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The discipline of geography has been changing in its methodological aspects for the last few decades. The impetus for this has been provided by the process of globalization, the growing concern for the change in the manner of reciprocity between society and the environment and the ushering in of a technocentric way of spatial analysis. While the map output of prolonged field surveys have always been appreciated and formed the founding stone for cartographic perception, the high resolution satellite images and their processing in a digital environment, the virtual earth and different desktop applications have formed an inseparable part of the present day geography students. Extraction of different thematic layers from toposheets and satellite images for the purpose of comparative analysis have been a favourite topic ever since the LANDSAT series of NASA was launched in the early 1970s. With a constantly improving resolution and its multi-temporal coverage, even the most subtle of the changes can be effectively detected and analyzed. In India, the products available from the IRS series have catered to the National needs along with pioneering works in this field by the agencies of IIRS, Dehradun. The present work focuses on the extraction of different types of data pertaining to Landuse/Landcover from Survey of India Toposheet and different Satellite imagery and their comparison. It also attempts a case study to investigate how the vegetation status can be analyzed and be related to its surroundings.

Location of the Study Area

A total area encompassing 474.3 sq. km extending between 23°20'N–23°30'N and 87°15'E–87˚30'E comprises the study area (Fig.1). It corresponds to Grids A1, A2, B1, B2, C1 and C2 of Survey of India Toposheet 73 M/7. Lying at an average elevation of 60 m above the mean sea level, the rectangular area covers parts of Burdwan district to the north and Bankura district to the south, the mighty south-east flowing Damodar river separating the two districts. This area is endowed with certain peculiarities that make it an interesting unit for the purpose of change detection—

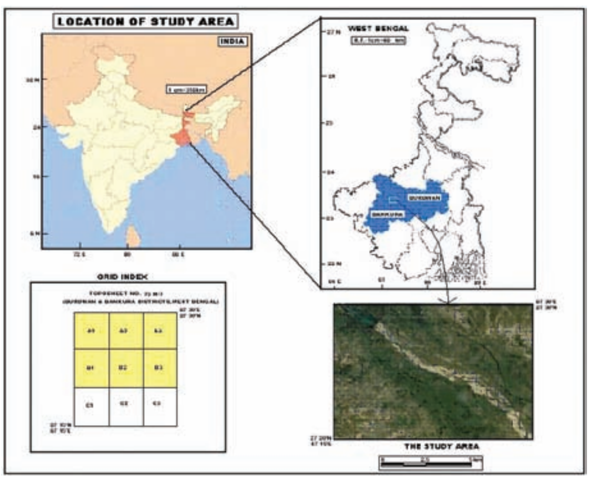


Fig.1

- The study area lies at the juncture of two contrasting realms— one that has experienced considerable growth spurts and is still en route further development. The other characterizing an area that has lagged behind and where any type of development effort progresses at a modest rate. The former is the left bank of Damodar R. in the district of Burdwan where the uptempo Durgapur— Panagarh line is fast undergoing transformation fuelled by industrialization. On the contrary, the right bank of the river is the district of Bankura— mostly agrarian and hence a slow pacer. Only very recently, the town of Barjora has been considered as a potential growth centre. Undeniably, Damodar bears the testimony to the fact what a natural barrier can really do to produce two realms of contrasts just within a kilometer or two.

- The Damodar R. channel has been further modified by the construction of Durgapur Barrage. The impact of this barrage is reflected in the change of channel deposition pattern from time to time and in the progressive thinning of the channel width.
- The two canals emanating from the river at the barrage site have effectively served as lines along which newer activities can develop and thus comprise an important focus for change detection.
- The forests lie at the two diametrically opposite corners of the study area— northeast (Burdwan) and southwest (Bankura). So changes in the areal extent as well as health can be analyzed with insight into the triggering factors for change.

Thus the study area forms a perfect set-up for analyzing the sweeping changes that are taking place spanning a period of over three decades, the pace of change, the differential character of change, the direction of change and the reasons that bind all these together.

Objectives

The major objectives of this paper are as follows —

1. to extract data layers from Topographical Maps, Google Earth Images, and Landsat Images with MSS, TM, ETM+ sensors
2. to detect and analyze the changes from the multi-dated data products

Methodology

The entire study was conducted through thematic mapping and analysis in a GIS package, digital image processing in Image Processing software and the results were verified with the help of ground truthing (Fig.2). The following shall throw light on the different procedures and the supporting sources of information. The base map used for the purpose of change detection was Survey of India Toposheet No.73 M/7 surveyed in 1970–71 and published in 1976 (1:50,000). The images are free-source Google-

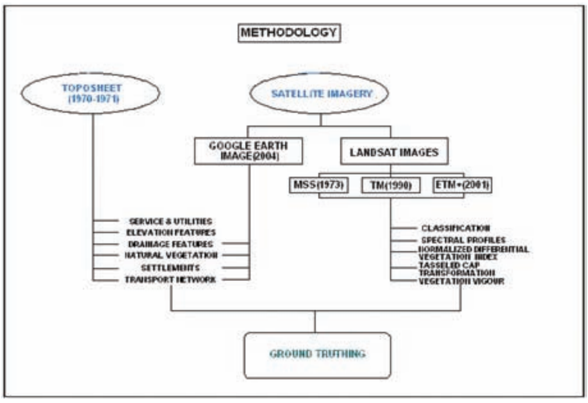


Fig.2

Earth images and Landsat images. Google Earth is a virtual globe that displays satellite imagery of the earth at varying resolution and varying perspective. Created originally by Keyhole Inc. it maps the earth by overlaying of images obtained from different sources like satellite imagery, aerial photography etc. The global resolution is 15 m, but it varies from country to country depending upon the locations of interest. In India the resolution is 200m. The co-ordinate system of Google Earth is geographic coordinates (latitude/ longitude) on WGS 84 datum. Since Google Earth projects the Earth as it appears from an aerial or space platform, it uses 'general perspective projection' – both normal and oblique cases, the point of perspective ranging between 100m to 1000 km.

LANDSAT originally called ERTS (Earth Resources Technology Satellite) has evolved continuously to provide ever improving resolution MSS images of the earth surface since its inception in 1972. The LANDSAT project is a joint venture of United States Geological Survey (USGS) and National Aeronautics and Space Administration (NASA) designed to repeatedly capture images of the Earth surface and thereby observe different phenomena and monitor changes that are taking place. Three landsat Images were considered for the study, their basic features being distinctive (Table – 1, 2, 3, 4).

Table – 1 : Basic Fact File about Landsat Program

Satellite	Sensor	Date of Launch	Present Status	Image Date of the Study Area
Landsat I	MSS	23/07/1972	Decommissioned on 06/01/1978	22/02/1973
Landsat V	TM	01/03/1984	Operational	21/11/1990
Landsat VII	ETM+	15/04/1999	Operational	26/10/2001

Source: Compiled by the authors from varios Books & Journals

Table – 2 : Orbital Information of the Landsat Program

Sensor	MSS	TM	ETM+
Altitude (km)	920	705	705
Inclination (degree)	99.2	98.2	98.2
Orbit	Sun synchronous Polar		
Period of Revolution (minutes)	103	98.9	98.9
Repeat Cycle (days)	18	16	16

Source: Compiled by the authors from varios Books & Journals

Table – 3 : Spectral Band Information of the MSS

Band	Wavelength (micrometer)	Resolution (m)	Applications
4-Blue	0.5 – 0.6	79 × 82	Sediment laden water & shallow water
5-Green	0.6 – 0.7	79 × 82	Cultural features
6-Red	0.7 – 0.8	79 × 82	Vegetation, boundary between land and water & landforms
7-Near Infrared	0.8 – 1.1	79 × 82	Penetrates atmospheric haze best and emphasizes vegetation, boundary between land & water.

Source: Gupta, 2003

Table – 4 : Spectral Band Information of the TM and ETM+

Band	Wavelength (micrometer)		Resolution (m)		Applications
	TM	ETM+	TM	ETM+	
1-Blue Green	0.45 – 0.52	0.450-0.515	30 × 30	30 × 30	Coastal water mapping; soil-vegetation & deciduous-coniferous differentiation
2-Green	0.52 – 0.60	0.525 – 0.605	30 × 30	30x30	Peak vegetation for assessing plant vigour
3-Red	0.63 – 0.69	0.630 – 0.690	30 × 30	30 × 30	Emphasizes vegetation slopes
4-Near Infrared	0.76 – 0.90	0.750 – 0.900	30 × 30	30 × 30	Emphasizes biomass content & shoreline
5-Mid Infrared	1.55 – 1.75	1.550 – 1.750	30 × 30	30 × 30	Discriminates moisture content of soil & vegetation; penetrates thin cloud
6-Thermal Infrared	10.4 – 12.5	10.400 – 12.500	120 × 120	60 × 60	Thermal mapping & estimated soil moisture
7-Mid Infrared	2.08 – 2.35	2.090 – 2.350	30 × 30	30 × 30	Mapping hydrothermally altered rocks associated with mineral deposits
8-Panchromatic	NA	0.500 – 0.900	NA	15 × 15	Sharpening of multispectral images

Source: Gupta, 2003

Techniques of Analysis

- The Survey of India Toposheet was registered and digitized in GIS Software Map Info to extract information about different patterns of landuse and land cover. Thematic Mapping was done based on services and utilities, contours, spot heights and BM, drainage, natural vegetation, settlements, transport networks, and transport density
- About 750 free-source Google Earth images for the same area was downloaded at an eye-altitude of 1km.These were merged in paint accurately to render a composite image of the area.The product was registered and digitized

in Map Info to extract the following thematic layers: drainage, natural vegetation, settlements, transport network, and transport density. Data tables were created for all the above mentioned layers to generate information about areal coverage of the polygon features and length of the linear features.The comparison of the results of Toposheet and Google Earth Images, both visually and through data generated formed the basis of the change detection.

- LANDSAT images were downloaded from landsat.org for MSS, TM and ETM+. These raw images were processed in the image processing software ERDAS to get the final image after layer stacking.
- The images were next classified following both supervised and unsupervised principles to derive the different types of landuse and land cover units and their changes spanning for a period of about 3 decades.
- Normalized Difference Vegetation Index (NDVI) for the 3 sets of LANDSAT images were calculated using inbuilt ERDAS model and the results so obtained were sliced into ten levels to categorize the vegetation health.
- Using both Raster and Vector based software TNT MIPS, the spectral profiles for the study area were analyzed for the three sensors. These spectral profiles were based on the changes that were detected from the previous analysis in Map Info and as such furnish details on the changes in reflectance of energy signals for different bands. This compliments the erstwhile study of areal changes of landuse in the way that the changes in the compositional attributes are also taken into account.
- A case study for depicting the changes in vegetation vigour for Panagarh and Bilaspur Protected Forest region was done from MSS,TM and ETM +.With the inbuilt model in TNT MIPS the first three indices of tasseled cap transformations(TCT) were calculated—brightness, greenness and wetness. These three are the indicators of the subtle variations that may occur in the vegetation of the region.
- Greenness Index is a direct indicator of the vegetation vigour compared to others. The Greenness Index above 5 for MSS and above 21 for TM was imported into ERDAS Imagine. This index was used to extract the result obtained from NDVI previously calculated. Thus, those pixels in space could be extracted from NDVI which also had a high greenness value. This shall augment the understanding of vegetation health there – how much of the vegetated area can truly be designated as being healthy. This is because while NDVI can both be applied for humid and arid regions, greenness index indicates how much canopy cover there is.
- All the above were substantiated by actual ground verification on the date 04/03/2010, the same season when the MSS image was taken. Any deviation from that observed in the satellite imagery can thus be effectively incorporated.

The Physical Landscape

The study area is located at the gateway to the Bhagirathi-Hoogly alluvial plain, representing a transition between the Rarh plain to the west and the riverine delta to the east. With Damodar forming the axis of the study area, mighty Ajay flows to the north and Dwarkeswar to the south. The mobile Gondwana rift valley forms the basement complex of this region, over which materials composed of a wide variety of rocks were deposited in the Miocene period by repeated marine transgressions. The pebble beds of Durgapur are evidence in this regard consisting of feldspathic sandstones, green shales, carbonaceous sandstones and slates and traces of dull coal. The process of alluviation pushed away the seafront. The Damodar river is experiencing changes in its course and consequent flooding and alluviation. This region falls in the Seismic Zone III that is in low hazard zone. The entire topography is undulating in nature varying in elevation between 50 m to 100 m. The primary slope of the land is from north-west to south-east and the secondary slope is towards the Damodar River from its both banks.

Based on Koppen's Climatic Classification the study area experiences a climate that is transitional between CWg and AW1 type, where, 'C' stands for 'warm temperate rainy climate with mild winter','W' means 'dry winter' and 'g' stands for 'Ganges type of march of temperature'. 'AW1' stands for 'tropical savanna type of climate'. Average summertime temperature is 32 C, while average winter temperature is 20 C. The average annual rainfall is 150 mm with a July –September maxima. The parent material bears no relationship with the Base Rock – Depicts materials transported by flowing water across many types of lithofacies. Subsequently, fluctuating ground water table coupled with rain and dry weather conditions have led to the formation of lateritic patches. However, once brought under plough, these lose their lateritic properties and tend to support limonitic soils because of accentuation of the leaching processes. Tropical dry deciduous forest type is seen in this region with common species as sal and eucalyptus. A considerable part has been cleared recently to extend agriculture. The following table gives an overall idea of the forest area in the districts of Burdwan and Bankura.

Table – 5 : Area Covered by Forests (1988)

District	Area covered (ha)		
	Forests	Non - forests	Total
Burdwan	8280	58000	66280
Bankura	12550	90000	215500

Source: Directorate of Agriculture, Government of West Bengal

The Socio – Economic Landscape

The study area entirely comes under the purview of the Damodar Valley Plan Project and has been conditioned by the operations of the DVC and allied growth impulses. Agriculture is practiced in this region with the aid of irrigation canals of Damodar Valley Project. The main crops grown are rice, potato and jute. The mineral endowment of the region is the prime thrust for the economy. Coal bearing Gondwana system, Iron-ore deposits in the quartz veins of Bankura, Fireclay in Burdwan along with pockets of Manganese, Limestone and Mica are noteworthy. This region constitutes 12.6% of the Indian coal reserves. These deposits along with the supplies from Orissa and Jharkhand have led to the development of Durgapur Steel Plant- the steel plant of West Bengal. Barjora is coming up fast as a choice of Industrial centre also. There are a number of power plants, chemical and engineering industries and metallurgical units in this region. DVC has supported 4 Thermal Power Stations in Durgapur. Two are working with existing capacity of 350 MW. Two others have been commissioned for operation on 09/2010 and 03/2011.

The Grand Trunk Road (NH2) runs along the Northern part of the study area.It have now been widened as a part of the Golden Quadrilateral project. The Panagarh – Darjeeling Crossing links Santiniketan to NH2. The Kolkata-Delhi Railway track passes through this region. There are Airstrips at Panagarh and Durgapur, the former with The Indian Air Force and the latter with SAIL. As of 1991 census Durgapur had a population of 425836 which increased to 492996. The Decadal Growth Rate was thus 15.77 %. Barjora in Bankura had a population in 1991 of 9559 and 11509 in 2001- a Decadal Growth Rate of 20.400%. The Index of Urbanization in 1991 in Burdwan was 35.09 and 8.29 for Bankura.

DATA LAYERS FROM TOPOGRAPHICAL MAP

Physical Landscape

The study area has a very gentle slope – almost a flat, featureless plain. The overall slope of the land is from north-west to south-east. Relative relief is of the order of 40 m. About 167.8 sq. km. has an area below 60m. A small deviation from the monotony is seen in South-East part of the study area in Bankura where contours attain height of 100m. There are signs of stony wastes around this region and is mainly forested.

The Damodar river, almost choked with sand deposits and vegetated bars forms the most conspicuous feature of the drainage. It has traversed the region in a North-West to South-East direction. The main boundary of the river maintains an overall straight course with the thalweg forming prominent loops swinging around the sand bars. The Durgapur barrage lies to the North-West part of the river course and the drainage reflects the modifications imbued upon by the barrage. Thus the little portion upstream of the barrage which falls within the study area shows much less signs of choking. All the vegetated bars downstream of the barrage have been inhabited by rural settlements. Even two of the sand bars show the same – implying the stability of the bars in these parts for a prolonged period of time. The particulars of the Damodar Main Channel are given below—

- Damodar Main Channel : Area – 60.85 sq. km; Perimeter – 73.09 km
- Mid-channel vegetated islands: Area – 15 sq. km.
- Channel sand deposits: Area – 35.60 sq. km.
- Total straight line distance – 31.73 km
- Total straight line distance downstream of barrage – 25.40 km
- Thalweg length downstream of barrage – 34.11 km
- Sinuosity Index – 1.34

The Damodar main canals both left bank and right bank emanating from the site of the barrage drains a significant part of the study area, more or less parallel to the river. Total length of these canals is 72.732 km. There are several other feeder canals that subserve the area, more so, along the right bank in the district of Bankura. This area is predominantly agriculture-oriented. Swamps and undefined channels between the main river and its left bank canal are indications of water logging and poor drainage- a possible shift in the river course. Barjora N. joins Damodar just above the barrage in the right bank embedded with sand deposits. Sali N flows for a short distance in the south central part and is also choked by channel depositions. Other streams to crisscross the region are Kukai N (left bank of Damodar in south-east part of the study area), Kanjor N. and Subhankari N. in Bankura, both joining the Kanjor reservoir. Two important wetlands are seen, viz., Kanjor and Rajarbandh. There are about 1838 artificial tanks (85% of which are perennial) and 94 natural ponds of which about 72% are perennial.

Two distinct tracts of natural vegetation has been discerned in the study area— (a) The Bilaspur protected forest of sal plantation and Panagarh protected forest of eucalyptus plantation in the north-east corner of the study area (Burdwan district), and (b) The Beliator protected forest, Gobindpur protected forest and Lakshminarayanpur protected forest, all being sal and eucalyptus plantations in the south western part of the study area (Bankura district). Total area covered by forest here is 25.97 sq. km. Scrub vegetation adjacent to Panagarh forest covering an area of 3.06 sq. km. Apart has been cleared to form Panagarh air force base in late 1960s.

The Socio-economic Landscape

The largest settlement is Durgapur township above the barrage. It covers a total area of 7.98 sq. km and represents an urban agglomeration with concentration of different services and utilities and a complex transport network served by NH 2 and S. E. Railway. The second largest agglomeration is Panagarh covering an area of 3.98 sq. km. Settlements have formed in a linear fashion along the Damodar bank. Linear settlements of rural type are formed along the pack tracks in the mid-channel islands. Total area covered by settlement is 52.37 sq. km.

The most prominent feature of the road transport here is that the NH 2 traverses the north-east part of the map for a length of 16.50 km. S. E. Railway runs more or less parallel to NH2 in Burdwan district for a total distance of 27.93 km. Three railway stations lie along its course for this stretch. Total length of metalled road is 150.25 km. Maximum length of a single metalled road is 16.58 km in the district of Bankura which runs in a more or less east-west orientation. But, Bankura has only 46.60 km, that is, 31.02% of the total road length, while the rest is in Burdwan district. Heavy concentration of metalled roads is seen in Durgapur and Panagarh area. Total length of unmetalled road is 249.52 km, maximum lying in Bankura district. The unmetalled roads lie along the banks of Damodar and along their canals for a large part. Cart tracks / village roads are the primary routes in the forest areas and the rest mainly act as connectors to other higher order roads. Panagarh and Bilaspur PFs have the highest density of it, total length being 265.07 km. Pack tracks are found in a dispersed manner. The significant feature of their distribution is that they are found crisscrossing sand deposits and vegetated bars in the Damodar channel supporting rural settlements along their tracks. Total length for which they run is 56.11 km (metalled road = 166.75 km, unmetalled road = 249.52 km, cart track = 265.07 km, pack track = 737.45 km). Overall, the right bank of Damodar in Burdwan District shows higher level of transport development positive impetus being provided by Durgapur township followed by Panagarh. On the contrary, Bankura though has a substantial road length, they are mostly unmetalled type/ The reasons are that this region is mainly agro-based and there is no large town to provide the necessary growth impulse-just linear settlements along transport lines.

Services and utilities are shown as point features in MAP INFO. Concentration of Telegraph Office, Post Office, Post and Telegraph Office, Police Station and Railway Station in Durgapur and Panagarh followed by Rajbandh and Barjora. Except the last one all others are in Burdwan. Elsewhere temples and chhatris predominate. Burdwan has a greater concentration of services and utilities in relation to communications indicating a higher level of development compared to Bankura which has more of temples and chhatris.

DATA LAYERS FROM GOOGLE EARTH

The Physical Landscape

There has been thinning of Damodar channel due to encroaching of anthropogenic activities into its domain. The cross-bank length along its thinnest part is 0.83 km and the same along the widest part of the course is 2.45 km, both downstream of the barrage. The right bank has more or less maintained its previous alignment while the left bank has shifted. The reason may partly be attributed to the greater pressure of anthropogenic activities in the left bank due to growing urbanization.

- Damodar Main Channel: Area – 43.42 sq. km.; Perimeter – 71.48 km
- Midchannel Vegetated Islands: Area – 14.38 sq. km.
- Channel Sand Deposits: Area –13.42 sq. km
- Straight line distance downstream of barrage – 25.40 km
- Thalweg Length downstream of barrage – 29.75 km
- Sinuosity Index – 1.17

There is a predominance of vegetated bars over the sand deposits. Upstream of the barrage the erstwhile sand deposits have been totally colonized by vegetation. The previous deposits of sand have been washed out and new ones are either in their nascent stage or in the process of merging. The largest sand deposit covers an area of 1.98 sq. km. and the largest vegetated bar covers an area of 6.69 sq. km. The Damodar left bank canal has proliferated in the north-east part of the study area – now crosses directly through Panagarh and Bilaspur protected forest. A total length of 9.45 km has been added in this way making the total length of the Damodar main canal = 82.18 km. The total length of feeder canal now is 114.02 km. The main addition is along the left bank Damodar main canal in Silampur, Naskarbandh and Panagarh. There are about 3452 artificial tanks and 45 natural tanks / ponds / bil or wetlands. Important is the disappearance of Baro bil for extending agriculture and almost obliteration of Dhanu bil by encroaching settlements. Both are in Bankura. An addition of reservoir to the west of Rajarbandh reservoir in Bankura is observed. Drainage nature of Barjora N. and Sali N. however remains unchanged.

Total area encompassed by natural vegetation is 15.40 sq. km. Small decrease in Panagarh P. F. resulting in a total area of 1.30 sq km. Remarkable decrease in Beliator P.F. forming discontinuous patches. Lakshminarayanpur P. F. has been degraded to scrubland. Total area now covered by scrub is 3.05 sq. km.

The Socio-economic Landscape

Total area encompassed by Durgapur township has now increased to 10.55 sq. km. It now extends along both the banks of Damodar left bank canals and extension is likely to continue in this direction. Area under Panagarh is 5.90 sq. km. and Barjora covers 1.68 sq km. The above three settlements show maximum change / increase in area. No settlement is seen occupying the vegetated bars / sand bars. The reason may be amounted as increasing encroachment of anthropogenic activities into the channel area. Thus the previously vegetated bars have been incorporated as part of the mainland resulting in continuous thinning of the channel area. This is especially conspicuous in the left bank of Damodar

Total length of metalled road is now 227.97 km. Important extensions of the metalled road are: (a) in the right bank of Damodar main channel along the river course, though in an interrupted manner, (b) in the wedge-shaped area between the main river course and the Damodar left bank main canal – mostly by improving the previously present unmetalled roads, and (c) a dense mesh in and around Panagarh area and the air force base has developed by increased number of edges within the primary set of vertices. The proliferation of transport network in Durgapur area is obvious. The significant feature of this development is an intricate mesh of unmetalled road along the right bank of the main left bank canal concomitant with the spread of Durgapur township in the area. Unmetalled roads now run along most of the length of the Damodar main canals. Total length of unmetalled roads I 704.907 km. Many hitherto unmetalled ones have been metalled. Barjora in Bankura shows prominent signs of further extending the transport network in future.

DATA LAYERS FROM MSS IMAGE

The MSS image of the study area is a medium resolution false colour composite. A visual interpretation of the image brings to light how the Damodar river has been choked with sediment. There are brownish and yellow-ochre tracts in the channel signaling the mid-channel islands that are cultivated, but are now fallow. Much of the area is agricultural land on the both banks of the river, but lies fallow during this time of the year. Certain tracts in the south-western part of the image give evidence towards the presence of bare ground from which the reflection is high. The settlements appear as clustering together of pixels of varying colours with varying reflectance values.

Supervised Classification

The MSS image bears only a thin thread of blue in the midst of the Damodar main channel (greatly choked with sand deposits) as a relict of what used to be once a mighty river. The time of the imagery is February – a dry period for this region. This is reflected in the higher proportion of the fallow land and lesser greenness of the vegetal cover. One of the major drawbacks in supervised classification is the grouping together of various pixel types in a settlement area. This has been reflected in large swathes of area being brought under the purview of settlement after classification.

Unsupervised Classification

The unsupervised classification of the study area reveals much finer results. This is because the entire spectral range has been decomposed into a large number of classes which has been subsequently merged to get the required final classified image. For instance, here, a finer distinction between the lands that are not going into agricultural uses can be accounted for in a much detailed way. There are thus inclusion of bad land – the regions which appear to be affected by erosion by streams and those land that appear to be wasted. Also, certain tracts of the channel deposits give the appearance of being wetted and could not be bought under any other class due to its reflectance nature.

Normalized Difference Vegetation Index

The NDVI images of the study area were grey scale continuous datasets. The vegetation cover is shown as varying level of brighter patches. The shift towards darker regions of grey is due to presence of bare soil,water bodies etc. The resultant transformed image is sliced into ten levels of contrast for the ease of analysis and is given pseudo-colour in varying sheds of green(vegetation) and blue(water). Calculation of NDVI for MSS reveals a poor vegetation health in general. Maximum of the area has a general contrast level of 0.33 followed by 0.44. A small area in Panagarh forest has a value of 0.55 which is the highest that is seen in this region. The time of the year should be taken into consideration while trying to rationalize this. This being a totally dry season, the vegetation are in their senescence and thus show this nature.

Tasseled Cap Transformation

The case study for Protected Forests in the Panagarh and Bilaspur region was done with an objective to analyze the vegetation health of the region and how it impacts the overall ecology. The Brightness Index and Greenness Index of the region provide an overview in this regard. The Brightness Index is based on the principle that lower the soil moisture, the greater is the soil brightness. Overall, the MSS has high brightness due to the dry season when the image was taken. The scrub vegetation shows a lower brightness than the forested region. This shows that the thick canopy of trees prevented the interception of soil moisture by the sensor. Higher greenness means higher canopy cover. The MSS image being taken in the month of february the wintertime shedding of leaves is reflected in the low value of greenness. A large part of the study area shows a value less than 2.The forest area shows greenness value between 3 to 5 the type of vegetation being Deciduous. Only a very small part shows value above 8.

Vegetation Health Derivation

The Greenness Index calculated for the MSS sensor when masked by the NDVI calculated for the same sensors help to extract those parts that have the greatest vigour of vegetation. This indirectly is an indicator of the ecological status of the region. A certain threshold value has been delineated. The regions that fall below the threshold value can be designated as being "Ecological holes" within the study area. The other regions may be looked upon as those that are impacted by the vegetal cover the most. These regions are ecologically most active and energy flow in the greatest. The settlements that lie here are the ones that have the greatest reciprocity with vegetation and this relation degreases outward radially. For MSS the Greenness values greater then 5 were considered. NDVI was extracted for those regions which had also had a greenness value greater than 5. This served to analyze the regions that were most healthy, particularly because even the greenness value was quite low due to the dryness of the period.

Data Layers from TM Image

Owing to improved resolution, the analysis from TM proved to be not only much easier but also certain significant results were derived. The time of the imagery being that of post-monsoon, the effects of prior rainfall are vividly reflected in the less blockage of the channel by deposition and the dark redness of the vegetation cover. This is the growing season for potato, pulses and oilseed and the sowing season for Boro paddy; this have their prominent impact on the reflection from the agricultural field in the region. Also, in terms of settlements, the their areal extensions, increased energy assimilation due to the growing complexities of anthropogenic activities and the higher retention of wetness due to the impervious nature of the soil there are potent factors to distinguish them from the surroundings.

Supervised Classification

TM image shows progressive thinning of Damodar main channel concomitant with changes in the midchannel deposit patterns. TM shows less signs of blockade by deposits compared to its predecessors. This is probably due to time of the year. TM image of the area dated 21-11-1990 is a post-monsoon period and as such showers diluting the channel deposits are common. Also the effect of any previous release of water from the barrage during the monsoonal period shall be highly reflected in the channel deposit pattern. The greater vigour of vegetation and lesser extent of fallow are also evident here.

Unsupervised Classification

Owing to the lush vegetation canopy, the unsupervised classification of TM image has led to the categorization of the vegetation into dense and less dense vegetation. The dense vegetation mostly covers the inner parts of the protected forests away from any human pollution. The agricultural fields, fallow areas and settlements retain their characteristic features as before.

Normalized Difference Vegetation Index

NDVI for TM shows a more vigorous vegetation growth. This is evident by the fact that most of the area has a NDVI above 0.55. Even certain parts, though small, has NDVI value of 1 which was not attained in MSS. This is an indicator of an extremely good vegetation health in this region. Quite a considerable part of Beliator and Panagarh forests have NDVI value of 0.88. These are the parts that are away from the settlements. Notably, the areas with NDVI values above 0.55 coincide with those areas that are being cultivated as per the unsupervised classification indicates.

Tasseled Cap Transformation

The brightness data obtained is based on the principle that lower the moisture value greater is the brightness. Thus, it is discerned from the image that for the most part the brightness ranges between 25 to 127 for a large part. The forest region has a brightness within the range of 102 -126, while it is 25 to 50 for the scrub region due to higher sensing of soil moisture in this area. Brightness value above 150 is discerned girdling the forest area. This is mainly in the zone of the settlements where the ground surface is largely modified. The TM image reveals lush greenness of the study area. The important fact to note here, is that the time of the year is that of post-monsoonal showers and so a high greenness is something to be expected. In general index value of above 17 is seen in the forest region. The maximum greenness that is attained is 59 in the Bilaspur protected forest area. The scrub vegetation region where the Panagarh air force base is located has greenness value less than 5. The wetness analysis, however, shows that most of the area has almost nil wetness, while the tanks and other water bodies have wetness of 70 and above. This shows a very high gradient. It may be inferred that the region has generally been rendered dry, but the effect of prior showers are incumbent in producing the greenness and brightness values.

Vegetation Health Derivation

The threshold value of greenness that has been considered for derivation of the health status of vegetation in Panagarh and Bilaspur forest region is 21. After masking this with the NDVI calculated it is seen that those areas that have NDVI value over 0.66 have been extracted. However this does not necessarily include all the regions having above the said value of NDVI. The inner parts of the Panagarh and Bilaspur forests have been included and many parts here have NDVI values above 0.88 where the greenness value is above 52. However, it is to be noted that not always a high greenness value been recorded in areas of high NDVI.

Data Layers from ETM+ Image

The addition of panchromatic band with a resolution of 15m has resulted in a much higher quality of image for analysis and interpretation. The Damodar has its trademark sediment choked course as before after a break that was seen in the TM image. This is the growing season for aman paddy, the dominant crop of the region and thus it is reflected in the bright redness of the entire stretch. The extent of fallow land and non-agricultural land has been reduced, partly by irrigation extension and partly by the contribution of monsoonal showers.

Supervised Classification

ETM+ sensor having greater resolution has enabled fine tuning of the features extracted. This has resulted in addition of few more lasses for the purpose of a closer analysis. Thus,the water in the Damodar channel has been decomposed into shallow and deep water based on the reflectance difference – shallow water predominates downstream of barrage and deep water upstream. Also, a new category under the name of 'planted vegetation' has been introduced. This is because along the Damodar left bank main canal for some stretch and near Durgapur township certain red spots of intense brightness is observed. In fact, these bright pockets, though of very little areal extent, have been very prominent and their areal coverage is seen to grow gradually from the images of the previous years. Another category by the name 'scrub' has been introduced which occupies certain parts of Panagarh forest-may be attributed to the declining vegetation health of the area. The area under agricultural land is greatest in ETM+ compared to MSS and TM sensors, while the area under fallow is least. Again the time of the year (October) is the key to understand this.

Unsupervised Classification

The unsupervised classification of the area shows a predominance of the agricultural area, but there has been a remarkable decrease in the area of dense, healthy vegetation canopy that was discerned in TM image.

Normalized Difference Vegetation Index

Comparatively speaking the vegetation health in ETM+ shows a deteriorating nature. Here the highest value attained is 1, but the area above NDVI value of 0.88 has decreased considerably compared to TM and such areas are hardly discerned in Beliator forest region. The sand deposits show a modest value of 0.33 with the growth of small scrub vegetation in their early stages. A large part of the agricultural region shows NDVI value above 0.66 due to the cultivation of boor paddy.

Tasseled Cap Transformations

The ETM+ sensor shows a much less gradient of brightness value: the minimum being 35 and maximum being 96. As before the settlements showed the greatest brightness value, the scrubland the least and the forest region lies in an intermediate region. The ETM+ sensor also reveals a lesser range of wetness, minimum 10 and maximum being 62. However, unlike TM imagery, the spread of the wetness value is much greater. For most of the forest region wetness lies within the range of 25-29. It lies within 35 to 49 for the western part of the Bilaspur forest. The maximum wetness lies in the region encircling the forest growth (above 52). The scrub region has a wetness to the extent of 10 to 14.
Spectral Profiles

The changes detected by employing the GIS tools so far have primarily been concerned with the changes in the channel deposit pattern or forest cover or settlement areas or road length. But with the changes in their areal extent, changes in their compositional attributes are also in tandem. A fall in the health of the vegetation of the area or an increase in the soil moisture shall be reflected in the energy reflected by them in all the wavelengths. By looking at the spectral response along different section lines for the multi-temporal LANDSAT images the energy signals and their changes can be identified for different objects on the land surface. This has been attempted for the study area by using TNT MIPS. For MSS blue, green and red bands are considered, and for TM and ETM+ green, red and infrared bands are considered – these are the channels via which the false colour composite is produced. In case of MSS the infrared band shows scan line errors that has almost nullifies the usage of this band for this region.

All together, 12 spectral profiles have been drawn for the study area based on the regions which have shown the greatest changes during visual interpretation of the LANDSAT images. Most of these profiles are across the banks of the Damodar. This is because of the fact that the river has been highly impulsive and this has a magnanimous impact on the adjacent landuse.

- In all the spectral profiles that have been drawn, there is a progressive increase in the interception of the energy from MSS to TM to ETM+. In MSS the pixel value barely reaches 60, while in ETM+ the same value shots upto 120.
- In the first 4 profiles that are constructed across Durgapur Township a prominent feature is the appearance of a bright red patch to the East of the Township surrounding a water body. This was given a separate class in the image classification of ETM+ under the banner of "Planted Vegetation". The spectral reflectance profile indeed shows that the reflectance value of the Infrared band has suddenly sky-rocketed in this part – an indicator of good vegetal cover.
- The next six spectral profiles are across the banks of Damodar river. The reflectance of each of the bands are effected primarily by the presence of the sand deposition where all bands show high pixel values and the presence of water where the pixel value for Infrared band reaches a peak.
- The last 2 profiles are across Bilaspur and Beliator forests.

Analysis and Inference

Thematic data layers about various parameters have been extracted, mapped and measured from various sources like, topographical map, Google Earth Image, MSS, TM and ETM+ images of the study area (Fig.3–35). The following salient features have transpired —

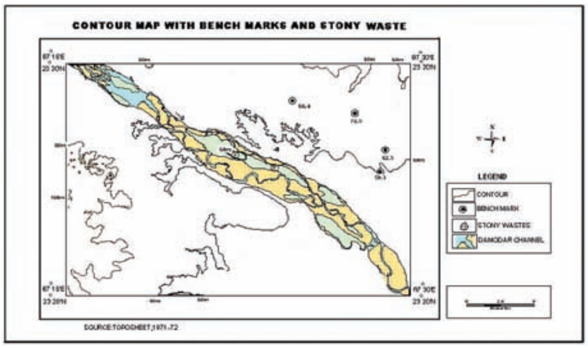


Fig.3

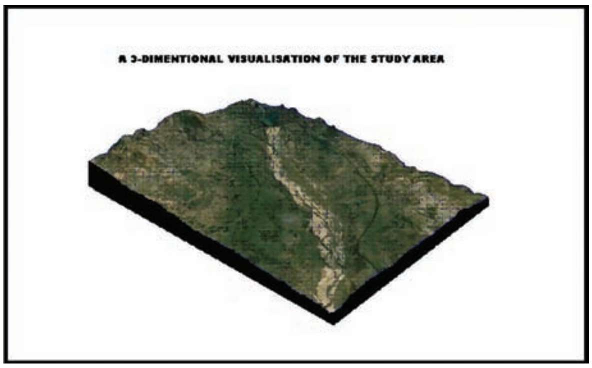


Fig.4

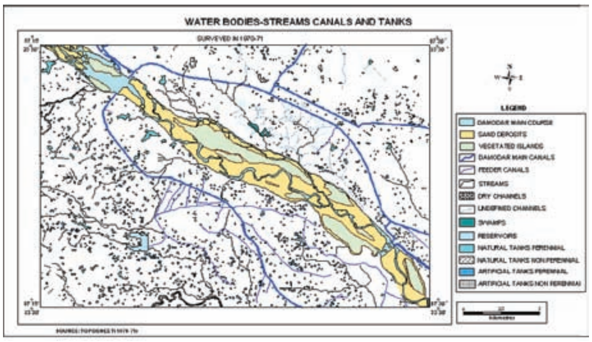
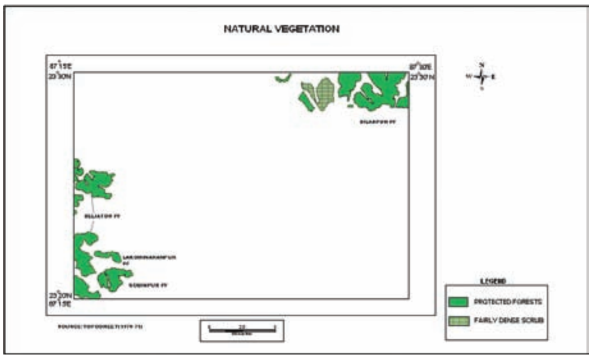


Fig.5



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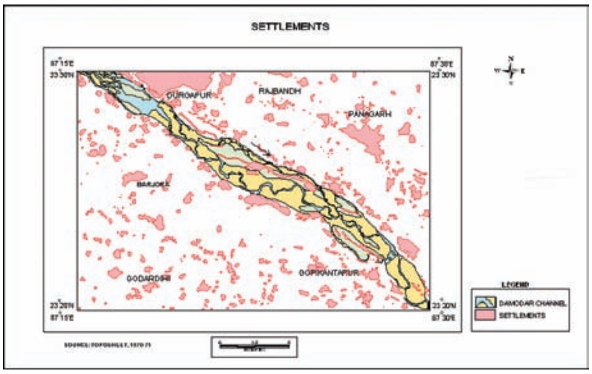

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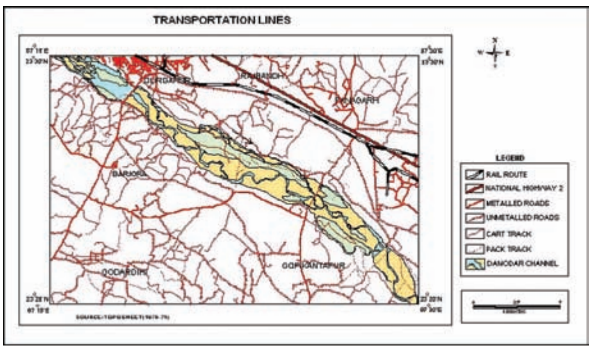

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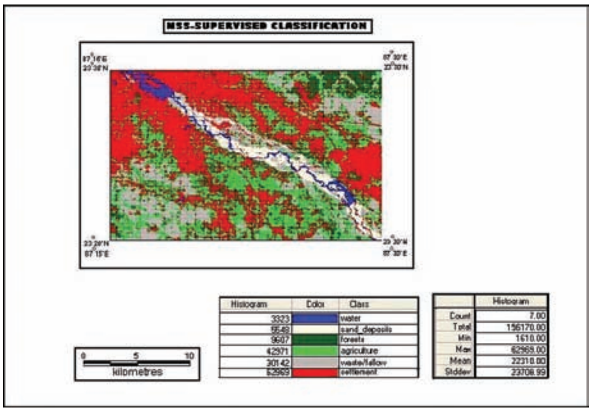

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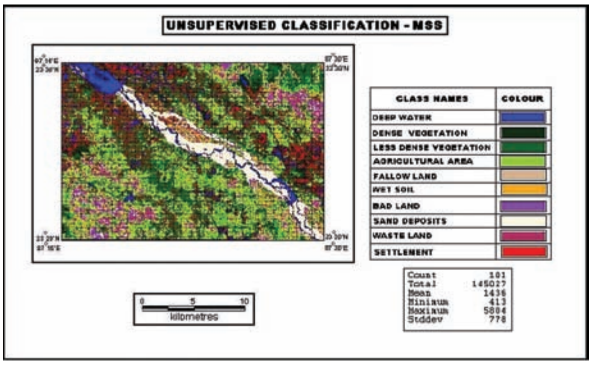

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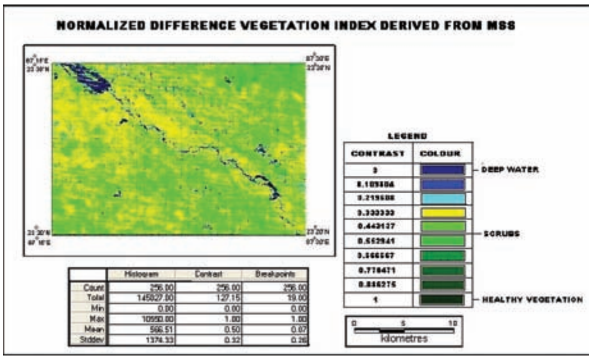

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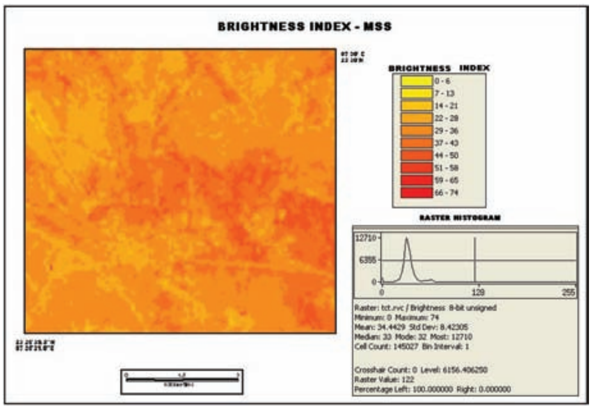

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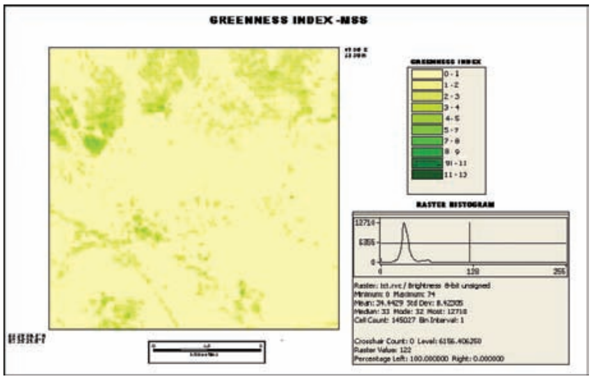

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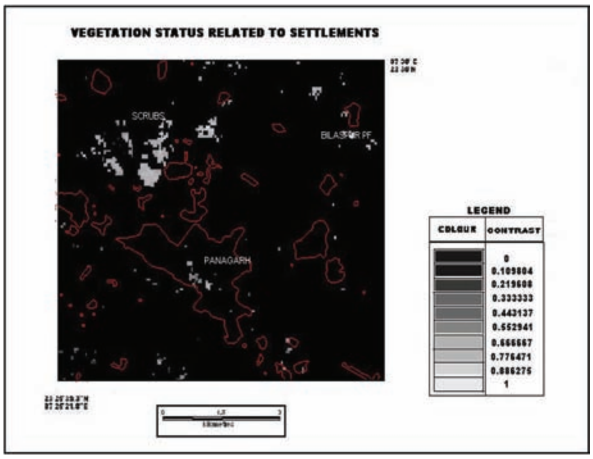

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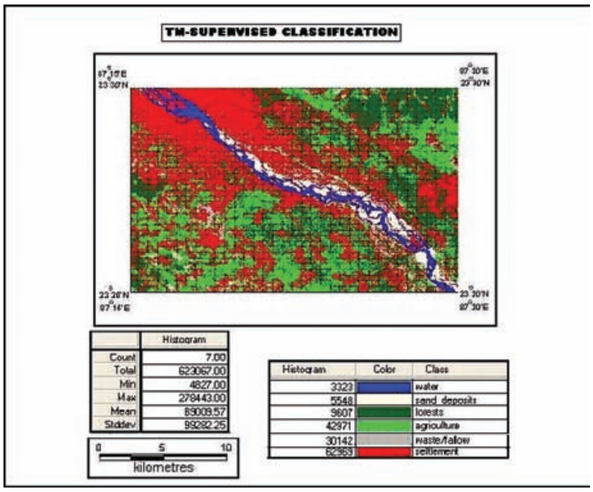

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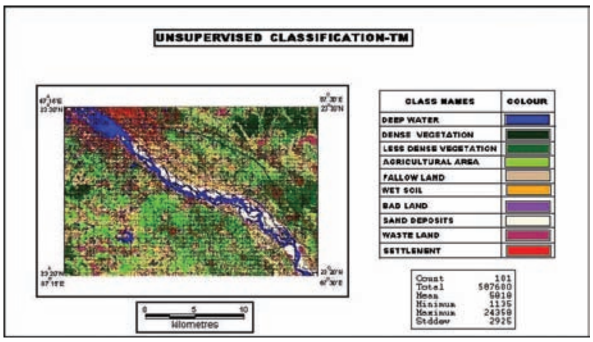

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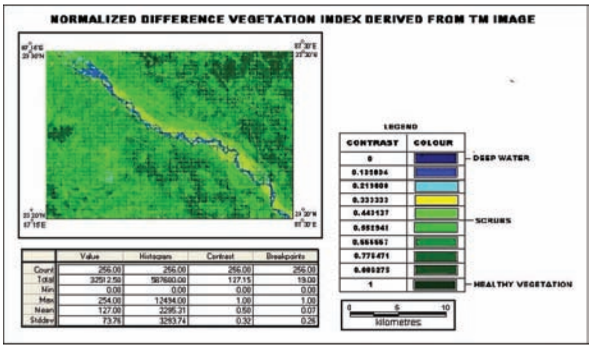

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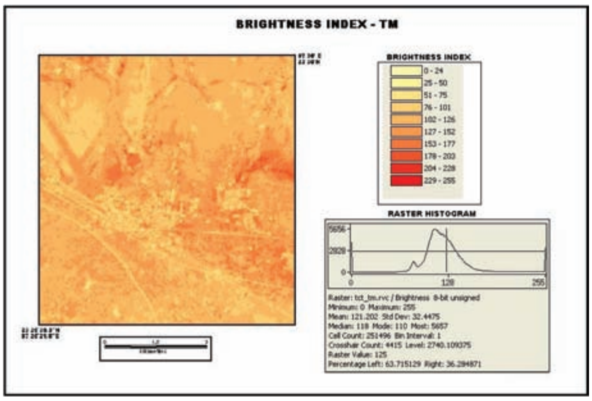

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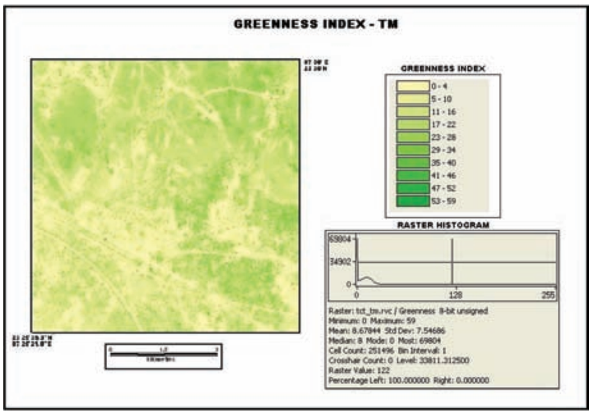

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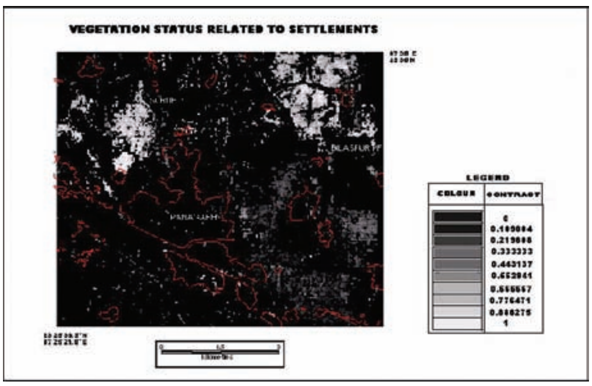

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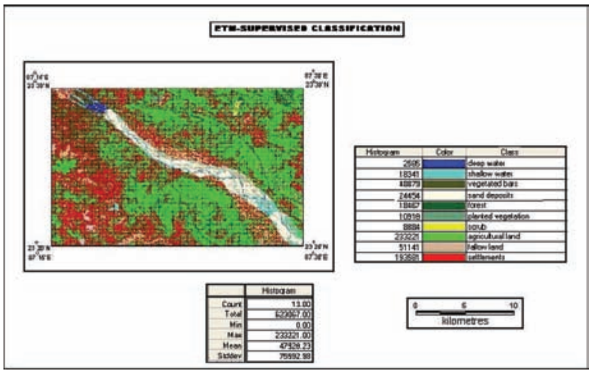

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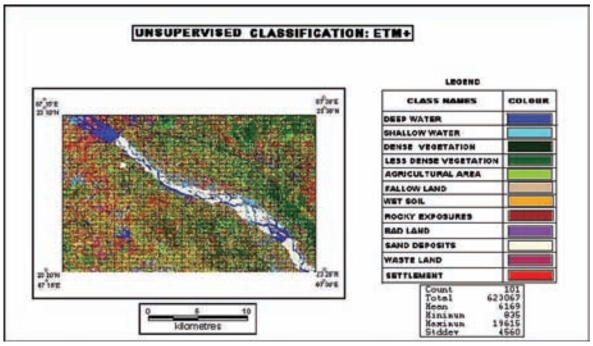

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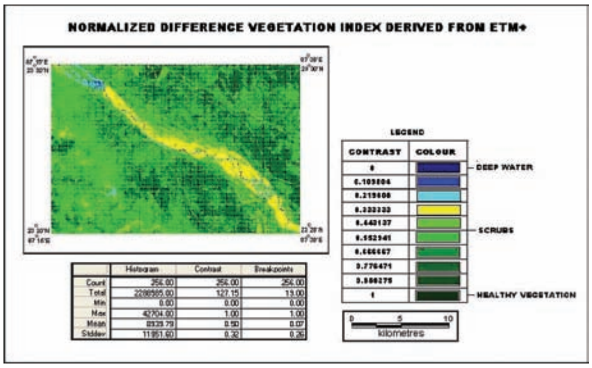

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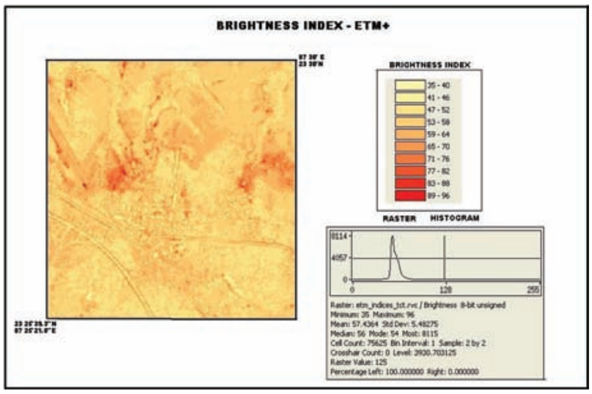

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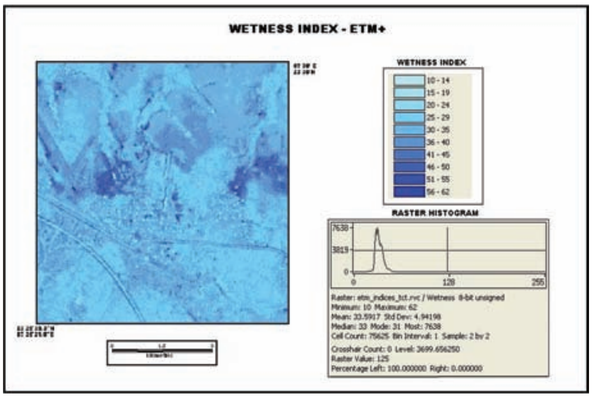

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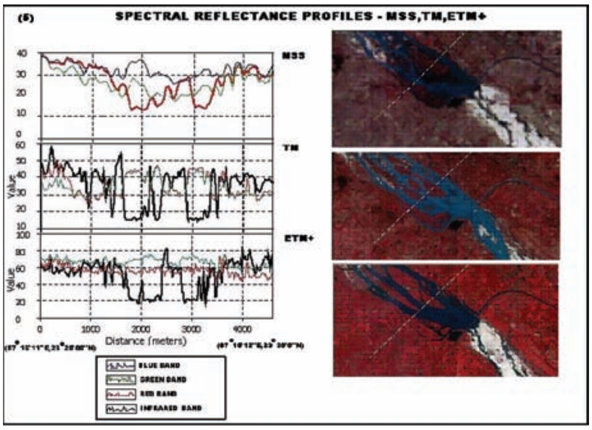

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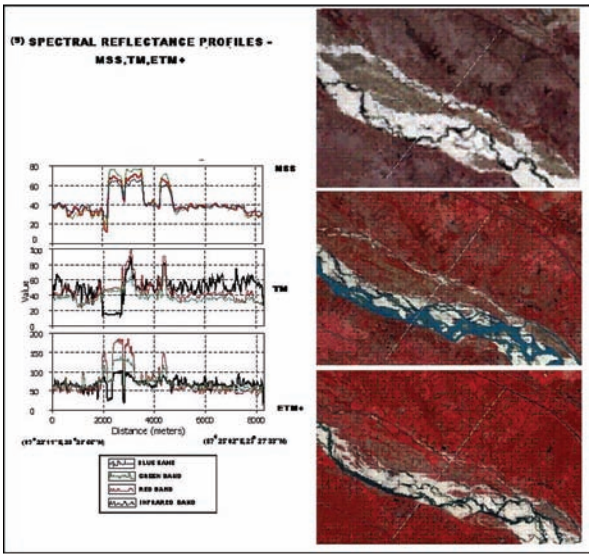

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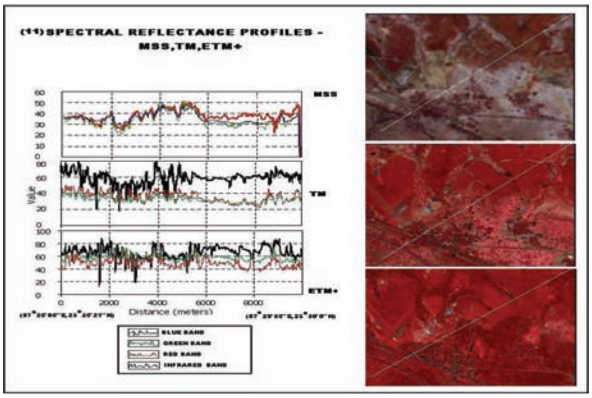

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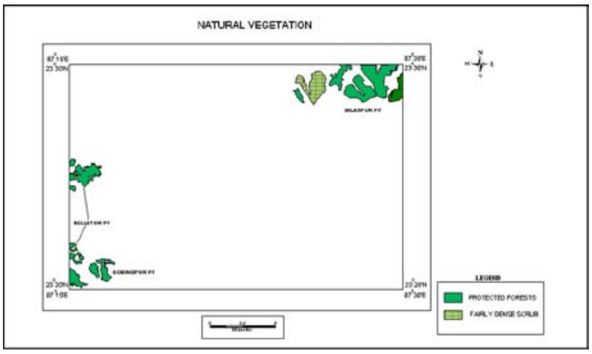

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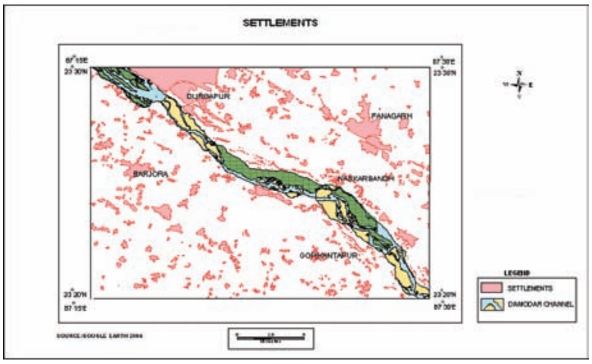

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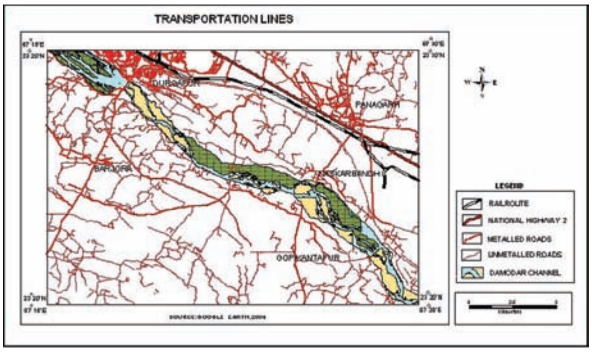

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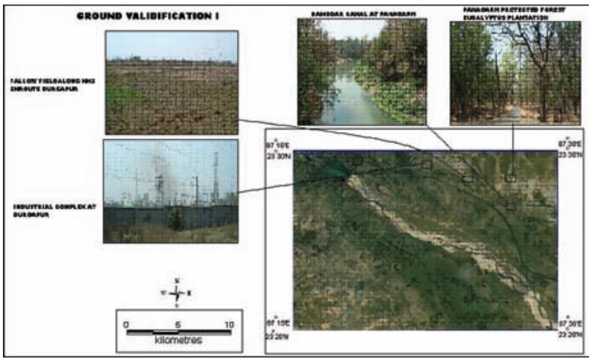

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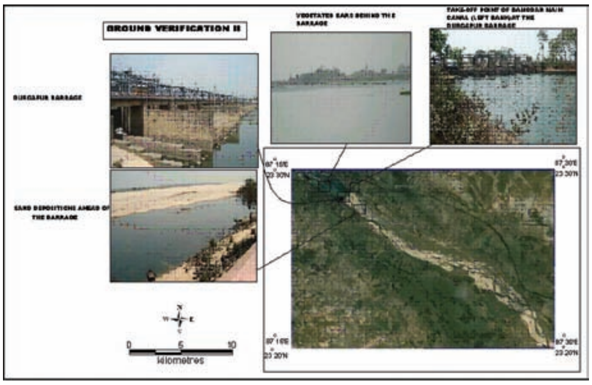

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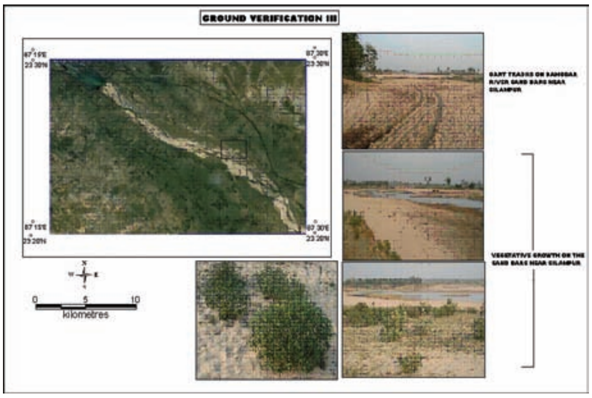

Fig.35

Note:
Fig.3 – 8: Data Layers from Toposheet (1970 - 71),
Fig.9 – 14: Data Layers from MSS Image (1973),
Fig.15 – 20: Data Layers from TM Image (1990),
Fig.21 – 25: Data Layers from ETM+ Image (2001),
Fig.26 – 28: Spectral Profiles (MSS, TM, ETM+),
Fig.29 – 32: Data Layers from Google Earth Image (2004),
Fig.33 – 35: Ground Truthing.

- Regarding drainage / water features, comparison has been done between 1970 – 71 Toposheet data and 2004 Google Earth Image data. Area of Damodar channel, vegetated bar, and sand deposit have decreased; length of the Damodarchannel perimeter, its sinuosity index, specially downstream side of the barrage and number of natural water bodies, like bils, ponds have also decreased. Length of the main canal, feeder canal, number of artificial tanks and reservoirs have increased. All the above changes are statistically significant ones (Table – 6).
- Regarding natural vegetation, settlement and transport network similar comparison has been done between 1970 – 71 Toposheet data and 2004 Google Earth Image data. It is found that area of forests and scrubland have decreased. Area under settlement and total length of transport network have decreased. Settlements like Durgapur and Panagarh have grown through huge spatial expansion. Lengths of both the metalled roads and unmetalled roads have increased. All these changes are statistically significant ones (Table – 7).

Table – 6 : Summary of Changes: Drainage / Water Features

Particulars	Toposheet (1970-71)	Google Earth Image (2004)	Change
Damodar Channel (sq. km)	60.85	43.42	–
Damodar Perimeter (km)	73.09	71.48	–
Vegetated Bars (sq. km)	15.00	14.38	–
Sand Deposit (sq. km)	35.60	13.42	–
Sinuosity Index (Barrage Downstream)	1.34	1.17	–
Main Canal Length (km)	72.73	82.18	+
Feeder Canal Length (km)	97.79	114.02	+
Artificial Tanks (No.)	1838	3452	+
Natural Tanks/Bils (No.)	94	45	–
Reservoirs (No.)	2	3	+

Source: Computed by the authors

Table – 7 : Summary of Changes: Forest, Settlement and Transport Network

Particulars		Toposheet (1970-71)	Google Earth Image (2004)	Change
Natural Vegetation	Forest Area (sq. km)	25.97	15.40	–
	Scrubland Area (sq. km)	3.06	3.05	–
Settlement	Total Area (sq. km)	52.37	75.94	+
	Durgapur (sq. km)	7.98	10.55	+
	Panagarh (sq. km)	3.98	5.90	+
Transport Network	Total Length (km)	737.45	949.37	+
	Metalled Roads (km)	166.75	244.47	+
	Unmetalled Roads (km)	570.70	704.90	+

Source: Computed by the authors

Table – 8 : Summary of Changes: Forest, Settlement and Transport Network

Particulars		Toposheet – MSS (1970–1973)	MSS – TM (1973–1990)	TM – ETM+ (1990–2001)	ETM+ - Google Earth (2001–2004)
Damodar Channel (sq. km)		–	–	–	–
Vegetated Bars (sq. km)		No Change	–	–	+
Sand Deposits (sq. km)		–	–	+	–
Natural Vegetation (sq. km)		–	–	–	–
Settlements (sq.km)	Total Area	+	+	+	+
	Durgapur	+	+	+	+
	Panagarh	+	+	+	+

Source: Computed by the authors

- Between 1973 (MSS image)and 1990 (TM image), the pattern of changes remained almost identical, except that the area of vegetated bar has been significantly reduced.
- Between 1990 (TM image) and 2001 (ETM+ image), the pattern of changes remained almost identical, except that the area of sand bar has significantly increased.
- Between 2001 (ETM+ image) and 2004 (GoogleEarth image), the pattern of changes remained almost identical, except that the area of vegetated bar has significantly increased.

Thus with time, human elements have increased while natural elements have decreased. It is the consequence of population growth, direct impact being increase in settlement's area, decrease in forest and water resources. It requires immediate attention from the naturalists and environmentalists for formulating strategies in order to maintain environmentally sustainable development.

Bibliography

1. Campbell J P (1996): Introduction to Remote Sensing, Guilford, NY
2. Cromley R G (1999): Digital Cartography, Englewood Cliffs: NJ
3. Chang K T (2002): Introduction to GIS, Tata McGraw-Hill, New Delhi
4. Chrisman N R (2002): Exploring GIS, John Wiley & Sons, NY
5. Duda R O, et al (2001): Pattern Classification, John Wiley & Sons, NY
6. Gupta R P (2003): Remote Sensing Geology, Springer Verlag, Berlin
7. Jahne B (1997): Digital Image Processing, Springer Verlag, NY
8. Jensen J R (2005): Introductory Digital Image Processing, Prentice-Hall, NJ
9. Jensen J R (2007): Remote Sensing of the Environment, Prentice-Hall, NJ
10. Joseph G (2003): Fundamentals of Remote Sensing, University Press, Hyderabad
11. Konecny G (2003): Geoinformation – remote sensing, photogrammetry and GIS, Taylor & Francis, London
12. Lo C P and A K W Yeung (2002): Concepts and Techniques of GIS, Prentice-Hall, New Delhi
13. Mather P M (2004): Computer Processing of Remotely Sensed Images, John Wiley & Sons, NY

14. Pratt W K (2001): Digital Image Processing, John Wiley & Sons, NY
15. Sarkar A (2009): Practical Geography – a systematic approach, Orient BlackSwan, Hyderabad
16. Walford N (2002): Geographical Data – characteristics and sources, John Wiley & Sons, NY
17. 17. Sabins f F (1997): Remote Sensing – principles and interpretation, Freeman, NY

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