MSS, TM & IRS)** to discriminate the shrimp farming sites; and
4. To integrate **RS** data into **GIS** for analysing, evaluation and mapping of the site changes between 1973-2000.

STUDY AREA

Semi-saline Coastal Area

The study area is in the semi-saline zone of the southwestern delta of Bangladesh. It is located in the south of Khulna city under the district of Khulna, borders with Bagerhat in the west and the mangrove forest of the Sundarbans in the south (Fig. 1). The area has the typical features of the Ganges tidal flood plain. The level landscape, formed in the process of erosion and alluvial deposit, is criss-crossed by innumerable meandering tidal creeks. There are levees along side the creeks and rivers, along the inner side of the embankment; they are also found along the smaller canals within the polder, which are the former tidal creeks now closed by the embankment. The increase of the salt content of the topsoil in the dry season, caused by capillary rise of the saline ground water, limits the possibilities for cultivation of a second crop.

Traditional Coastal Land Use and Associated Problems

Traditional coastal land use. On the basis of different physical environment, coastal areas having distinct types of traditional land use, such as, agriculture, shrimp cultivation, homestead with vegetation, and others. Shrimp cultivation in the coastal areas were first started in some Upazilas of Satkhira district. Gradually, it expanded to almost all Upzilas of the coastal districts (Elahi et al 1998). Previously in the Satkhira region majority of the population were engaged in agriculture. Fallow lands were used for grazing and fishing ponds were used for culture fisheries. The most common practice was agriculture (June to Oct) and then long fallow period (Nov to May).

Land use change and associated problems. Different types of land use practices are shown in Bangladesh coast using Landsat data for identifying land use features, and may be used for quick look detection of changes in land use features due to environmental changes.

A study of Alam et al (1990) on aerial estimation of land use of Paikgacha Thana, 1975-1987, shows the changes of land use from agriculture to shrimp farm, and revealed the broad land use change. Depletion of forest in the coastal region for increasing human interference and haphazard horizontal expansion of shrimp farming devoid of proper planning not only damages coastal environment but also bring about an imbalance in the land use and environmental system as a whole (DDP 1995).

Shrimp Farming Environment of Debhata

The Debhata is known for its extensive shrimp farming area. Like all other shrimp farming areas, the occurrence of shrimp farms are subject to the availability of some specific environmental factors which includes:

* Low-lying coastal area with high rates of water salinity.
* Land must be adjacent to and/or well connected with active tidal channels wherein regular tidal exchange takes place.

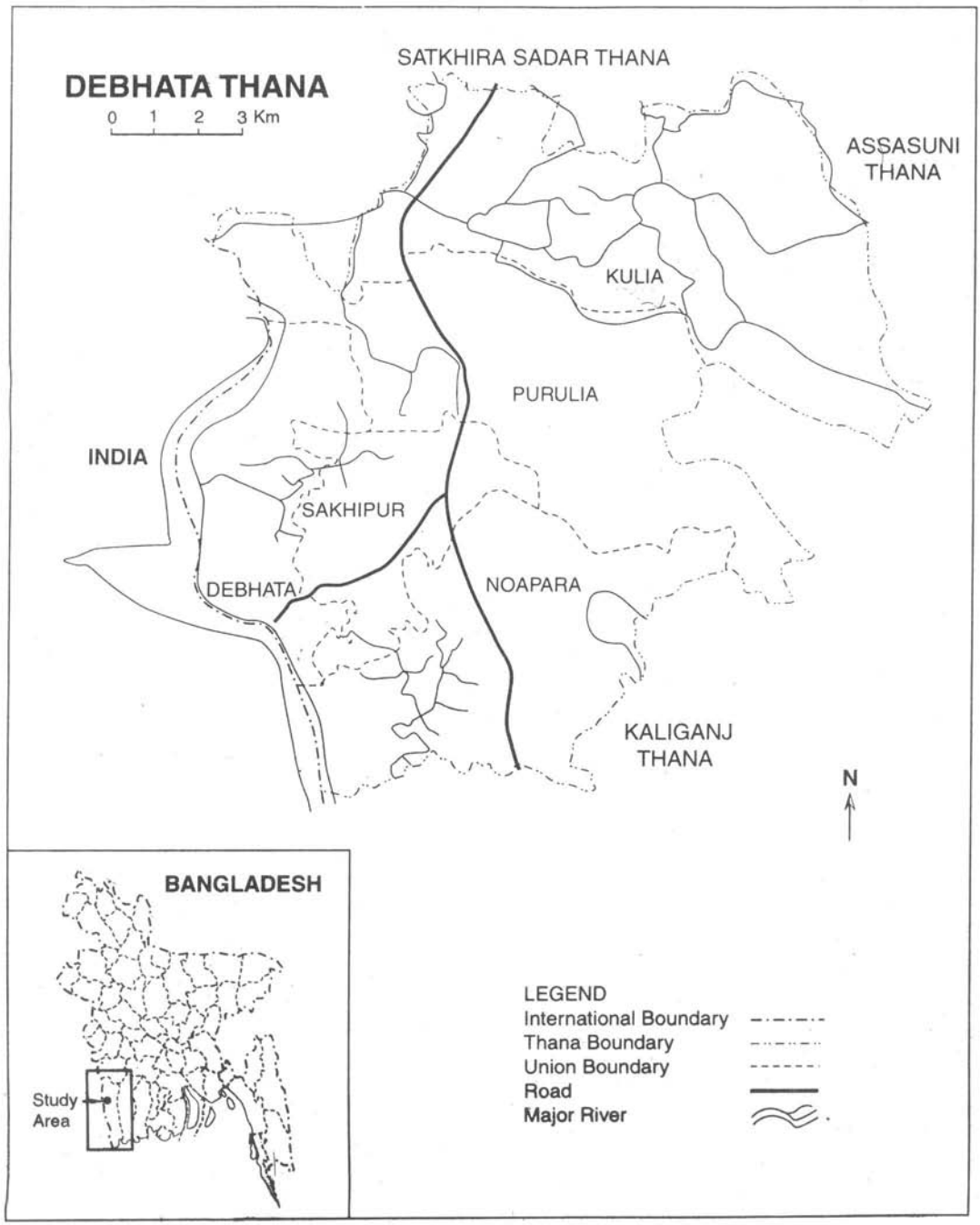

Fig. 1 Study Area

* Low population density has helped on switching over easily to extensive farming practices instead of traditional paddy culture. There are very large size plots, which were previously treated as wetlands and traditionally used for paddy cultivation, as a monocrop.
* Due to semi-saline condition of the area, the traditional cropping practice cum extensive grazing have limited scope to shift economically to other agricultural practices instead of shrimp farming, considering the net rate of return. That is why, the saline aquaculture practices have been increasing in this area.
* Because of almost flat terrain, land can be easily converted into shrimp farm.

Area and Location

Debhata Upazila is situated on the western side of Satkhira District. The study area is a part of Satkhira district, located at the western boarder of Bangladesh, and is connected with Sadar Upazila on the northern side, Ashashuni and Kaligonj on the eastern side, Kaligonj and West Bengal (India) and Satkhira Sadar Upazila on the western side (Fig. 1). It is situated between 2203' to 22041' north latitude and 88056' to 89006' east latitude, covering an area of about 17107 hectare (171 sq. km.) with 5 unions. Out of the total area, 0.57 sq. km. is water body and river (Saifuzzaman 2000).

DATA AND METHODOLOGY

Types of Data

Both published and unpublished data were used in coastal change analysis. Detailed characteristics of satellite data used in the study are referred in Table 1. The **RS and GIS** methods and other statistical data summarisation techniques have been used for change detection analysis. The functions of remote sensing in the study are to identify the coastal shrimp farming areas of different study years, evaluate the land use map data of different years, overlay the maps of different year for identifying changes, and generate statistics. The GIS functions are used for combining vector layer into the RS raster data for identifying land use and land cover. The data are analysed by using different GIS and RS software.

Table 1 Types of RS Data Utilised in the Present Study and their Sources

SENSORS	TIME	BANDS	SOURCE
LANDSAT MSS	1973	1,2,3,4	EGIS-IIBangladesh
LANDSAT TM	1990	1,2,3,4,5,6,7	SPARRSO,Bangladesh
LANDSAT TM	1997	1,2,3	SPARRSO, EGIS-IIBangladesh
IRS-1C	1998	Panchromatic	EGIS-IIBangladesh

Vector GIS data combines both geographically referenced or spatial data and non-spatial or attribute information. A large number of attributes information were necessary and the information were collected from primary and secondary sources.

Methods of Data Processing and Analysis

The research design is based on the research activity and approaches in order to fulfil the aims and objective. It is composed mainly satellite and other data collection, visual interpretation and digital analysis of the original image such as geometric correction, extraction of the study area, data classification (unsupervised), ground verification, statistics generation from the data, overlay maps of different years image for change analysis and vector and raster data integration and analysis. Figure 2 shows in a flow chart the research methods used in coastal change analysis. For image processing ERDAS Imagine 8.4 has been used. Arc/Info and ArcView software have been used for all GIS related analysis, which includes statistics generation, map overlaying and map generation. Specific data layers used for map overlaying consisted of multiple visible and infrared bands of the satellite images, as referred in Table 2. This was purposely done, as the available base image of 1973 consisted of visible and infrared bands.

Table 2 Satellite Data Layer Used in the Study

SENSORS/PLATFORM	YEAR	LAYER USED	VISIBLE & NEAR INFRARED BAND
LANDSAT MSS	1973	4	Red (4), Green (2), Blue (1)
LANDSAT TM	1990	7	Red (4), Green (3), Blue (2)
LANDSAT TM	1997	3	Red (3), Green (2), Blue (1)
IRS-1C	1998	Single	Single

SPATIAL CHANGES IN SHRIMP FARM 1973-1997

The results of the analysis for the special types of land use changes of Debhata Thana between 1973 and 1997 are presented in this part.

Changes in the Study Area as Inferred from Visual Interpretation

The objective of the visual interpretation was to identify the feature diversity in the images of each year and, then, to interpret the changes of feature diversity between the images. For feature identification, different FCCs have been tested and the optimum one has been selected for the image of each year. Table 3 shows the interpretation keys of the three LANDSAT images inferred from visual interpretation.

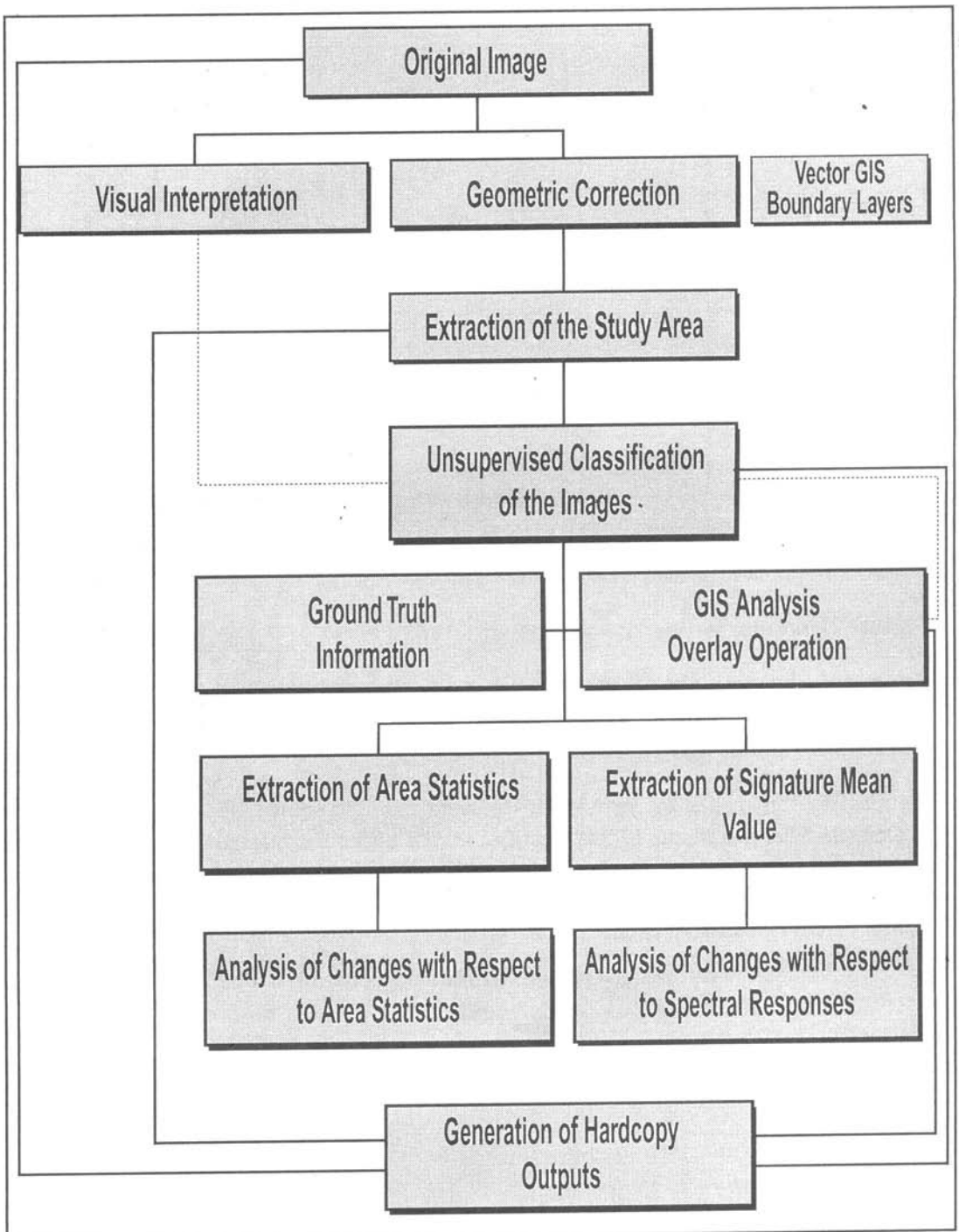

Fig. 2 Flow chart shows the methodology of the present study

Table 3 Interpretation Keys Developed for the Three Images (modified from Saifuzzaman, 2000)

FEATURE	TONE	TEXTURE	SHAPE	LOCATION	ASSOCIATION	REMARKS
Settlement	Deep red	Rough	Mainly linear	With Vegetation	Agricultural and fallow land	Homestead is merged with vegetation
Vegetation	Red and Light red	Medium smooth	Irregular		Settlement near the River	
Bare Soil	Reddish blue	Smooth	Irregular			
Shrimp Farm Area	Blue and Deep blue	Coarse	Irregular		Canal and khal	Low lying part and river
Dry Shrimp Bed	Light blue	Smooth	Blocky		With big river	
Water bodies	Deep dark	Smooth	Blocky		With river or canal	
River	Blue	Smooth		North to South	Low Land	

Feature Dynamics in the Area during the Study Period

The feature dynamics means the changes in the type and extent of the features. These dynamics have been observed from the comparisons of the generated feature classes, its area statistics and its mean spectral responses between the three study years.

The classified images of the year 1973, 1990 and 1997 are shown in Fig. 3. The total area of Debhata Thana is about 17,342 hectare. Areas under the land use class for the three years are given in Table 4. The land use classes and their spatial changes are given below:

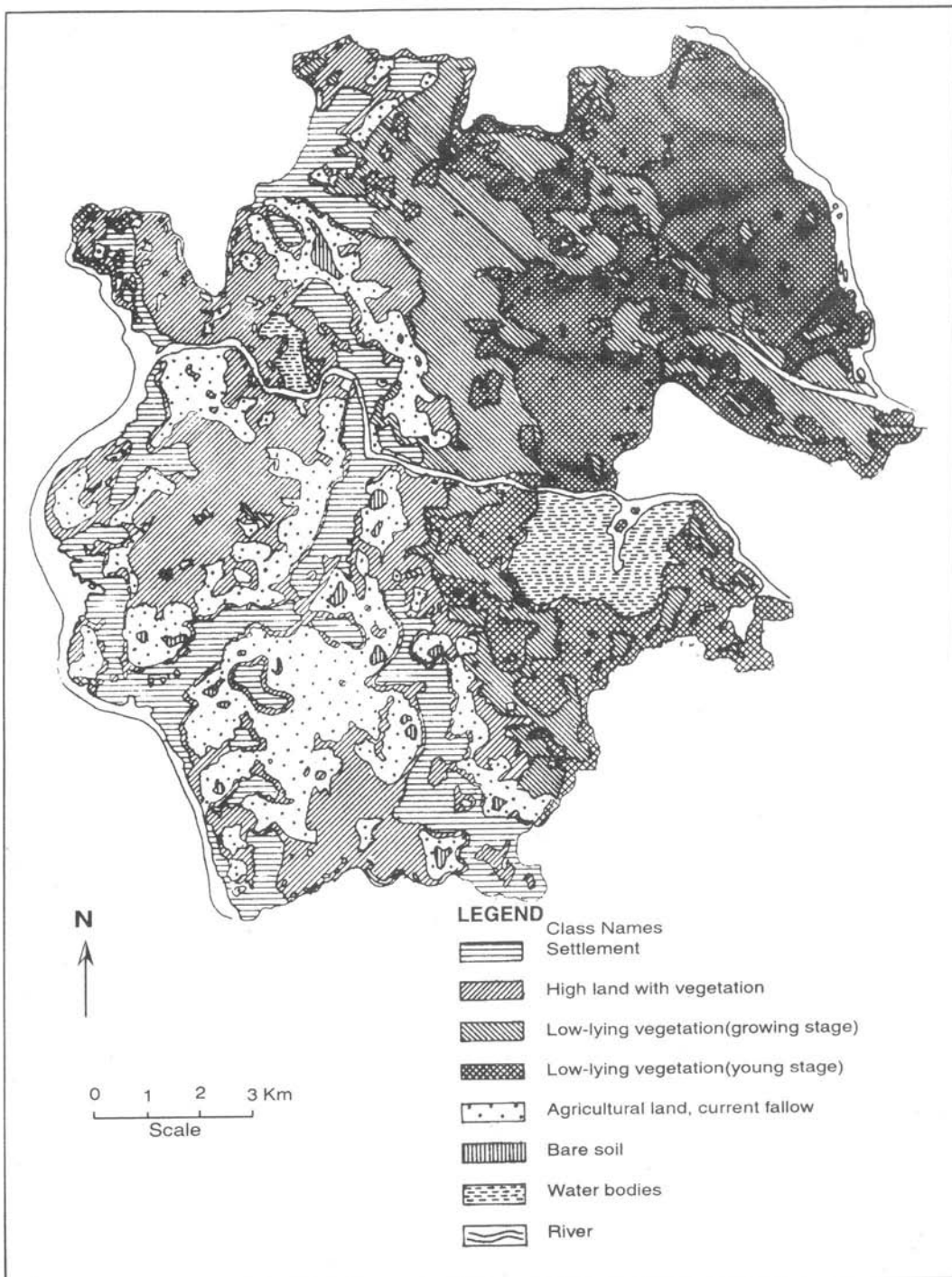

Fig. 3a Map from MSS Image of 1973

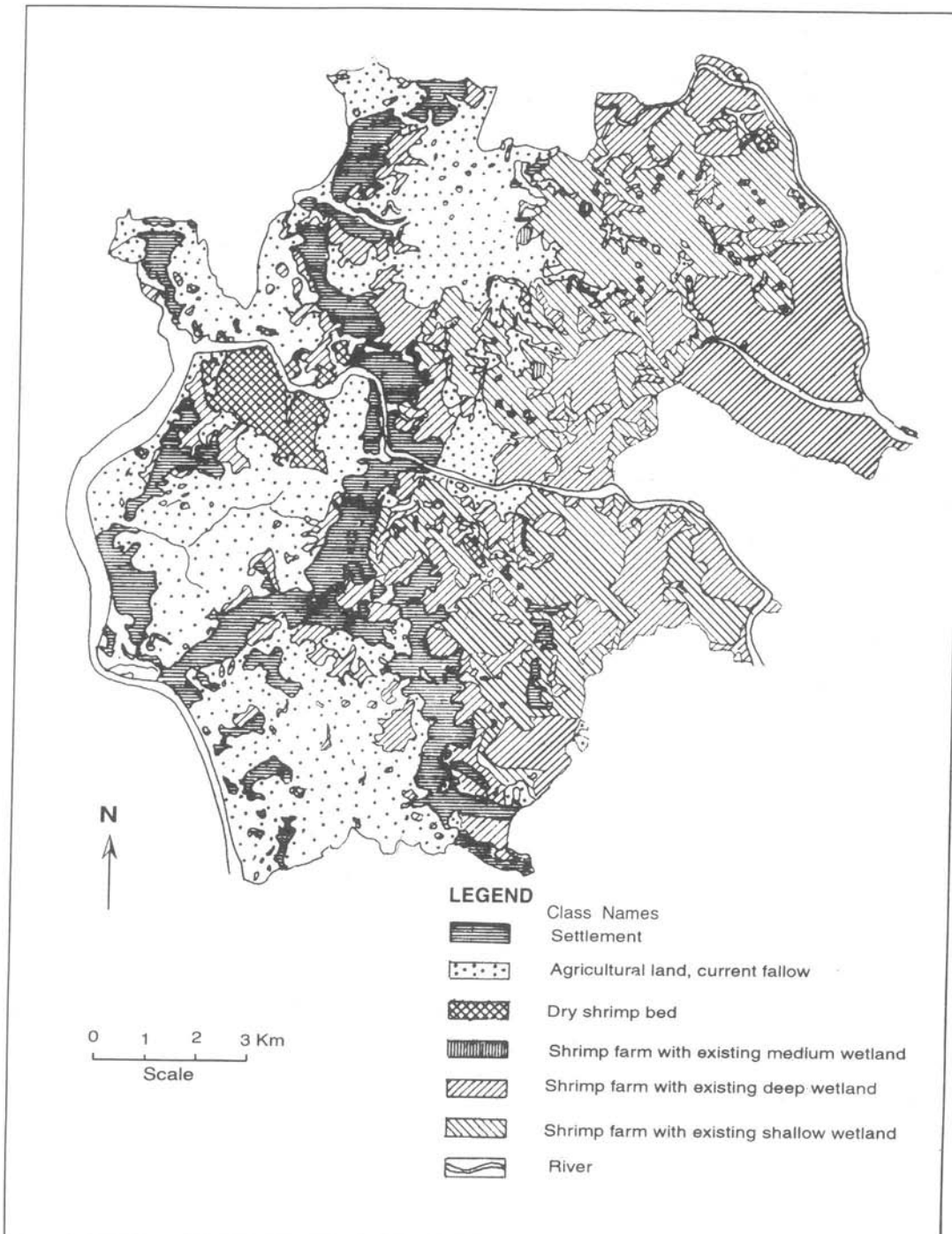

Fig. 3b Map from Landsat TM Image of 1990

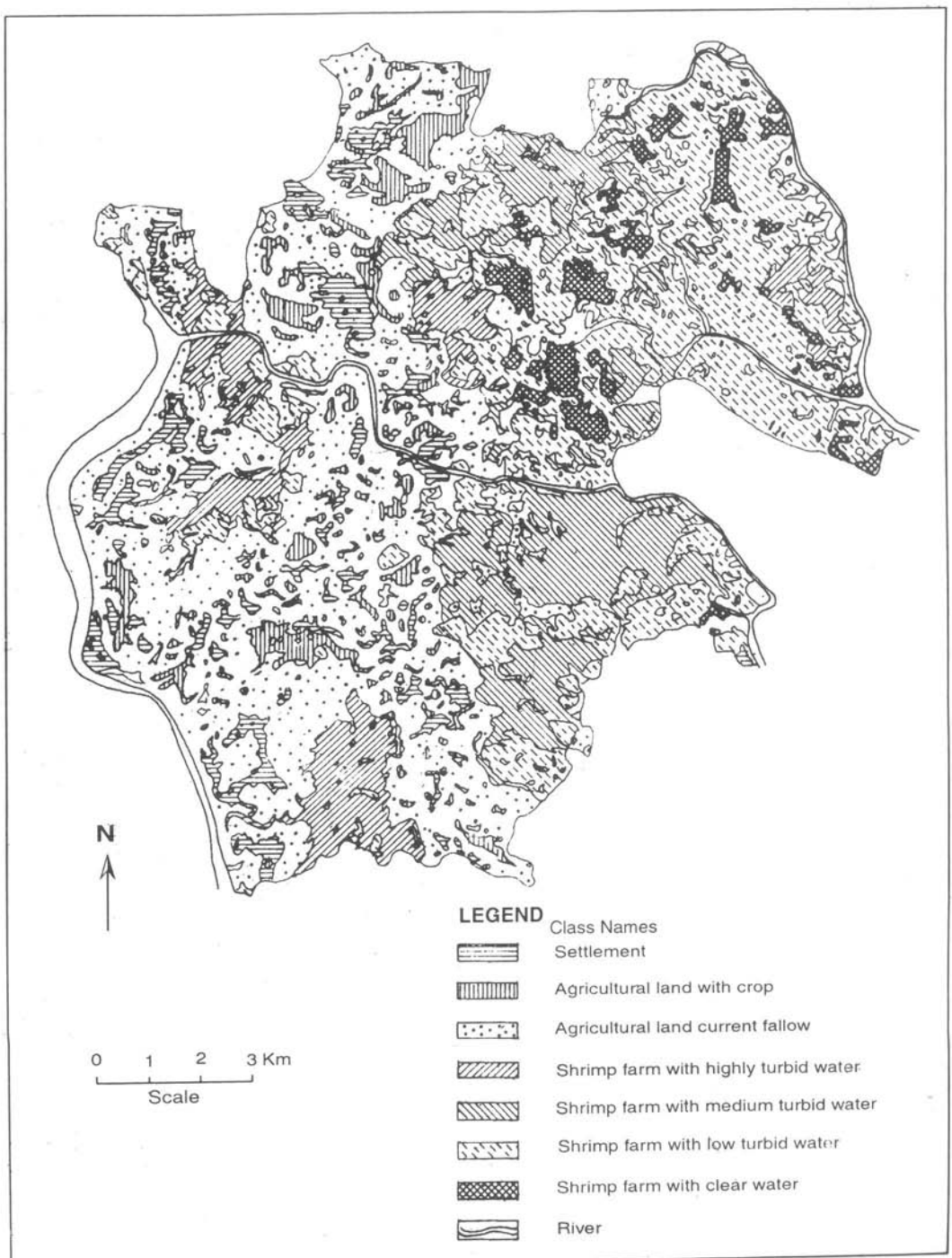

Fig. 3c Map from Landsat TM Image of 1997

Table 4 Areal Extent of Land use/Land Cover Changes of Debhata Upazila from 1973-1997

Sl. FEATURE	1973		1990		1997	
	Area in hec	% of total area	Area in hec	% of total area	Area in hec	% of total area
1. Settlement	**2114**	**12**	**2891**	**17**	**3546**	**21**
2. Vegetation	**13982**	**80**	**4446**		**4194**	**24**
Highland with vegetation	3265	19	-		-	-
Low-lying vegetation (growing stage)	3806	22	-		-	-
Low-lying vegetation (young stage)	3806	22	-		-	-
Agricultural land with crop	4248	24	-		2720	16
Agricultural land, Current fallow	2663	15	-	-	1474	8
3. Bare Soil	**182**	**1**	-	-	-	-
4. Shrimp Farm Area:	-	-	8324	48	8689	50
Shrimp farm with deep water	-	-	4680	27	1008	6
Shrimp farm with Medium water	-		910	5	3947	6
Shrimp farm with shallow water	-	-	2734	15	3734	6
5. Dry Shrimp Bed	-	-	**771**	**4**	-	**23**
6. Water bodies	**717**	**4**	-	-	-	**21**
7. River	**508**	**3**	**890**	**5**	**892**	-
Total	**17,321**	**100**	**17,321**	**100**	**17,321**	**100**

* Total area in a class has been represented in bold face

Shrimp farm. There was no trace of shrimp farm at the study area of Debhata Upazila in 1973. This particular type of land use has been developed in the late 1980s. In 1990, the coverage of shrimp farms was 8324 hectare, which was 48 percent of the total area; and this has risen by 50 percent in 1997.

Water bodies. This class constitutes with pond and other marshy land of the area that covers 717 hectare (4% of the total area) in 1973. In 1997 and 1990, there are no water bodies left, all came under shrimp farming.

The total areas of Debhata Upazila estimated from the images are 18,245 hectare in 1973, 17,321 hectare in 1990 and 17,323 hectare in 1997 (Table 4). The actual area of the Upazila is 17,107 hectare (BBS 1991). The variations of the estimated area are due to the pixel sizes and inclusion of boundary pixels. The variation of estimated area from 1973 image is much higher because of the comparatively big pixel size. The pixel size of LANDSAT TM is 30m x 30m, whereas that of MSS image is 80m x 80m.

Changes in Shrimp Farm

Major changes in the shrimp farming classes have been analysed in this section. Estimating the distribution of the areas of a class in a reference year to the different classes in a latter year has been carried out in the analysis. However, the minor changes have not been considered in the analysis.

Changes between 1973-1990. High land with vegetation about 53 percent of this area has changed of which settlement received 19 percent and shrimp farm received 34 percent in 1990. About 50 percent area of Debhata Upazila was covered with low-lying vegetation in 1973, 70 percent of the low-lying area has been converted into shrimp farm in 1990, and it raised to 78 percent on 1997 (Table 5). The agricultural land (current fallow) was about 2663 ha (15% of the total area) in 1973, which has been distributed into the settlement (58%) and shrimp farm (42%). Bare soil of Debhata Upazila in 1973 was only one percent (182 ha) of the total area. The total bare surface has been converted into the settlement (23%) and shrimp farm (43%). About 80 percent of the closed water bodies has been converted to the shrimp farm because of its suitability for shrimp cultivation.

Table 5 Distribution of Major Changes in the Debhata Upazila between 1973-1990

FEATURES IN 1973	FEATURES IN 1990 (AREA IN HECTARE)			
	Settlement	(%)*	Shrimp farm	(%)*
Settlement	-	-	-	-
High land with vegetation	601	19	1094	34
Low-lying vegetation	-	-	5639	70
Agricultural land, Current fallow	1546	58	1108	42
Bare soil	41	23	78	43
Water bodies	-	-	603	84

* % of the total area in a class / feature in 1973.

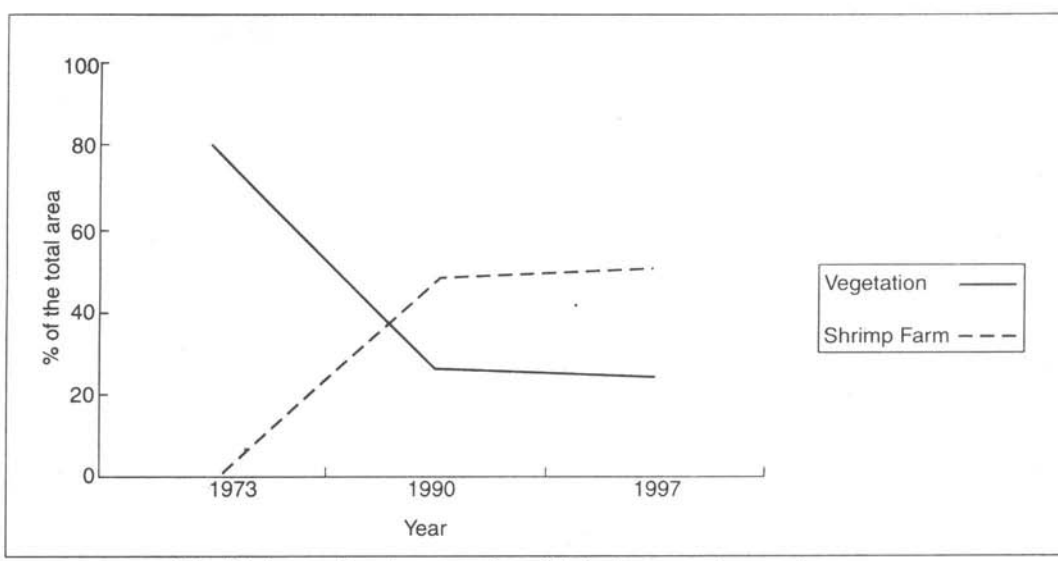

Fig.4 Shrimp cultivation expansion with the decrease of vegetation cover

Changes between 1973 - 1997. In the long time span of about 24 years, the land use and land cover have been changed drastically in the Debhata Upazila. The feature of 1973 is redistributed into different features in 1997 (Table 6). The high land vegetation is distributed to settlement (21%) and shrimp farm (35%). About 78 percent of the low-lying vegetation in 1973 have been converted into shrimp farm by 1997. More agricultural land (current fallow) has been changed in 1997 than that of 1973. The conversion of the class into settlement is about 29 percent and shrimp farm is about 21 percent. The closed water bodies in 1973 have been completely changed into the shrimp farms (92%) and agricultural land (current fallow) (7%). Because of the suitability of shrimp cultivation, the land has gone under the shrimp farm.

Table 6 Distribution of Major Changes in the Debhata Upazila between 1973-1997

FEATURES IN 1973	FEATURES IN 1997 (AREA IN HECTARE)							
	Settlement	(%)*	Agricultural Land With crop	(%)*	Agricultural Land, Current Fallow	(%)*	Shrimp farm	(%)*
Settlement	-	-	-	-	-	-	-	-
High land with vegetation	690	21	685	21	-	-	1153	35
Low-lying vegetation	596	8		14	-	-	6242	78
Agricultural land, Current fallow	1632	61		-	-	-	568	21
Bare soil	48	26		73	-	-	-	-
Water bodies	-	-	-	-	49	7	658	92

* % of the total area in a class / feature in 1973.

Changes in Spectral Behaviour for Shrimp Farming Area Identification

The spectral behaviour of various coastal land features has been analysed in this section. Mean spectral values **(DN)** of different classes in the images of 1973, 1990 and 1997 are shown in Fig. 5.

Spectral behaviour in the image of 1973. LANDSAT MSS images having four spectral bands are used for 1973. **MSS** bands 1 and 2 are invisible, and bands 3 and 4 are in near infrared region.

Water bodies and river. In Fig. 5, it was observed that the responses of the closed water bodies are lower than that of the river/canal. DN values of rivers are higher than that of the closed water bodies, but are lower than that of the other features. The DN values of river water are higher than that of the closed water bodies due to its high turbidity level. The turbidity of river water in coastal region is very high because of high tidal action in the area. So, the closed water bodies and rivers are clearly identified in the coastal area on the basis of its response characteristics. There were no shrimp farms in 1973 in the study site.

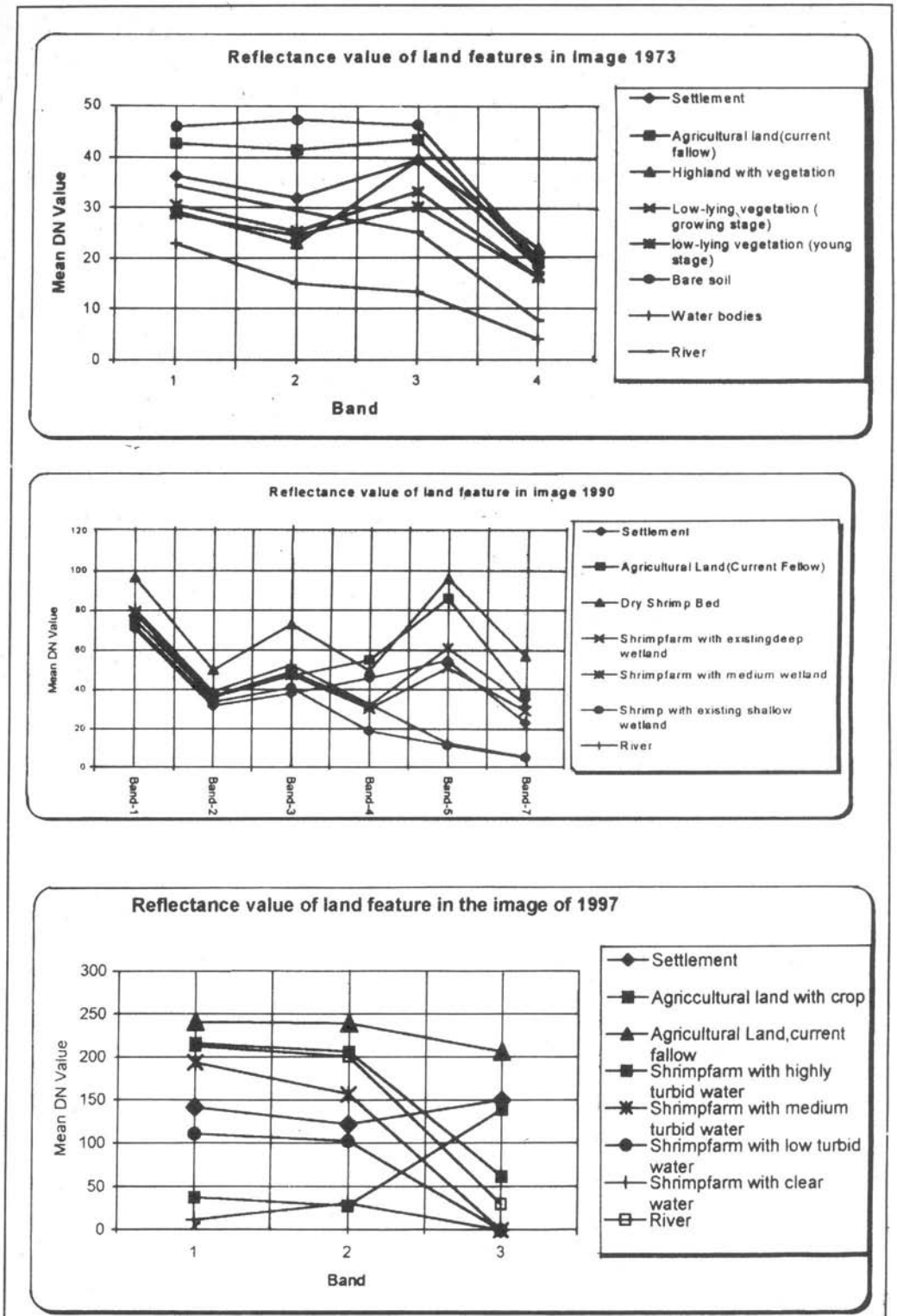

Fig. 5 DN Values of Land Feature in the Image of 1973, 1990 and 1997

LANDSAT TM image of 1990. This image has seven bands. Out of these, bands 1, 2 and 3 are invisible, band 4 is in near infrared, which is biomass sensitive, and band 5 is in middle infrared that is moisture sensitive. The intensity in band 5 increases with the decrease of moisture content in the features.

River. It was highlighted earlier that the reflectance value increases with the increase of water turbidity and decreases as water gets clear in visible bands. For this image, closed water bodies (shrimp with existing water) have lower DN values than river and exhibited similar environmental condition as obtained from the image of 1973.

Shrimp farming area. Depending on the DN values, the shrimp farming areas are divided into four subclasses. One subclass contained water and the other subclasses contained different amount of moisture contents in the soil. This moisture level can be inferred from band 5; and it is seen that 'dry shrimp bed' was the driest part in the area.

The response of shrimp farm with wetland is higher than the value of medium wetland and lower than dry shrimp farm. Thus, the shrimp-farming sites of the area had divisions on the basis of land height and land quality. The area is suitable for shrimp farming but the shrimp is not cultivated everywhere at the same time.

LANDSAT TM image of 1997. Three image bands were available. These are green, red, and near infrared bands.

Shrimp farm and river. Three subclasses are identified here. Two of which contained water and one contained dry shrimp bed with higher moisture content. The water contained in the shrimp beds were less turbid than that of the river as is inferred from their lower DN values than river water.

DISCUSSION AND CONCLUSION

Geographical Information System and Remote Sensing, as modern tools of change detection, have been applied for coastal change analysis. The result concludes that it is possible to identify the overall change of vast and complex coastal area by using these technologies. It was observed that major changes in land use and land cover have occurred in the study area over the years. Besides, the techniques were very helpful for creating spatial and attribute coastal database and feature discrimination. The high-resolution IRS data and medium resolution LANDSAT TM data were found very helpful and also successfully used for identifying the coastal complex land features. The minor features were easily detectable with the behaviour of reflectance curve.

The land use and land cover of the study area have certain distinct characteristics in 1973, 1990, 1997 and 1998 which were observed from the digital and visual image

interpretation. The remarkable changes have occurred between 1973-1990, but the changes are not much significant between 1990-1997. The land cover, with low lying and high land vegetation (acquired 60 percent of the total area) in 1973, have been changed drastically and converted into shrimp farm in 1997. The gradual expansion of settlements has taken up considerable agricultural land. The wetlands and other water bodies are totally changed into shrimp farm.

The land use change was occurred from the middle part to eastern boundary due to expansion of shrimp farm in Debhata Upazila. Some river/canal/khal are dried up and some were raised because of tidal accretion.

Biomass content of various features, like homestead vegetation have declined with the change of land use and land cover. With the expansion of shrimp cultivation, agricultural related vegetation has been substantially reduced.

It is seen from the present study that, changes in the land use and land cover are possible to infer from the differences between 1973 and 1997 image status. The low-lying and highland vegetation have decreased due to human interference with the increase of shrimp farming and improper management of forest cover.

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