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* Report to the UNDP/UNESCO Regional Project: Research and its application to the Management of the mangroves of Asia and the Pacific (RAS/86/120) - Submitted in May 1990 - updated in 1993

International Society for Mangrove Ecosystems (ISME)

ISME was inaugurated on 23 August 1990 and the seat of the Society is Okinawa, Japan. ISME takes over from the UNDP/UNESCO Regional Mangrove Ecosystems projects. ISME is affiliated to ICSU (International Council of Scientific Unions) and is part of IUBS (International Union of Biological Sciences) through IABO (International Association of Biological Oceanography). The Society was certified as a Foundation on 23 October 1992 in Japan.

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Objectives of the Study

1 Stereoscopic air photo-interpretation
2 Interpretation of the Landsat image by computer enhancement
3 Interpretation of Landsat image and aerial photographs by digitization
4 Preparation of a vegetation map of the study area
5 Change detection study

Abstract

This study shows the rate of deforestation of Chokoria Sundarbans situated along the coast of South Eastern Bangladesh using remote sensing techniques. The study was done using a series of aerial photographs and Landsat imagery supplemented by a number of ground truth verifications. Examination of black and white aerial photographs taken in 1981 shows that destructive deforestation had already started at that time whereas the study of 1975 aerial photographs did not show destruction features. Yearly deterioration of forest cover parallel to an expansion of shrimp farms is shown in graphical form. Gradually shrimp farms replaced mangrove vegetation.

As observed in the Landsat TM data of 1988, the mangrove forest had then been completely removed except for some patches on the banks which were measured to add up to only 973 ha out of a total of 7,500 ha of the original Chokoria forest. Almost all the forest area is now under shrimp farming. A land-use map was prepared at 1:50,000 scale using remote sensing techniques; the map shows existing mangrove vegetation cover and shrimp farms.

A partial inventory of the shrimp resources of Chokoria Sundarbans was carried out. In this survey year wise average shrimp yield per hectare was estimated. In 1989 the average annual yield was 167 kg/ha. The total yield was 1,100,000 kg approximately and their approximate value was 165.0 million taka. A shrimp yield/ha and mangrove forest cover VS year bar chart was prepared. It shows that the shrimp yield/ha increased with time with the exception of 1986. The destruction of mangroves in the area apparently does not have any effect on the shrimp yield. It must however be pointed out that no analysis of the amount and cost of alternative artificial inputs into the system such as feed, fertilizers, lime, power, manpower and others was made. These costs are usually high while the natural inputs into the mangroves are free of cost.

According to the local shrimp farmers, shrimp yield does not depend on the mangroves in this area. The source of food for shrimps seems to be the sea. If mangroves contribute at all to the shrimp food supply, this may be coming from the surrounding areas.

The socio-economic study shows that the economic value of the poor people living around the forest area did not improve. Some of them have become jobless, fishermen have been converted into day laborers and the peasants have lost their grazing land. The biotic pressure that was earlier exercised on this forest has now been transferred to the mainland forest.

As the natural protection due to the mangroves has been lost, this area suffered immense losses in terms of lives and property during the cyclone of 1991.

1. The Mangrove Forest

The mangrove forest is a swamp forest of low to tall trees and shrubs associated to salt marsh herbs. It occurs naturally along the borders of eastern and western Bangladesh shores where wave action is not intense, where mud is deposited and peat is formed. Most plants are halophytes well adapted to salt and brackish water conditions and to fluctuations of tidal level. Several species have well developed viviparity, the hypocotyl of their seeds develops while the fruits are still on the tree. The seedlings are usually so shaped, impermeabilized and weighted that they may float for long distances before taking root. The mangrove community in the Chokoria Sundarbans was developed as a distinct halosere with a zonal pattern from the open water landward with a succession of different species. The landward zone species develop on the sediments which were earlier deposited in the seaward zone and later weathered as peat. Sediment deposition extends outwards at sea and forms islands in shallow quiet waters. The mangroves when intact afford some protection against erosion and cyclones; mangrove swamps play a significant geomorphological role.

1.1 Status of the mangrove forest in Bangladesh

According to location the mangrove forest of Bangladesh is divided into three forest zones. They are the Sundarbans, the largest continuous single productive forest of the world; the Chokoria Sundarbans which is now a denuded forest and the coastal mangrove plantation forest which was started during the sixties. For the first time the inventory of the Sundarbans was carried out in 1960. According to a recent inventory carried out in the Sundarbans in 1985, it has a total merchantable volume of 10,649 million m^3 of wood in trees with more than 10.0 cm in diameter at DBH (Chaffey, 1985). Compared with the past stocking of the Sundarbans forest inventory of 1960, there has been some deterioration in the quality of the crop and this may depress future annual yield unless adequate measures are taken for the restoration of the quality of the crop to its optimum productive capacity. According to a recent inventory report, 65% of the Sundarbans has a tree cover of more than 70%; about 30% between 30% and 70% tree cover, and about 5% has less than 30% tree cover. It has been suggested to exploit the Sundarban forest at a level below its optimum productive capacity.

Mangrove plantation practices were introduced in Bangladesh in 1964. They have since been carried out in the coastal belt stretching from Teknaf in Cox' Bazar in the East to Barisal and Patuakhali in the West over an area of 800 km^2. The plantation of mangrove species is primarily done to raise fuel-wood and for pulp-wood production. The present growing stock in the coastal plantation is estimated to be 0.606 million cubic meters. The Chokoria Sundarbans started to deteriorate in the sixties. As found in the present study, this forest area has now been denuded almost completely and shrimp farms have been established over this area, following deforestation.

1.2 Forest inventory

The Forest Inventory is the qualitative and quantitative description of a forest. It deals with the preparation of an updated stratified vegetation map, measurement of trees and stands, estimation of volume and stand density, prediction of growth and preparation of felling programmes. Accurate sampling methods are basic for the inventory design and subsequent programming. The present Inventory of the mangrove forest of the Chokoria Sundarbans using remote sensing techniques was initiated to make an updated vegetation map to estimate the standing stock available of local species and to make a socio-economic study of the people living around the forest area. As the forest area has been completely denuded, the objective of making a timber volume inventory had to be diverted to study the periodic rate of degradation of the forest cover; the forest area has been converted into shrimp farms. A partial inventory of the shrimp resources of the Chokoria Sundarbans was made, a socio-economic study was carried out to investigate the role of human interference on deforestation as well as the impact of deforestation on the environment.

Two studies (Khan *et al.*, 1985, 1987) had been carried out previously with support from the UNDP/UNESCO Projects, both were on Timber volume Inventory of the Sundarbans (Khan *et al.*, 1990). Computer techniques were developed for rapid mangrove forest inventory. In the first study, comparison of two sample designs used in the forest inventory has been made. In the other study changes in size classes, basal area and volume were recorded and top dying of Sundri (*Heritiera fomes*) trees was found to be prevalent. Remarkably the study found that Sundri is being replaced by Gewa (*Excoecaria agallocha*) in the study area. That study also developed methods for estimating timber volume using large scale aerial photographs without field surveys thus reducing much labor, time and money.

2. The Chokoria Sundarbans

2.1 Location of the forest

The Chokoria Sundarbans Forest lies between lat. 21°36'N and 21°45'N and long. 91°58'E and 92°05'E. It lies in the delta of Matamuhuri river of Cox' Bazar district (Fig.1). The mangrove forest had a well demarcated boundary as it was surrounded by waterways on all sides. In the northern subdivision, the forest had a common boundary with the unclassed state forest of Chittagong Hill Tracts, in the East and in the north-west the forest bordered agricultural land. In the south-east it adjoins settled land and faces the Maiskhal channel that opens in the Bay of Bengal to the south. The boundary at all places follows a zigzag path along the edge of the hill. There are many low-lying islands mostly submerged at high tide. The water is of brackishwater Sundarbans type and the tidal amplitude is of medium class as in the Khulna Sundarbans. The main difference between the two areas is the abundance of Chulia Kanta (*Dalbergia spinosa*) in the Chokoria Sundarbans and profusion of Nunia (*Aegialitis rotundifolia*) which formed dense pure forest in the Chokoria Sundarbans, while they occur only sporadically in the Khulna Sundarbans.

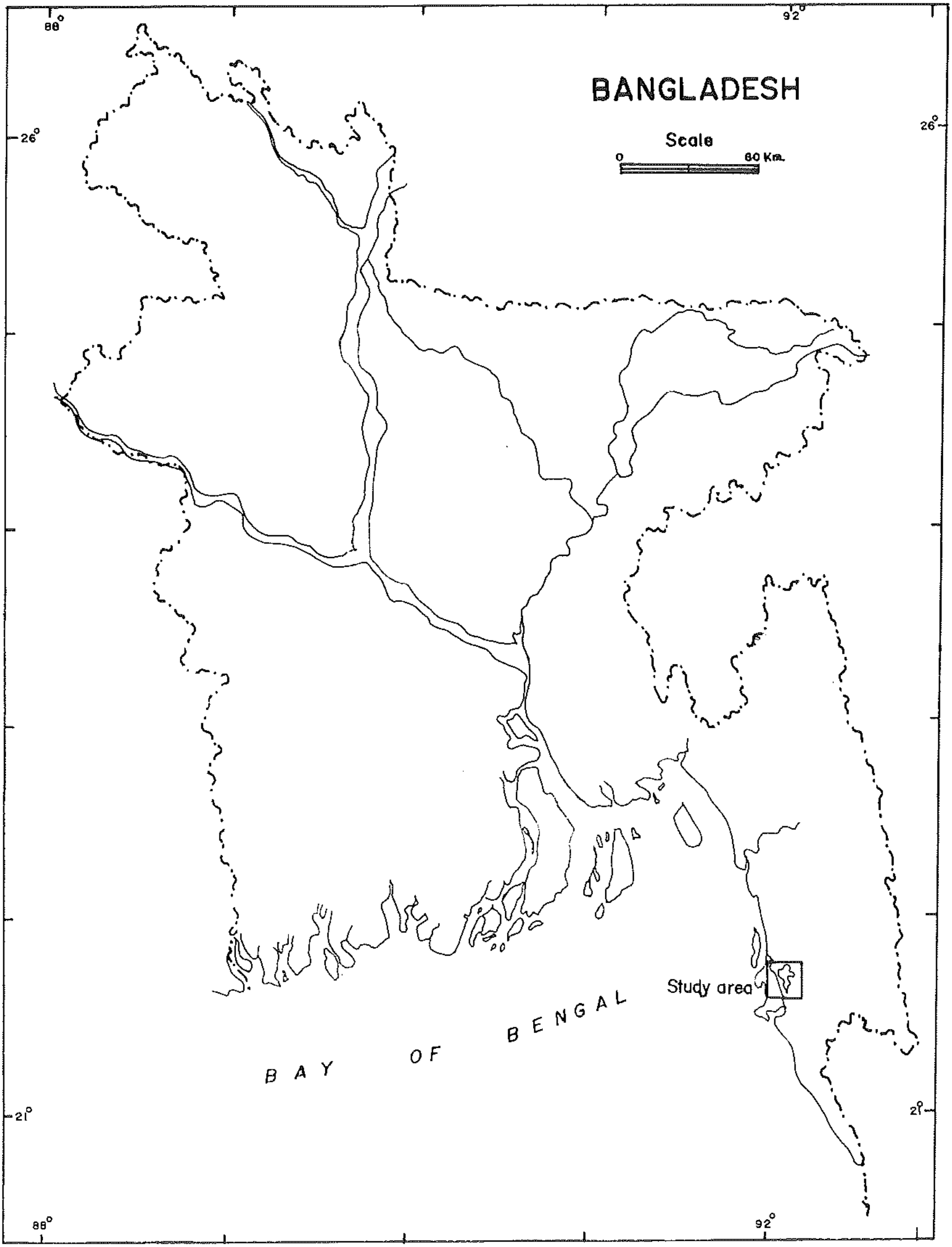


Fig. 1. Outline sketch of Bangladesh

There were only twenty tree species in all, they attained a maximum height of about 12.0 m. Baro baen (*Avicennia tomentosa*) was the most common large tree and grew almost everywhere but it did not form pure forest stands anywhere in the area. Except for Baro Baen the forest consisted of Dulia Bean (*A. alba*), Kala Baen (*A. officinalis*), Tushia (*Bruguiera caryophyloides*), Ruhinia (*Kandelia candal*) and Lasalong (*Aegiceras majus*). In specially low lying areas, Natinga (*Bruguiera gymnorhiza*), Karamphala (*Carapa obovata*) and Ail (*Carapa moluccensis*) were occasionally found. Gutia (*Ceriops roxburghiana*) formed a dense thicket in the interior of the forest. It occupied mostly coppiced shoots 1.5 m to 4.5 m high with an upper storey of scattered Baen. A large area on the western side had pure Nunia forest. On the sea front and along the banks of the main rivers where they are muddy and shelving, Keora (*Sonneratia apetala*) was the most frequent species. In the North-west portion of the area where the land is higher and the river banks were steep and not shelving, Sundri (*Heritiera fomes*) was the main tree species, all gradations from almost pure Sundri forest to Sundri mixed with Gewa (*Excoecaria agallocha*) were found. Dulia Baen, Hanthal (*Phoenix paludosa*) in gregarious clumps and Urussia (*Tamarix gallica*) with Natinga were present on lower ground. On the banks of the smaller streams, the commonest trees were Gorjan (*Rhizophora conjugata*), Kala Baen and Keora. Natural regeneration was good throughout, but Nunia (*Aegialitis rotundifolia*) that multiplied very easily tended to oust better species in open brackish areas. Most species coppiced well.

2.2 Deterioration of mangrove vegetation

Traces of deterioration of the forest vegetation in the Chokoria Sundarbans was first noticed in the sixties (Choudhury, 1967): "the condition of the forest crop was very poor. During the last working plan period there was sudden heavy demand of fire wood for salt manufacture. The demand was much heavier than the capacity of the forest. Also with the opening of the Chittagong-Cox' Bazaar highway and along with the large scale working of the Garjan forest in the area, the concentration of the management was completely diverted to mainland tropical forest. As a result the management of the Chokoria Sundarban forest was seriously neglected and there was much illicit cutting of the forest in the area, this was disastrous and hardly any tall tree was available over the whole Chokoria reserve forest. Natural regeneration was good but due to heavy incidence of grazing and perhaps partly due to higher water salinity, regeneration could not take place and as a result the condition of the forest started to deteriorate from bad to worse. Destructive deforestation by clear cutting of mangrove vegetation in the Chokoria Sundarban forest areas was first noticed to be widespread on the aerial photographs of 1981. After stereoscopic examination of the aerial photographs it was found that about 2104 ha of forest cover had been completely opened for shrimp farming. Recent studies from Landsat TM imagery reveal that the forest vegetation has almost completely been removed and shrimp farming is established in the area.

2.3 Destructive deforestation

The destructive deforestation of the Chokoria Sundarbans forest is due to various causes. Amongst them their management and the socio-economic condition of the people living around the forest area were most important. Natural disasters also contributed to accelerate the destruction. Breach of forest laws, like illicit removal of timber and other forest produce is one of the most common and most destructive ways of damaging forest crops. Unlawful practices were rampant in this area. Insufficient forest staff, lack of cooperation from the local population and the greed of the forest produce traders are some of the many causes of deforestation. Abuse of the pass system was another cause of damage of the forest crop. In the past the disposal of the forest produce on pass system was one of the commonest and easiest ways of removal of forest produce, by this system there was very little control on felling and extraction.

This forest area has been subjected to periodic cyclones of severe intensity, while cyclones of more or lesser intensity occur frequently and cause large scale damage to forest trees and forest properties. Most of these storms are followed by storm surges and the damage and destruction caused by them is considerable.

The whole area of the forest was open for grazing by cattle. Uncontrolled grazing affected regeneration seriously and there was no regrowth of the lost stock. A system of rotational grazing was tentatively enforced to control losses due to grazing, but forest guards could not stop the traditional grazing. As a result the forest continued to deteriorate.

Fishing in this forest area was an age-old practice of the fishermen living in the vicinity. In the past, fishing was permitted throughout the year under a system of annual permit. Permits for fishing and for collecting dry fire wood for the fishermen were issued separately. This gave the fishermen a chance to enter into the forest and in the course of extraction of the fishing stakes and dry firewood, considerable damage was done to the forest. The fishermen also practised a type of fishing by which they built earthern dams at the mouth of the creeks. Incoming tidal water was thereby blocked and kept stagnant inside the forest area for a considerable period. This water was drained off after some time according to the needs of fishermen and the fish was collected from these drained out areas. The mangrove seedlings within this area failed to survive because of stagnant saline water. As a result, in most of these areas natural regeneration was a complete failure. This type of traditional fishing in the forest area was another important cause of degradation of the forest. The forest department issued limitations and restrictions on this type of devastating system but they failed to enforce them and slow deforestation continued for many years.

The Chokoria Sundarbans came under Government management in 1903. From that time 8,500 ha of forest remained under the management and full control of the Provincial Forest Department. From the total forest area 7,489.8 ha of land was declared Reserved Forest and the remaining 1,012.2 ha was declared Protected Forest. For proper maintenance and control Bangladesh Forest Department divided the 7,489.8 ha of Reserved Forest into two blocks, namely Rampur with 3,827.5 ha and Charandwip with 3662.4 ha.

In 1977, M/S Shrimp and Duckery Farm Ltd. took lease of 228.3 ha of land from the Forest Department. In 1978, by another Government Order 2024.3 ha of land were handed over to the Fisheries Department for developing shrimp ponds in the area. Later another 694.4 ha of forest land was transferred temporarily to the Fisheries Department for shrimp culture. But the Fisheries Department was not given the possession of the land.

Different individuals and companies started to acquire land forcibly from the forest area. In 1978 when 2,024.3 ha of land were transferred to the Fisheries Department for shrimp culture, encroachers little by little started shrimp culture in the forest area. In 1982 they were all driven away from the forest area with Government support. After their departure the situation in the area was normalized.

Again after some time the Fisheries Department started to lease water areas of the forest. This time powerful buyers became active again and started to acquire forest land and establish shrimp pond farms. The Forest Department with their limited number of forest guards could not check the destruction of the forest. This act of forest land acquisition by shrimp farmers continued for many years and consequently the Chokoria Sundarban was clear-cut, burned and ponds excavated. At the beginning of the eighties the price of shrimp in the international market rose remarkably. Some traders were attracted by the prospect of rich gains through export of shrimps and they found the Chokoria Sundarban area most suitable for shrimp production. In the first stage they were quite successful and proceeded to establish shrimp pond farms on the whole area by removing the forest vegetation. Now the whole area is under shrimp farming except for some patches of vegetation on the banks of the rivers and channels.

Usually the shrimp farmers acquired the land first; then they opened the forest by cutting the vegetation and cleared it by burning. Some evidence of destructive deforestation are shown in Figs. 2-9.

3. Stereoscopic Photo-Interpretation

3.1 Stereoscope

Image interpretation through photogrammetric methods is based on the ability of the human brain to accept two images of an object, one from each eye, with the aid of a stereoscope; these two images are then united in the brain to create a three dimensional or stereoscopic model of the object. When each eye looks at air photographs of the same area taken from different air stations, the brain creates a three dimensional image of the area on the ground. In order to get maximum information from air photography, three dimensional models are essential for stereoscopic vision.

The stereoscope assists the eyes to reconcile focus and convergence by reducing the angle of convergence. The optical instrument does this by orienting the optical axes until they are nearly parallel. Three types of stereoscopes are available for airphotointerpretation. They are the lens, the mirror and the differential stereoscope. Lens stereoscope is a simple stereoscope consisting of two magnifying lenses set in a framework the legs of which are at a height equal to the focal distance of the lenses. Its magnification is 2x - 3x. It is necessary to overlap the photographs when viewing, which is a disadvantage of this type of stereoscope, but it is easily

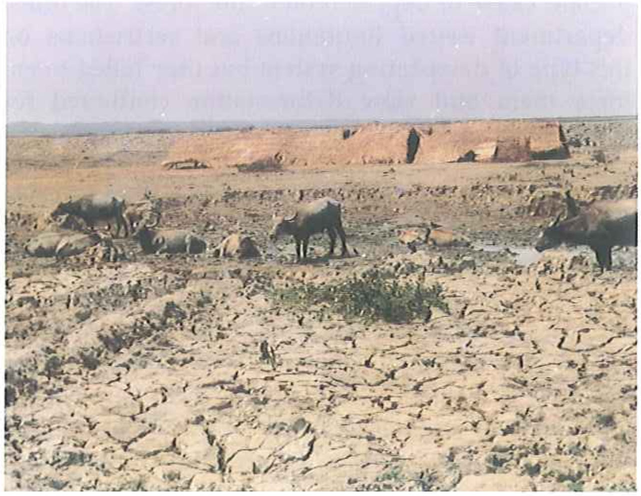


Fig. 2 (top left). A panoramic View of the Chokoria Sundarbans. Only one kewra tree (*S. apetala*) is standing lonely in the area. Forest boats are waiting to take away the scanty forest produce.

Fig. 3. (bottom left). Pilfering of seedlings and mangrove scrub by young boys. Head loads are sold in the nearest market.

Fig. 4. (top right). Pilfering of seedlings and scrub by the young men. The forest produce will be sold in the nearest market and partly will be used by themselves.

Fig. 5. (bottom right). Deforestation by domestic animals. The buffaloes are chewing the cud in the deforested area of the forest.

transported and is ideal for field use. It is also known as pocket stereoscope.

The mirror stereoscope gives a wider field of vision than the lens stereoscope and the photographs can be separated so that there is no need for them to be overlapped. It can give up to 8x magnification but has only a restricted field of vision.

The differential stereoscope can accept two air photographs at different scales. They are brought into focus at the same scale by the operator. A zoom system is also incorporated in some sophisticated and expensive instruments.

3.2 Photo-interpretation

Photo-interpretation is defined as the examination of aerial photographs to identify details and to process the information in a form suitable for further uses. Stereoscopic inspection of photographs is necessary for the interpretation and very good stereoscopic vision is essential. The impression obtained from stereo-models is exaggerated vertically; objects on the photographs will appear taller than they are in reality. Photo-interpretation is a complex process of selection and rejection in which expectation affects observation. Expectation is closely related with education and is stimulated by all senses and by associative thinking.

Fig. 6 (top left). Destructive deforestation by cutting of mangrove trees.

Fig. 7. (bottom left). Destructive deforestation by setting fire in the forest area.

Fig. 8. (top right). Ponds are being excavated for the purpose of establishing shrimp farms.

Fig. 9. (bottom right). Scene of a typical shrimp pond established in the Chokoria Sundarbans. The above scene is found now all over the forest area.

3.3 Vegetation and forest image interpretation

Before starting forest image interpretation the interpreter would know the difference in scale between the air photographs and the final reproduction, and the limits of the area and sizes that can be interpreted. Smaller scales give less information and small changes in height become less detectable. The flight diagram and film report are essential to find out the location of the forest area, the limit of the air photography cover, the date of flying (season), the time of day (shadow) and finally the weather condition at the time of the flight (haze). The interpreter should appreciate the height exaggeration under the stereoscope, tone and texture variation and dodging of the aerial photographs. He should also have some prior knowledge of the interpretation area. From the aerial photographs, high forest, secondary forest, woodland, thickets, grassland, bushes and scattered trees, bamboo, mangroves, swamps, cultivation, shifting cultivation, plantation etc. can be recognized and identified. Plantation age recognition, species composition and species identification, deforestation and erosion can also be identified. After interpretation, the information generally is transferred to a base map and given for reproduction. These maps are then put to various uses in forestry.

3.4 Photo-interpretation of the Chokoria Sundarbans

Black and white aerial photographs at 1:30,000 scale taken in 1975 and 1981 and color infrared of 1:50,000 taken in 1984 of the study area are available at SPARRSO. These aerial photographs were studied under a Mirror Stereoscope. A base map was prepared using the 1984 aerial photographs and the topographic map. The interpretation result obtained from the aerial photographs of different dates were transferred to the previously prepared base map and three maps were prepared independently. These maps have been used in the change detection study. The results are described under #V.

The final vegetation map of the study area was prepared by interpreting the Landsat TM data of 1989 supplemented by ground truth data. The Landsat MSS and TM CCT of the study area was analysed at SPARRSO by using the I^2S of the Vax-computer system (described in # IV). These maps are shown in Figs. 10, 11, 12 and 13.

4. Interpretation of Landsat Imagery by Computer Enhancement

For the mapping and temporal study of the Chakoria Sundarbans, the Landsat data were used along with data from other remote sensing and conventional sources like aerial photos and ground data.

The present Landsat satellites have two sensors; Multispectral Scanner (MSS) and Thematic Mapper (TM). The sensor characteristics of these instruments are given below.

The MSS takes observation in four spectral bands known as bands 4, 5, 6 and 7. The ground resolution of the MSS is 80 m. The description of the bands is as follows:

Bands	Wave length (micrometer)	Nature of radiation
4	0.5-0.6	Green
5	0.6-0.7	Red (chlorophyll absorption band)
6	0.7-0.8	Near infrared (chlorophyll reflection band)
7	0.8-1.1	Near infrared (chlorophyll reflection band)

The MSS scans over a swath of 180 km across the satellite track. It collects data in two visible and two near-infrared bands, and has been found suitable for applications to various land-use/landcover mapping and study. The Landsat TM may be used more effectively for these kinds of applications, because it has higher ground resolution and larger number of spectral bands. The maximum ground resolution of TM is 30 meters and it has seven spectral bands fairly well distributed in the visible, near-, middle- and far-infrared regions of the electro-magnetic spectrum.

From the above it is seen that there are three bands in the visible (1-blue, 2-green and 3-red), one in the infra-red (band-4), two in the middle infrared (bands 5 and 7) and one in the far-infrared. The ground resolution in the far infrared band (band 6) is 120 meters.

The TM bands are described below:

Bands	Spectral regions (micrometer)	Characteristic
1	0.45-0.52	Blue
2	0.52-0.62	Green
3	0.62-0.69	Red, chlorophyll absorption band
4	0.75-0.90	Near infrared, chlorophyll reflection band
5	1.55-1.75	Middle infrared, vegetation moisture sensitive band
6	10.4-12.5	Far infrared, soil/plant, canopy temperature measurement, plant heat stress determination (ground resolution 120 meters)
7	2.08-2.35	Middle infrared, hydrothermal/soil mapping, moisture sensitive

Both MSS and TM scan over a distance of 180 km across the satellite track. The Landsat pass has the return time of 16 days over the same area.

In the present study we used the Landsat MSS and TM data for investigation and mapping of the mangroves of the Chokoria Sundarbans.

4.1 Spectral signature of the major surface features

The interpretation of the satellite data is dependent on the differential spectral response of the ground objects/features to incident radiation. The MSS bands 4 and 5 correspond to the visible green and red. The TM bands 1, 2 and 3 correspond to visible blue, green and red respectively. In the visible region of the electromagnetic spectrum, the green vegetation has a high absorption capacity. This absorption is very strong in the red region (band 3 of TM/band 5 of MSS), while in the green region (TM band 2/MSS band 4) there is relatively high reflection by the leaves compared to red and blue.

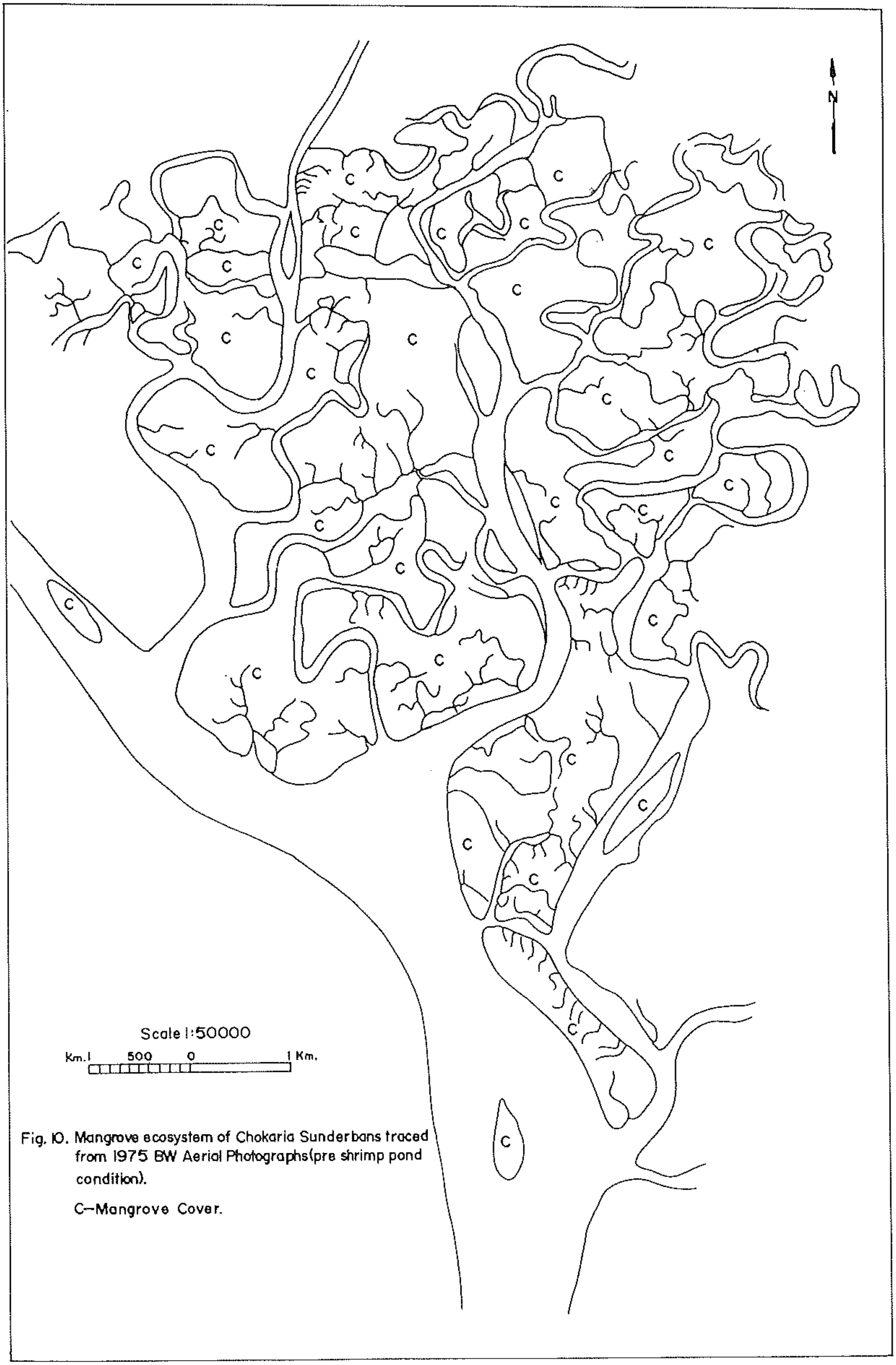


Fig. 10. Mangrove ecosystem of Chokaria Sunderbans traced from 1975 BW Aerial Photographs (pre shrimp pond condition).

C–Mangrove Cover.

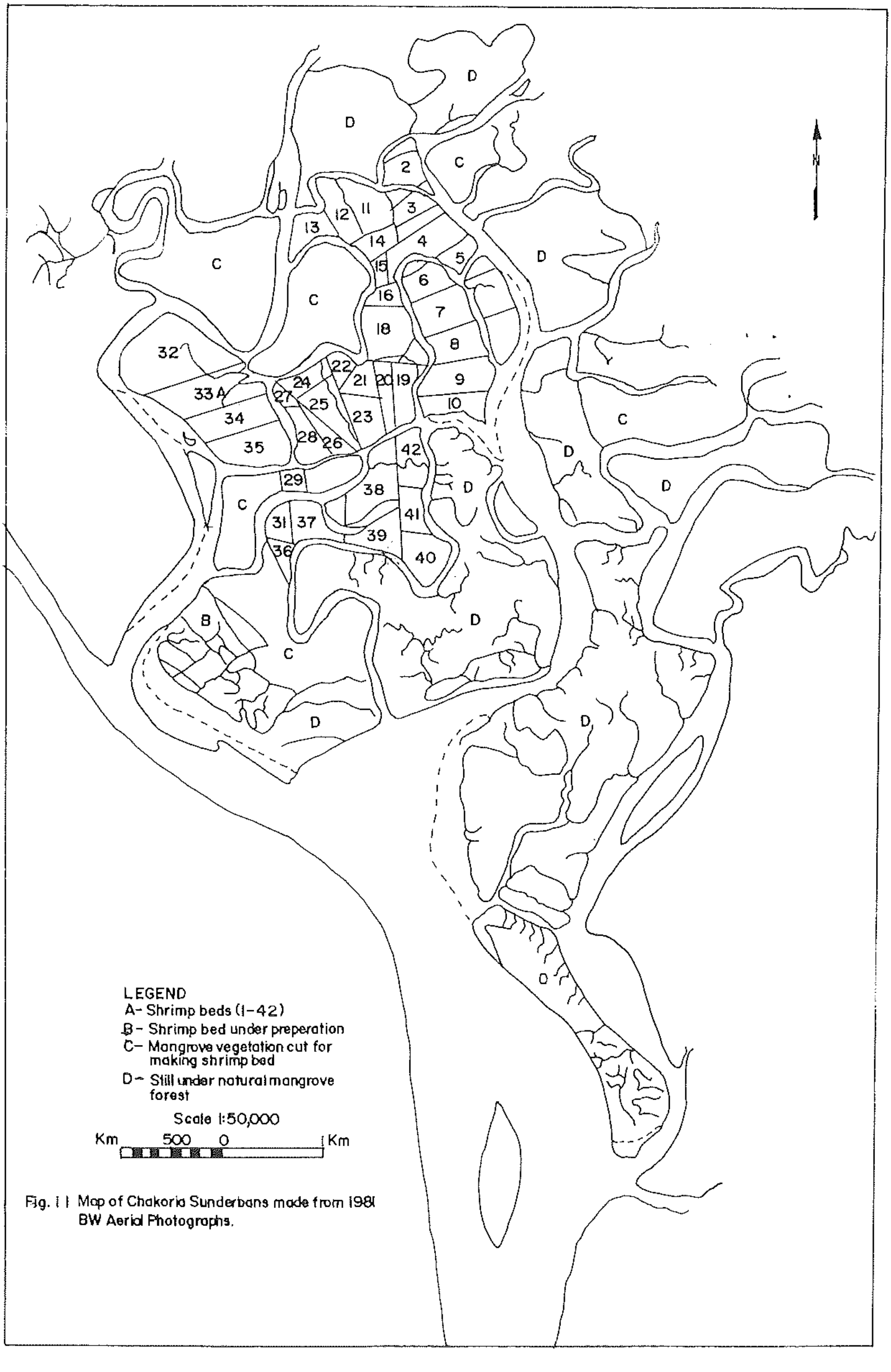


Fig. 11 Map of Chakoria Sunderbans made from 1981 BW Aerial Photographs.

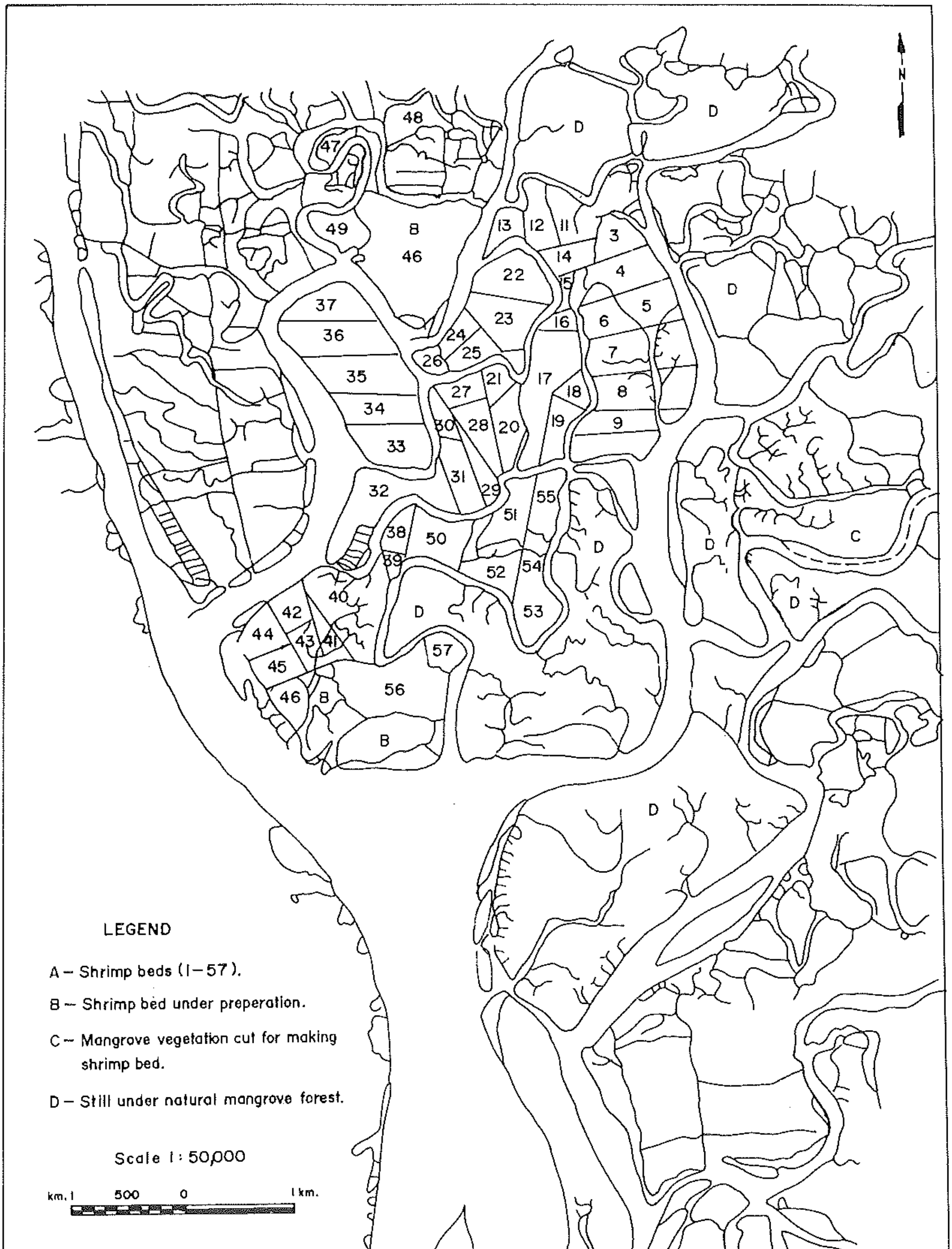
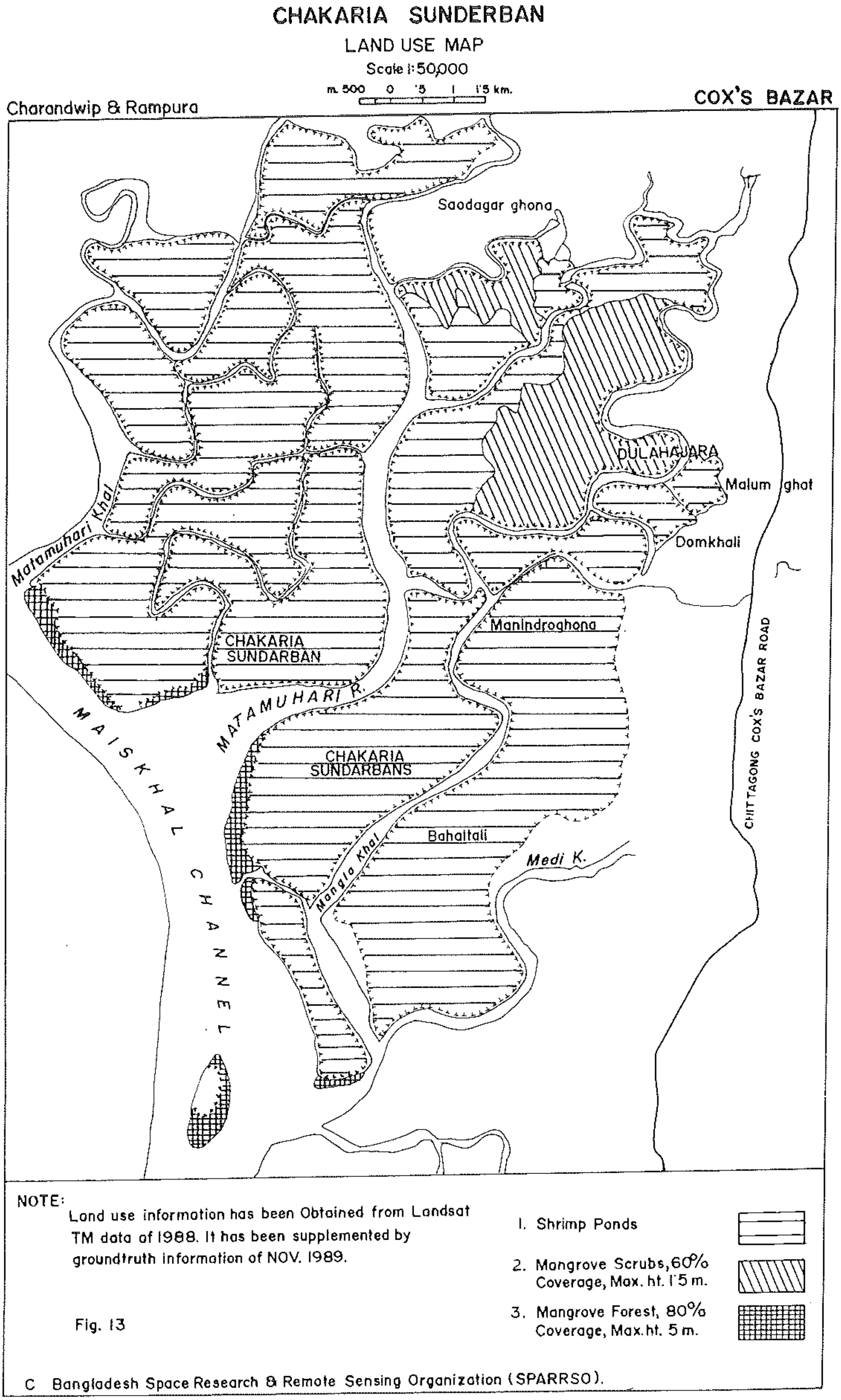


Fig. 12. Map of Chakoria Sunderbans made from 1983 Aerial Photographs.


CHAKARIA SUNDERBAN
LAND USE MAP
Scale 1:50,000
m. 500 0 ·5 1 1·5 km.
Charandwip & Rampura
COX'S BAZAR
Saodagar ghona
DULAHAJARA
Malum ghat
Domkhali
Matamuhari Khal
Manindroghona
CHAKARIA SUNDARBAN
MATAMUHARI R.
MAISKHAL CHANNEL
CHAKARIA SUNDARBANS
Bahaltali
Medi K.
Mangla Khal
CHITTAGONG COX'S BAZAR ROAD
NOTE:
Land use information has been Obtained from Landsat TM data of 1988. It has been supplemented by groundtruth information of NOV. 1989.
1. Shrimp Ponds
2. Mangrove Scrubs, 60% Coverage, Max. ht. 1·5 m.
3. Mangrove Forest, 80% Coverage, Max. ht. 5 m.
Fig. 13
C Bangladesh Space Research & Remote Sensing Organization (SPARRSO).

band 2/MSS band 4) there is relatively high reflection by the leaves compared to red and blue.

The near-infrared radiation is highly reflected by the green vegetation. MSS bands 6 and 7 and TM band 4 correspond to this part of the electromagnetic spectrum and register high reflection from the green vegetation. Landsat TM has two bands in the middle infrared region (band 5 and 7) that are sensitive to vegetation and soil moisture. For higher moisture conditions, both the vegetation and soil absorb radiation in these channels more strongly than those for relatively lower moisture conditions.

For bare soil, the reflectance increases with the increase of wave-length within the visible, near infrared and middle infrared region. But the reflectance is lower for wet soil than for dry soil. Reflectance is very low for water. Reflectance gradually decreases from the blue to the red region and in the near-infrared/infrared region the radiation is almost completely absorbed by water. Thus the near-infrared and middle infrared bands after suitable enhancement are used for land-water boundary separation. It may be mentioned that none of the bands can effectively discriminate the different features and this is done by several image processing procedures. Digital image enhancements, three bands false color composites, arithmetic manipulations, digital classifications, etc. are the major image processing techniques which are generally used for the interpretation of the surface features. For mangrove studies of the Chokoria Sundarbans, the following processing of the Landsat MSS and TM data was made.

4.2 Digital processing of the data

I. Landsat MSS digital CCT data of March 1984 (Fig. 14) were used. Enhanced three band color composites of bands 7, 6 and 5 were produced.
II. Multispectral classification of the MSS data was performed and interpreted.
III. Landsat TM digital CCT data of October 9, 1988, were used. The following enhanced color composite imagery was made.
   - Bands 3 (red), 2 (green) and 1 (blue) - natural color (Fig. 15)
   - Bands 4, 3 and 2 (Fig. 16)
   - Bands 4, 5 and 2 (Fig. 17)
   - Bands 4, 5 and 7 (Fig. 18)
IV. Band ratioed image was produced by taking the ratio of TM bands 4 and 3. This image is called the Ratio Vegetation Index (RVI) (Fig. 19)
V. Multispectral classification of the TM data using the unsupervised classification

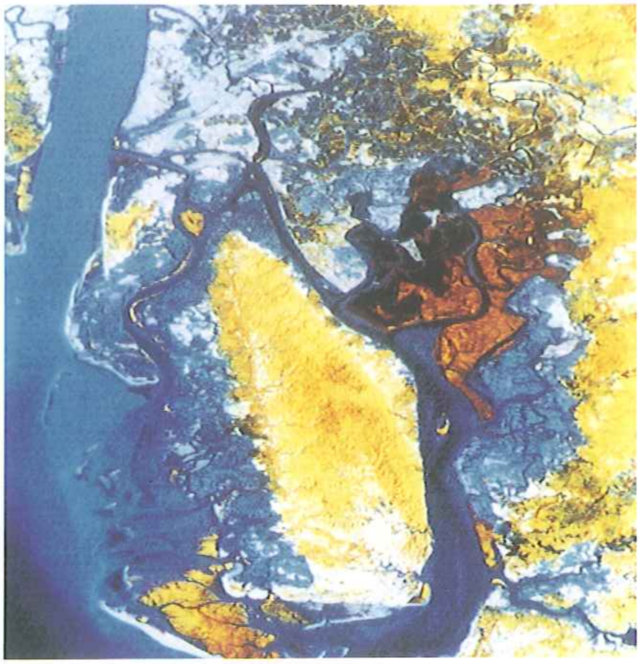


Fig. 14. LANDSAT MSS Composite, bands 7, 6, and 5 March 1984.

It may be mentioned here that more detailed digital processing and interpretation of TM data of 1988 was made as this was the only set of the most recent remote sensing data of Chokoria Sundarbans available.

All the image processing work was performed using the I^2S image processing system and VAX 11/750 computer of the Agroclimatic/Environmental Monitoring Project (ACEMP) of SPARRSO.

4.3 Interpretation of the Landsat data

The color composite and classified MSS data of 1984 were used along with the aerial photographs of that year to map the vegetated areas of the Chokoria Sundarban. In the color composite image, the Chokoria Sundarban area appears to be prominent with the overall dark and red tones compared to the surrounding areas with bright and yellow tones. The mangrove forest appears red, water appears blue and the bare soil appears gray and white. The vegetation outside Chokoria appears yellow. The classified image was interpreted with the help of the color composite image and the areas with mangroves were clearly identified. The areas where the mangroves were cleared were also detected. The features identified in the imagery were transferred along with those from aerial photographs to a 1:50,000 map.

Fig. 15. (top right) LANDSAT TM Composite bands 3, 2 and 1 (Natural Colour). October 9, 1988

Fig. 16. (bottom right) LANDSAT TM Composite, bands 4, 3 and 2. October 9, 1988

Fig. 17. (top left) LANDSAT TM Composite, bands 4, 5 and 2. October 9, 1988.

The interpretation of the Landsat TM data of 9 October 1988 over the Chokoria Sundarban area has been made using the false color enhancements of various band composites, band-ratioed image (band 4/3) and the multispectral classification using the unsupervised classification. The interpretation was made for identification of the vegetated/mangrove areas and the areas with water, bare lands etc.

The enhanced color-composite of bands 3, 2 and 1 provides the natural color representation of the area. Here forest/vegetated areas are seen to have dark/dark greenish tone, the bare soil appears to be gray and the turbid water appears to be bright. Most of the Chokoria Sundarban areas are found to have non-uniform gray/bright tones showing the presence of bare areas or areas with water having large amounts of suspended sediments. Only a very small part of the Chokoria area have vegetation/ mangroves identified as the dark areas. In the north-eastern portion, there are some small clouds/haze in the imagery. The representation of green vegetation is clearer in the false color composite of bands 4, 3 and 2. Band 4 is in the near infrared zone and the radiation in this channel is highly reflected by the green leaves. Band 3 is in the red zone where the radiation is highly absorbed by green vegetation. Water has higher reflectance in band 2 than in band 3 and in band 4 energy is highly absorbed by water. For soil the reflectance is high for all these bands. In this false color composite band 4 is represented by "red" color, band 3 is represented by "green" color and band 2 is represented by "blue" color. Thus the vegetation appears red, clear water appears dark, turbid water appears light blue and bare soil appears gray. The dry soil/sand appears white.

Fig. 18. LANDSAT TM Composite, bands 4, 5 and 7. October 9, 1988.

The mangroves are seen to be red and are present over very small areas in the eastern bank of Maiskhal channel. Another small area of mangrove scrub is seen in the imagery to the northeast of the Chokoria Sundarbans area in spite of the interference of some shallow clouds. The rest of the areas are bare or under water. Ground truth shows that most of these areas have come under shrimp culture. The embankments, the banks of the shrimp ponds etc. are identified in the image. The other reddish areas are not mangrove but are aquatic vegetation and grasses. The red areas away from the Chokoria are other kinds of vegetation.

Fig. 19. Band ratioed image (gand 4/3) of LANDSAT TM, October 9, 1988.

The false color composite of bands 4, 5 and 2 is shown in Fig. 17. Here band 4 is represented by "red", band 5 by "green" and band 2 by "blue". Band 5 is situated in the middle infrared region and is highly sensitive to soil/vegetation moisture. The higher the moisture content or wetness, the higher is the absorption in band 5. The mangrove forests are more humid than the other forest vegetated areas in the surrounding. Thus the mangrove looks red while other vegetation appears yellow, thus the mangrove looks different in this image. In this image the whole Chokoria area is found to have blue/bluish tones. The embankments and the shrimp ponds can be seen in the image having brighter tones. It is seen that very small areas of Chokoria still have mangroves.

The false color image of bands 4, 5 and 7 are shown in Fig. 18. Band 4 is represented by "red", Band 5 by "green" and Band 7 by "blue". In this image the water appears dark due to high absorption of radiation by water in these channels. The wetland vegetation appears red but the dryland vegetation appears orange/yellow. The bare soil appears light blue. The mangrove is identified as having the red/dark red color. Embankments and other structures are very clear in this enhanced color composite.

In all the above mentioned false color composite imagery, it is seen that the mangrove has almost totally disappeared except for some small areas to the south-west and north-east of Chokoria. The shrimp ponds and the embankments are clearly seen in this imagery.

The band ratioed image (band 4/3) is represented in black and white (Fig. 19). This band ratioed image is also known as Ratio Vegetation Index (RVI). It is very easy to identify vegetation, bare soil and water areas. For a radiometrically corrected image the ratio values smaller than 1.0 represents water. Ratios greater than 1.0 indicate land with greater degree of vegetation coverage. The higher the value of this ratio, the denser is the greenery cover.

The brighter areas in the RVI image are covered with green vegetation. Very dark areas are water, gray areas are bare soil or land areas with low level of vegetation. In the RVI image the Chokoria Sundarban area is seen to have dark gray and gray tones showing the overall low level of RVI indicating large scale deforestation. The embankments made for shrimp ponds are also clearly seen as in the composite imagery. Areas with high values of RVI to the eastern bank of the Maiskhal channel and in the mouth of the Matamuhuri river are relatively dense mangrove forests. Another area to the north-eastern part of the Chokoria having high value of RVI has been found to be covered with mangrove scrubs by ground truthing. Areas with RVI less than 1.0 are rivers or shrimp farms. Areas having RVI higher than 1.0 but lower than 1.5 are bare soil or soils with very low coverage of vegetation.

The interpretation of the Landsat TM data were made on the digitally classified image. The classification was performed using bands 2, 3, 4, and 5 of the TM using the unsupervised classification techniques. Eight classes were obtained and were color coded. This is given in the cover page of this paper. These classes were interpreted as follows: classes 1 and 2 are water, class 3 is mangrove scrub and grasses, class 4 is bare soil, class 5 is tall/dense mangrove over the Chokoria, class 6 is embankments and banks of the shrimp ponds and bare land, class 7 is other vegetation and class 8 are clouds. The classified image has been color coded for easy identification of the classes. The final interpretation was made using the ground truth information. Most of the Chokoria Sundarban forest has now been transformed into shrimp farms. The forest vegetation area has been mapped from the classified image and compared with the information for the past few years obtained from aerial photographs of 1975 and 1984.

As only a negligible area of mangroves is left we have not attempted to determine the forest density and to estimate the timber volume of the mangrove. The latest TM data of 1988 show that the Chokoria is no longer a forest area, almost the whole of it has been turned into shrimp farms.

5. Change Detection Study

Stereoscopic examination of aerial photographs and digital analysis of Landsat data of the study area shows that a lot of change has taken place during the last ten years. Deterioration of the forest cover and the subsequent establishment of shrimp farms were the major changes observed. However, to obtain an idea of the dramatic deforestation and the establishment of shrimp farms, a series of aerial photographs and Landsat imagery were examined and analysed.

Black and white aerial photographs of the study area obtained in 1975 was interpreted stereoscopically but no traces of destructive deforestation was found at that time. all species were found to be of the right size but the whole forest seems to be under stress. a vegetation map was prepared at 1:50,000 scale and is shown on Fig. 10.

Examination of black and white aerial photographs taken in 1981 shows that destructive deforestation had already started then. Some forest cover had been removed. Shrimp ponds and their embankments could be very clearly seen. A map at 1:50,000 scale was prepared showing the removal of forest cover and the establishment of shrimp farms (Fig. 11). Measurements show that about 2,104 ha of forest had been removed.

Digital analysis of Landsat MSS imagery of 1984 and color infrared (CIR) aerial photographs of same date were studied simultaneously. It was found that the deforestation process continued, with more and more shrimp farms being built in the earlier forest area. The 1984 imagery/photographs show that about 2,560 ha of forest were destroyed. The map showing deforestation and establishment of shrimp farms is shown on Fig. 12.

Digital image processing and analysis of Landsat TM data of October 1988 show that almost all forest vegetation had been removed and shrimp farms had been established throughout the area, only some patches of mangrove vegetation remained on the banks of the channels, totaling 973 ha of poor scrub forest cover. The interpretation was supplemented by ground truth data.

A land-use map has been prepared showing the areas under vegetation cover and shrimp farms (Fig. 13). The year/wise deterioration of forest cover is shown on Table 1 and in graphical form in Fig. 20 that also gives the expansion of the shrimp farms.

Table 1. Yearwise Mangrove Forest Cover in Hectare

Year	1967	1976	1981	1984	1,988
Hectare	7,500	7,500	5,396	4,940	973

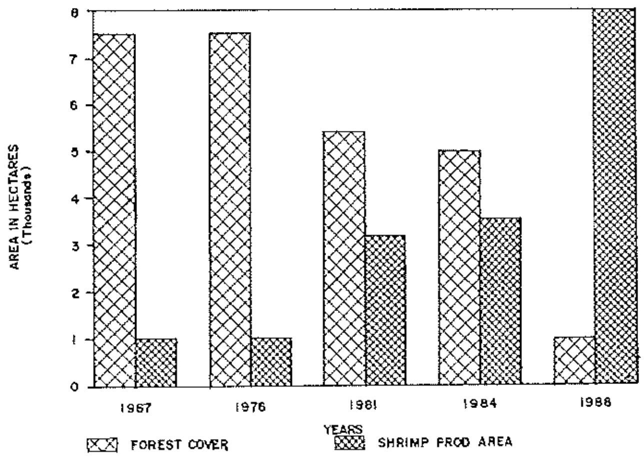


Fig. 20. Bar diagram showing forest area *vs* shrimp farm area.

6. Impact of Deforestation of the Environment

6.1 Socio-economic study

A socio-economic study was carried out to understand the impact of deforestation on the environment. The objective of the study was to find out:

a- the degree of deforestation caused by the people living around the forest area

b- the change of socio-economic status of the people caused by the establishment of shrimp farms and removal of forest vegetation;

c- the effect of deforestation on the environment.

For collecting socio-economic data a questionnaire - Ann. I - was designed and was made ready for field work.

Eighty five people living around the forest area were interviewed by our field staff and their statements were recorded in the tally sheet. Analysis of the tally sheet reveals that there is some influence by the local peasants on the long term deforestation process; people collected poles for house posts and firewood for home use. The incidence of illicit timber collection, grazing by buffaloes and cattle were common practices in the forest area. As a result destruction of saplings and seedlings contributed to the process of deforestation. Fishermen also used to make earthen dams at the mouth of channels and creeks that were kept in place for several days. Tidal waters were dammed and remained stagnant in the forest area for considerable periods. The seeds and propagules falling within this area generally failed to survive in the stagnant saline water. As a result in most of these areas natural regeneration was a complete failure. Therefore, the influence of fishermen in the long term deforestation of the area was considerable.

The common people living around the forest had very little influence on the destructive deforestation which had actually started in the beginning of 1980. Only the urban rich men who had the capability of large scale investments for shrimp farming contributed actively to destructive deforestation with a view to establish shrimp farms in the area.

Establishment of shrimp farms in the Chokoria Sundarbans Forest by total felling of the forest failed to improve the socio-economic status of the poor people living around the area; in many instances it actually worsened their condition and some of them are now jobless. Only the shrimp farmers have improved their economic condition by exporting shrimp to the world market.

6.2 Effect of deforestation

Due to depletion of the mangrove forest of the Chokoria Sundarbans, the people who used to depend on it for their house posts, firewood etc. now collect them from the mainland tropical forest. Though grazing is not allowed in the forest, the people are doing it hiddenly finding no alternative way to keep their cattle and buffaloes. People who lived by selling firewood from the Chokoria Sundarbans now collect it from the inland forest.

Illicit felling in the area will also increase. The biotic interference in the forest is increasing day by day and if preventing measures are not taken against such interference the forest area is liable to be degraded beyond repair.

There is apparently no direct effect of mangrove deforestation on shrimp farming and shrimp production. It has been found that production has increased with time. As natural culture is less economic, shrimp farmers are proceeding from semi-intensive to intensive shrimp culture and for this no mangrove vegetation is required, but the cost of production also increases day by day because of artificial inputs.

It has been stated before that due to deforestation some people have become jobless. Fire-wood collectors now seek other jobs for their living. Fishermen have lost their fishing grounds and they have been converted to daily laborers. Peasants are facing lot of troubles in keeping their cattle and buffaloes. In one word the socio-economic status of the common poor people did not improve at all. Only the rich men of the area have changed their fate by exporting shrimp in the high price international market. The Government earns a lot of foreign currency by exporting shrimp each year from this area.

Natural disasters like cyclones, storm surges etc. are common phenomena in the coastal area and they hit almost every year causing loss of lives and property. Forest belts along the coastal area minimise the loss of life and property by dissipating the energy of cyclones and surges. As the area is now exposed people should be more alert about the onset of cyclones and storm surges because they will be hit undoubtedly with greater energy and there are no shelters. The Chokoria Sundarban was once a wonderful mangrove eco-system formed by the interaction of plants and animals. Once this forest area was rich in its wild life wealth; deer, monkey, reptiles and birds lived in this forest. During the recent destructive deforestation, most of them have been killed and the rest have taken shelter in the nearest mainland tropical forest or have disappeared.

Land-slides, erosion and sedimentation processes are very common in the coastal area. It is well known in practice that vegetation cover protects against land-slides and soil erosion and promotes land accretion and subsequent land reclamation that can be accelerated by planting mangrove trees in the coastal area. Reclamation of land in the coastal area of the bay of Bengal by raising mangrove plantations is now a well established practice. The Chokoria Sundarbans area is now completely denuded and devoid of vegetation and it is anticipated that it is susceptible to land slides and soil erosion. The decomposed soil will be washed down to the sea by wave action and subsequent conditions may be greatly altered.

7. Inventory of the Shrimp Resources

7.1 Objective of the study

Massive deforestation was carried out for intensive shrimp culture in the Chokoria Sundarbans. In order to obtain a comprehensive idea about the status of production of shrimp in the area a partial inventory of shrimp resources was carried out. The objectives of the inventory were to find out:

i The annual average yield of shrimp in the area;
ii The relationship between shrimp production and mangrove forest in the area;
iii Present techniques of production;
iv Estimation of average shrimp yield per hectare and total production of the area.

To achieve the objective of the study a number of field trips was carried out in the study area. Before leaving for the field a questionnaire was designed and prepared for a partial inventory of the shrimp resources of the area (Ann. II).

The following maps and documents were used in the field:

1.	aerial photographs (CIR)	1984
2.	Landsat TM imagery	1988
3.	Topographic map	1975
4.	Forest map	1969

In order to estimate the annual average shrimp yield, data were collected from 30 shrimp farms. Annual yield of shrimp from 1982 to 1989 were recorded on the tally sheet. In addition to yield data, nutrient source, world market prices, annual expenditure, larval input, average salinity, pH of water, causes of deforestation and others were also recorded. During this time the 1988 map prepared from landsat TM imagery was also corrected by partial ground truthing. In this map the present vegetation cover is shown.

7.2 Tally sheet analysis

After careful examination of the tally sheets (enclosed in Ann. 2) the average annual yield of shrimp was found to be as follows:

Year	Annual average yield/ha of shrimp
1982	120 kg/ha
1983	116 kg/ha
1984	148 kg/ha
1985	181 kg/ha
1986	96 kg/ha
1987	106 kg/ha
1988	162 kg/ha
1989	167 kg/ha

Fig. 21 is a bar diagram showing the year of production vs annual shrimp production per hectare. The bar chart indicates that the annual average shrimp production per hectare increased irregularly from 1982 to 1989. This increased rate continued up to 1985 and the production reached a maximum of 181 kg/ha. Suddenly the production rate decreased to almost half in 1986 due to sudden changes in shrimp farming policy. Earlier each grower had 30 to 300 acres of land for shrimp farming, then government changed the policy and decided to allocate 10 acres of land to each grower. As a result big farms were divided into smaller plots and the production was hampered. However, from 1987 the production again started to rise and in 1989 it reached 167 kg/ha; however the cost of production are not recorded.

7.3 The species available

The following species of fish and shrimp were available in the study area. Culture concentrates on Bagda Chingri and the rest comes up as side product.

1. Bagda Chingri (*Penaeus monodon*)
2. Lolia Chingri (*Metapenaeus monoceros*)
3. Sada Chingri (*P. indicus*)
4. Chama Chingri (*M. brevicornis*)
5. Golda Chingri (*Macrobrachium rosenbergii*)
6. Koral (*Lates calcarifer*)
7. Bata (*Mugil cephalus*)
8. Tilapia (*Tilapia nilotica*) and other small fish.

Macrobrachium rosenbergii is the largest of edible crustaceans available in the study area, 4-5 of which make a kg. Its rotation is six months; its maximum yield is approximately 988 kg/ha. *Penaeus monodon* is the most productive shrimp species and it is the one with highest exportable potential; 20-25 shrimps of this species make one kg. Its maximum yield was found to be 370-617 kg/ha. *Metapenaeus monoceros* 400-500 shrimp make one kg; *Penaeus indicus* takes

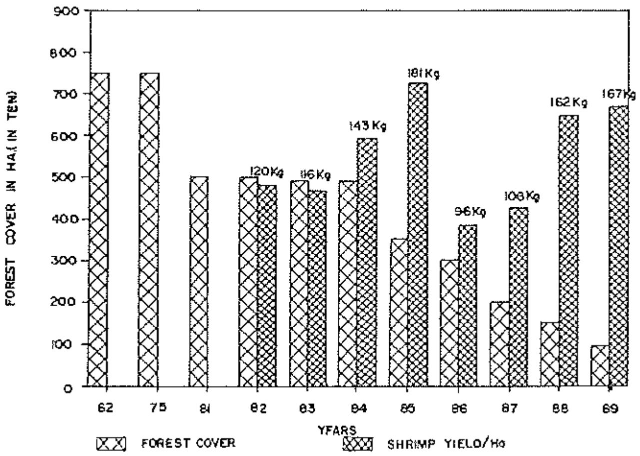


Fig. 21. Bar diagram showing forest area *vs* shrimp yield.

40/45 shrimps to make one kg and it takes *M. brevicornis* 40-45 shrimps to make one kg. All these species are exportable.

The 1989 inventory shows that the average yield of *P. monodon* is 167 kg/ha. The productive area for shrimp in the Chokoria Sundarbans is about 6,527 ha. the total yield was approximately 1,100,000 kg with an approximate return of about 165.0 million taka. Return would have been larger if the market price had not fallen from 250 taka to 150 taka per kg. Production of shrimp in this area appears to be promising and growers are slowly changing to intensive methods of shrimp culture.

7.4 Mangrove vegetation and shrimp farming

The artificial production of shrimp does not depend exclusively on nutrients of mangrove origin. It has been found that the production does not increase substantially with the additional supply of organic and inorganic nutrients to shrimp ponds, therefore some growers are not using additional nutrient to shrimp pond; the hypothesis therefore is that the shrimps get their nutrients mainly from the sea. Before 1987 growers collected shrimp "seed" (larvae) naturally by allowing tidal water into the ponds. This system fails to give satisfactory results because large carnivorous fish like Koral enter into the ponds and eat the shrimp larvae and other fish fry. Shrimp farmers at present do not collect shrimp seed from tidal waters, but from the seed collectors. If shrimp fry would depend entirely on mangrove vegetation there would be a scarcity of shrimp "seed" as the shrimp farm area is now devoid of mangrove vegetation. The ponds however are located in such a manner as they get mangrove nutrients from the Sundarban forest and coastal mangrove plantations as there are tidal connections with the Bangladesh coastal area.

According to some of the shrimp growers of the area the ponds should be free of trees as the leaves make the water toxic when they decompose and thus hamper the growth of the shrimp. That is why trees have been removed from all the ponds. Other growers however say that trees of some other species are beneficial for the growth of shrimp as they provide also some shade; alternate light and shade is good for production; and water can be changed by draining it out regularly. No adverse effect from lack of mangrove vegetation inside the shrimp ponds were found. Therefore in the Chakoria area trees inside the pond do not appear so far to be a must for production. What is more important is to maintain the salinity of the pond water. Many growers said that production was adversely affected in 1988 due to reduced rainfall and increased evaporation; salinity increased in the bunded ponds and shrimps were of reduced size. Salinity control of water in the ponds is an important factor for shrimp production. Growers produce shrimp in the ponds in the absence of mangrove vegetation and they do not use much organic and inorganic matter in the ponds. However, since we have not quantified nor estimated the cost of artificial inputs in the ponds it is impossible to reach any conclusion on the biological, ecological and economic cost-benefit balance.

8. Conclusions

It is evident from this study that slow deforestation started before 1970. In aerial photographs taken in 1975 there was no significant evidence of deforestation. Massive deforestation by widespread cutting of trees took place from 1975 to 1981. This study shows that only 973 ha of scrub forest cover exists in the study area today compared to 75,000 ha in 1975. The remaining area has been cleared and shrimp farms have been established. The main cause of this type of unplanned management was the high price of shrimp in the international market. With decrease of the mangrove vegetation cover shrimp production has not decreased, on the contrary it shows an increasing trend due to intensive culture methods that require a large amount of inputs. The growers do not seem to face problems due to absence of mangrove vegetation. They are shifting to semi-intensive and intensive shrimp culture. It was found that in 1989 about 1,100,000 kg of *Penaeus monodon* was produced only in the Chokoria Sundarbans area and its approximate value was about 165.0 million taka. In the past growers earned more money as market price was higher than at present. Such a large amount of money could not have been earned by selling forest produce. Shrimp farming is the most profitable business now and the growers are producing shrimp with great economic benefit. It seems that shrimp production figures do not depend on the mangrove forest locally; however the nature, amount and cost of artificial inputs was not analysed. Nutrients from mangroves may be coming from surrounding mangrove areas. For semi-intensive and intensive shrimp culture presence of mangrove forests does not seem to be essential, but this study did not carry out a detailed cost-benefit analysis.

As most of the mangrove vegetation was cleared for shrimp farming only scrubby negligible vegetation without any timber was left in place in Chakoria Sundarbans, therefore there was no scope for carrying out a timber volume inventory as had originally been planned.

The socio-economic status of the poor people of the area tends to change for worse. Some people have become jobless, the local fishermen have been converted into daily laborers, cattle and buffaloes have lost their range lands. The biotic pressure that was earlier on this land has been transferred to the main-land tropical forest. The environment is completely changed, the whole area is now open and is exposed to cyclones and storm surges which are a regular phenomenon in the coastal area of Bangladesh.

A balance should be maintained between mangroves and other development activities like fish culture for the preservation of the environment.

As envisaged in the study the loss of lives and property due to 1991 cyclone in the Chakaria Sundarban regions was enormous. The loss of lives and property could have been much less had this region been covered with forests. During the cyclone, not only the homesteads and agricultural land were damaged but also shrimp farms were washed away by the storm surges associated with the cyclones.

Hence it is recommended that a protection belt of mangrove forest be created around the shrimp farms.

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Annexure

Bangladesh Space Research and Remote Sensing Organization (SPARSO) Socio-Economic Study Chokoria Sundarbans

November 1989

1. Location ________________ Date ________________

1.1 Interviewer ________________

1.2 District ________________ 1.3 Upazila ________________

1.4 Union ________________ 1.5 Village ________________

2. House No. (if any) ________________

2.1 Name of Respondent ________________

2.2 Age ________

2.3 Sex ________

2.4.1 Head of house hold________________

2.4.2 If not specify ________________

2.5 Illiterate, can sign Yes_____ No_____

2.6 Number of family-member attending the educational institution ________________.

2.7 Total number of family member________________.

2.8 How long have you lived here ________ years.

2.9 Where did you live before ________________

2.10 Distance from previous habitat ________________

2.11 Reasons for voming ________________

Affected by cyclones Yes_____ No_____

Refugee from abroad Yes_____ No_____

Land less Yes_____ No_____

Others Yes_____ No_____

If other specify ________________

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2.12 Occupation: Fish Farmer/Cultivator/Fisherman/Wood cutter

Daily Labour/Business man ____________________

Daily/monthly/annual income ____________________

Source of income ____________________

Area of land under cultivation ____________________

Number of ponds under fish farm ____________________

Others ____________________

3. Land used by the household:

	Indicate approximate area in decimal	
	Inside Forest area	Outside Forest area
3.1 Homestead		
3.2 Paddy land		
3.3 Salt-belt		
3.4 Fish farm		
3.5 Non paddy land for other use		
3.6 Land for fruit and other tree		
3.7 No. of trees		

4. Employment:

4.1 Do you or any other member of your family worked as a daily labourer for the Chokoria Sundarban forest ____________________

4.2 If yes, what was the daily wages ____________________

4.3 Other employment information ____________________

5. Collection from the forest area:

Product Code		Unit of measurement	Code
1	Fire wood	Quintal	Q
2	Twigs, branches	Quintal	Q
3	Supporting sticks	Number	N
4	Cattle fodder	Head loads	H
5	Cattle grazing	Number	N
6	Post/Poles (timber)	Number	N
7	Timber	Cft	C
8	Fish (Prawn)	Quintal	Q
9	Salt	Quintal	Q
10	Rice	Quintal	Q

6. Definition:

Collected from either I = inside forest area
O = outside forest area
P = permite
NP = no permite

House hold consumption		Market selling	
Product code definition	Qty and unit code	Product code	Qty and unit code

6.1 Quantity per month during the season enter Code, Quantity, Unit.

6.1.2 Duration of Collecting season in months in one year.

6.1.3 How many trips/month during the season by you.

6.1.4 How many trips/month during the season by your wife.

6.1.5. How many trips/month by your children

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6.1.6 How many trips/month by others.

6.1.7 Distance/round trip (km).

6.1.8 Time/round trip.

6.1.9. Activity usually combined (children collect twig while grazing).

7. Market sales

If you collected or harvest product from the forest for sale in the market, use product code and unit code of 6.

A: Employed to do this

7.1 Wage Rate/unit.

Product code	Response and unit

7.2 Months/Year

7.3 Where do you deliver to

B: Self Employment

7.4 Selling price/unit

7.5 Months/Year

7.6 Market place

8 Purchase from Market.

Price code 6	Total only	Price unit

9 Domestic Energy for Cooking

	Number
9.1 Number of Stoves	
9.2 Inside Chulas	
9.3 Outside Chulas	
9.4 Others (spceify)	

9.2.1 Quantity of fuel used/month over the year.

Fuel	Qnty/month during season	Number of used

9.2.2 Cooking requirement. Relation between defferent types of energy.

		% relation (use annas)
9.2.2.1	Fire Wood Split/fire wood cut sticks twigs, leaves of old house/construction material.	
9.2.2.2	Agric. residence cowduing, Jute sticks etc.	
9.2.2.3	Kerosene	

9.2.3 Relation between wood based energy from homestead and from the forest

	% from homestead
All wood based energy split fire wood cut sticks twigs, leaves	
	100 %

<u>Fuel Code:</u>

	Fuel description	Unitee of Measurement	Code
01	Split firewood	Quintal	Q
02	Twigs leaves	Quintal	Q
03	Cut sticks	Quintal	Q
04	Old supporting stickes	Number	N
05	Agricultural residence	Quintal	Q
06	Cowdung	Quintal	Q
07	Jute sticks	Quintal	Q
08	Old construction material	Quintal	Q
09	Others		

	Specify Yes	No
10 Did you and your family graze cattle in the forest area?		
11 Did you and your family collect fire wood and other consumption from the forest?		

12 From where they collect now?

13 Cause of the deteerioration according to you?

Code	Yes	No	%	Time
1. Cattle damage				
2. Theft of seed ling/sapling				
3. Theft of trees/logos				
4. Settlingg incidental fire				
5. Accidental fire				
6. Poor management				

**Bangladesh Space Research and
Remote Sensing Organization (SPARRSO)**

Partial Inventory of Fisheries Resources
in the Chakoria Sundarbans

1. Name of the Shrimp farmer/owner:

2. Date of establishment:

3. Area in ha.

4

Species available	Annual yield in kg. for last ten years	Price in Taka

5. Nutrient source
   a. Organic
   b. Inorganic

6. Annual Expenditure for the farm:

7. Average Annual Income:

8. Why do you select the farm in Chakoria Sundarban?:

9. Average Annual Income from the Shrimp farm

								Year
								Taka

10. Are you increasing the area of the farm?:

11. Are you trying to culture other species than conventional one?:

12. Are you adopting any modern shrimp culture technique to increase the production rate? If so how?:

13. Larval Input/Cumulative:

14. Average Salinity %:

- Shokoria Sundarbans

15. Average PH.:

16. Average water temperature °C:

17. Average dissolved O_2 mg/l.:

18. Causes of deforestation according to you:

- ISME -
International Society for Mangrove Ecosystems

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