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Coastal Geomorphology and Landuse Changes along Coastal parts of Goa: An RS-GIS Approach

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Abstract

GOA, endowed with natural & scenic beauty, is famous for its silvery sand & golden coastline. In the recent years, a lot of changes (both natural & man-made) have occurred rapidly which have direct impact on the human environment. These changes in the nature have to be delineated for better understanding and for taking the necessary mitigate or remedial measures. Further, the management of natural resources has become a complex task as more & more socio-economic activities such as urban development, agriculture, waste disposal, nature conservation, shipping, harbor development, fisheries etc., are taking place. Present paper discusses the geomorphology of coastal features as observed and maps the land use changes that have occurred during the period from January 1999 and March 2001 due to rapid pace of urbanization, detected on the basis of field observation and with the use of IRS-1C Satellite Imageries using RS & GIS methodologies. In all, about fourteen (14) coastal features have been observed from various band combinations and their chacteristics have been delineated. From the study, it is observed that 1) there is an overall increase in the barren area within the mining belt in March 2001, 2) an overall decrease in the thick vegetation (category) shown by the vegetation index images, and 3) highly turbid water in the northern region indicating active sedimentation along the coast moving in the southeasterly direction.

Keywords: Goa, India, remote sensing, Image processing, Landsat images

INTRODUCTION

Goa is endowed with its natural & scenic beauty has become a famous for its silvery sand & golden coastline. However, in the recent years a lot of changes have occurred over the area. These changes are both natural & man-made. For better management, these changes have to be detected and delineated using Remote Sensing (R.S) & Geographic Information System (G.I.S.) techniques.

The management of natural resources has become a complex task as more & more socio-economic activities such as urban development, agriculture, waste disposal, nature conservation, shipping, harbor development, fisheries, oil & gas production are taking place in coastal areas. Remote Sensing & G.I.S were found effective in managing & determining the various changes that have occurred in the area & for carrying out analysis related to natural resource management. Geographic Information System is very useful in integrating, modeling, visualizing & interpreting different types of data.

Murthy et al, (1981), studied the aspects of the morphology of the beaches in relation to the environmental factors like wind, waves & fluctuations in the groundwater tables, etc. Rao et al, (1985) had undertaken the study of the geomorphology of Goa based on the aerial photos and Landsat imageries. They identified three physiographic zones & four planation surfaces. They concluded that the configuration of the Goa coastline is controlled by the fractures and mega lineaments and modified by the sea level changes during the Quaternary. Kunte (1990), studied a variety of image enhancement & analysis techniques to delineate the geological features, lineaments & several land use features through the information gathered from the LANDSAT Multi-Spectral Scanner (MSS) data, both in the visual & digital form.

Wagle (1993) studied the geomorphology of Goa & the Goa coast by interpretation of the LANDSAT images, aerial photographs & extensive fieldwork. Physiographically, he classified the region broadly into: a) the coastal tracts, b) the sub-ghat region and c) the high ranges of the Western Ghats. The overall landforms are the result of a combination of structure, lithology, intrusions, volcanism, denudation & Quaternary Sea level changes. Kunte & Wagle (1994) processed the space-borne data covering the coastal zone of Goa state using digital & visual image processing techniques. SPOT images & aerial photos of the coastal zone of Goa were analyzed & fluvial, estuarine, marine, vegetational & near shore features were identified. Landsat images have been used to study the distribution & variation of the turbid waters. Highly turbid waters are mainly restricted in the vicinity of the river mouths that are the main source of sediment discharge. The waters at the river mouths being highly turbid, its boundaries are easily distinguished from clear waters in the satellite imageries. Areas of highly turbid waters are generally restricted to the inner shelf where the seabed sediments are fine grained & clear water to the outer shelf where the seabed is covered by the relict coarse grained sediments.

The present paper attempts to understand the usefulness of Remote Sensing & Geographic Information System techniques in applying for change detection for two different years (January 1999 & March 2001) with the following objective in mind:

- Study the two years satellite images by visual interpretation.
- Image analysis using various enhancement techniques like band ratioing, Image filtering, vegetation index, principal component analysis & image differencing.
- Prepare a land use pattern classification of the study area.

Study area

The GOA state is situated along the central west coast of India between the Arabian Sea & the Western Ghats, covering an area of about 3,702km^2. It lies between the latitudes N $15^0 48' 00''$ & N $14^0 53' 54''$ and longitudes E $74^0 20' 13''$ & E $73^0 40' 33''$ representing part of the Konkan coast. It has a coastline of about 105kms, composed of alternately situated headlines, estuaries, bays & world famous beaches. It is situated to the west of Karnataka state & south west of Maharashtra state. Along the eastern margin of the state, the highly imposing massive chain of hills of the Western Ghats runs in a general north south direction. Goa experiences a tropical & humid climate. It receives rainfall from the southwest monsoon winds from June to September. The annual rainfall is of the order of 250 to 300 cm. The temperature in the region ranges from 20^0 to 37^0 C.

The area for the present investigation, Tiswadi taluka, is bounded between the latitudes N $15^0 37' 30''$ - $15^0 50' 00''$ & longitudes E $72^0 55' 00''$ - E $74^0 00' 00''$ **(Figure 1).** It forms the central part of the Goa state, included in the Survey of India (S.O.I) topographic maps number 48E/14 & 48E/15. The area is surrounded by the Mandovi River in the north & by Zuari River in the south, both having estuarine characteristics.

METHODOLOGY

The study envisages the use of digital image processing techniques & GIS methods for determining the various changes that have occurred in the study area over the two years. Various enhancement operations like band ratioing, vegetation index, filtering (edge detection), principal component analysis & image differencing, have been performed on the images to improve the interpretability of the images. Ground truth information was collected at selected spots with field photography (**Figure 2**).

RESULTS

Enhancements are used to make it easier for visual interpretation & understanding of the imagery. The digital imagery allows manipulating the digital pixel values in an image. Some of the enhancement techniques used in this work are: 1) color composite, 2) band ratio, 3) filtering (for edge detection) 4) principal component analysis, 5) vegetation index & 6) image differencing.

i) Color Composite

Data can be displayed in two basic forms, either one band at a time in black & white or in combination of three bands by assigning one primary color to each band. Combining the bands 1, 2, 3 corresponding to the visible red, green & blue gives an approximation of the true color of the surface. It is more usual to combine the wavebands from outside the visible spectrum, sometimes with one or two visible bands, sometimes the color being exclusively a result of the totally invisible variations in the surface reflectance. Such images are called as False Color Composites (FCC) (Jenson, 1996). Color composite of the two satellite images for two different years were done to identify various features present in the images **(Figure 3 & Table 1)**.

ii) Band Ratio

Band ratio images are produced by a process in which the brightness values of the pixels in one band are divided by the brightness values of their corresponding pixels in a second band in order to create a new output image (Mitra, 1999). This ratio may enhance or subdue certain attributes in the images based on spectral characteristic in each of the two bands chosen. Various combinations of the ratioed images were taken to select best combination for producing the well-enhanced composite image.

iii) Filtering

In ENVI image processing system, convolution filters are used for enhancing image data. The convolution filters include: High pass, Low pass, Laplacian, Directional, Gaussian high pass, Gaussian low pass, Median, Sobel, Roberts etc. and user-defined filter.

a) <u>High pass filters</u>: is used to remove the low frequency components of an image while retaining the high frequency. It is used to enhance the edges between different regions as well as to sharpen the edges.

b) <u>Low pass filters</u>: preserve the low frequency components of an image which smoothes it.

c) Laplacian filters: emphasizes the maximum values within the image by using a kernel with a high central value typically surrounded by negative weights in N-S & E-W direction & zero values at the corners.

d) Directional filters: selectively enhances the image features having specific directional components (gradients). The sum of the directional filter kernel element is zero. The result is that the areas with uniform pixel values are zeroed in the output image while those that are variable are presented as bright edges.

e) Gaussian filters: passes a Gaussian convolution function of specified size over the image. The default is 3x3 kernel.

f) Median filters: smoothes an image while preserving the edges larger than the kernel dimensions.

g) Sobel filters: is a non-linear edge enhancement, a special case filter that uses an approximation of the true Sobel function & is a preset 3x3, non-linear edge enhancement operator.

h) Robert filters: is a non-linear edge detector filter similar to Sobel filter. It uses a preset 2x2 approximation of true Roberts function, a simple 2-D differencing method for edge sharpening & isolation.

i) User-defined convolution filters: Here the custom convolution kernel can be defined by selecting & editing a user kernel.

For edge detection in the image, the directional filters are employed using ENVI software. A black & white image was selected, then from the main menu filter was selected & then performed convolution. From convolution sub menu directional filter was selected and accordingly the computer processed the image & resultant image was obtained.

iv) Vegetation Index

Vegetation index is used to transform the multispectral data into a single band representing the vegetation distribution. The NDVI (Normalized Difference Vegetation Index) values indicate the amount of green vegetation present in the pixel. If the values are higher than it, then it indicates green vegetation (Gokul et al., 1985). NDVI uses following standard algorithm:

$$NDVI = (NIR-Red) / (NIR+Red)$$

Vegetation index for the area was calculated using the NDVI procedure in ENVI software. The input file is selected first, then in the calculation parameter dialog box, the specifications for the calculation are mentioned & then output file is given.

v) Principal Component Analysis

Principal component analysis is a digital processing of four spectral bands, which is performed to generate four new Principal Component (PC) images. As the influence of the oceanic features on each is highly correlated, compressing all the bands into a single plane improves the identification of the individual features. For this reason principal component

analysis was performed. The four new images produced are named as PC1, PC2, PC3, & PC4. Out of the four images, the first image PC1 exhibits the maximum contrast.

Principal component analysis was carried on the area to achieve an overall ground cover enhancement by selecting the best information from the raw data. After getting the four principal component images, a false color composite of first three principal components was generated & was visually interpreted on the basis of color, tone, texture & their association with the other features.

vi) Image Differencing

Image difference is used for the change analysis with the imagery that depicts the same area at different points of time. With image difference you can highlight specific areas of change in whatever amount you choose. Two images are generated from this image-to-image comparison; one is a grayscale image while the other is a five- class thematic image.

The first image is a Difference image, which is a grayscale image, composed of a single continuous band. The image is a result of subtraction of the first image from the second image. The difference image calculates the change in the brightness values over the time & reflects the change using a grayscale image. The increase in brighter areas indicates clearing of forest area and the decrease in darker areas indicate that an area has become more vegetated. Or the previous area was dry & is now wet.

The Highlighted difference image divides the changes into five categories, which are: Decreased, Some decrease, Unchanged, Some increase & Increase. Image differencing was carried out by subtracting the first image (January 1999) from the second image (March 2001). The resultant grayscale image & the highlight image were obtained.

vii) Classification

Supervised classification was carried on the area by defining the training sets & creating signatures based on the familiarity with the area. After assigning the sites, the image was classified & resultant image was obtained. In all, seven classes were assigned to the various features identifiable on the imagery. The classification was carried out on both the images with the same number of classes.

DATA ANALYSIS AND INTERPRETATION

Digital analysis

LANDSAT data of the study area were processed & studied using the various processing techniques mentioned earlier & the following results were obtained.

From **Figure.4** it is seen that:

- The data in band 1 highlights some of the land as well as shore features. The image shows picture of turbid water in the near shore region. The tonal variation helps to measure the turbidity concentration. The current directions are indicated by sediment plumes that become elongated & pointed in the flow direction. In the Mandovi & Zuari estuary region, the plumes travel first in westerly, then in southerly to southeasterly direction.

- In band 2, the land features, thick vegetation cover, barren land, beaches & the sediment pattern are easily noticed. However, the water bodies are not clearly visible.
- In band 3, only the water bodies, in dark tone, are very clear & sharp such that they can be mapped. The lineaments are seen along NE-SW direction. Several features like spits, estuary islands, offshore islands & the beach stretch are seen distinctly. The mining belt is also visible but not very clear. The vegetation cover is not seen in this image.
- Band 4 gives apparent 3-D effect. The contrast variation between the mangroves & the other vegetation is seen clearly. The vegetation density is moderate, indicated by gray color, while the white patches are barren lands. The lineaments are seen along NE-SW direction. The beaches are seen as a linear stretch in white color. The water bodies are seen clearly.

Band ratio

Band Ratioing of January 1999 & March 2001 images:

Out of the six combinations of the four bands taken two at a time, band ratio 1/2 for the entire Goa provided the maximum amount of information. In this ratio image, the mining belt & the sediment dispersion pattern are seen clearly. The mining belt is along NW-SE direction. The gray color indicates vegetation cover while the black color represents the barren land **(Figures. 5 & 6)**. For the Tiswadi area, band ratio's 1/2, 1/3, 2/3 & 3/4 provided the maximum information.

- In 1/2 band ratio image, the vegetation cover over the area & the sediment pattern are seen. In 1/3 band ratio image, the water bodies with their inlets & the saltpans are clearly enhanced. The sediment pattern is seen but not that clearly. In 2/3-band ratio image, the water bodies, sediment dispersion pattern, the tidal flat areas along Cumbarjua & the vegetation cover are seen clearly (Drury, 1992). In 3/4-band ratio image, the mangrove vegetation & the other vegetation present in the area are easily distinguishable. In the other two ratioed images i.e. 1/4 & 2/4 nothing much can be make out because band 1 & band 2 are of similar intensity **(Figures. 7 & 8).**

- False Color Composite image was created using the ratioed images & it was seen that the ratioed images 3/4, 2/3 & 1/3 in RGB gave the best FCC image **(Figures.9 & 10).** However, ratioed-FCC image is less informative than the original FCC image. In the image, the red color indicates very dense or thick vegetation; the green color indicates moderate vegetation & the greenish blue color indicates water. The sediment pattern is seen well in the FCC image. Comparing the two FCC images of two different years, it is seen that the thick vegetation cover has decreased in the March 2001 image & the moderate vegetation cover has increased. However the mangrove vegetation on The Divar Island has increased in March 2001 image.

Filtering

Edges of lineaments are highlighted in filtering process & hence for lineament detection the directional filtering is used. Two prominent lineament directions have been detected in this image. They are: NE-SW & NW-SE. It is shown in the **Figure.11.**

Vegetation index

The map produced from the vegetation index for the year January 1999 shows thick vegetation cover over the entire region especially in the Western Ghat region. The vegetation is

shown by black color **(Figure.12).** In the March 2001 image, the vegetation cover has become less. This could be because of the month during which the image was clicked or actual clearing of the vegetation. The white color indicates either moderate vegetation or barren land while the thick vegetation is seen in black color **(Figure.13).** Comparing the two vegetation index images, it seen that there is decrease in thick vegetation category in March 2001 image over the entire Goa, especially in the eastern part in Sanguem taluka.

Principal component analysis

Out of the four principal component images produced from the LANDSAT data **(Figure.14)**, PC1 contains the largest percentage of variance contained in the original four bands data. This image gives an impression that it is produced by a combination of data from all four bands. Through this image the water bodies with their inlets, beaches, mangroves, other vegetation & spits are seen easily. The black water bodies are very clear & sharp such that they can be mapped. The lineaments along NE-SW direction are seen clearly. The second PC image (PC2) brought out the topographic highs. It shows the turbid water in the near shore region. The mining belt can be distinctly seen. Barren lands as well as vegetated land are seen. In the third PC image (PC3), except for the turbid water flow nothing else can be make out. There is a sharp contrast between sediment-laden waters, which is clear & mappable. Based on the tonal variation, which is a measure of turbidity concentration, three distinct types of turbid water are identified:

- Highly turbid water off the Terekhol coast, the Zuari bay, Benaulim beach & Mobor beach.
- Moderately turbid waters off the Calangute beach, Cape Rama & Central portion of the Mondovi bay.
- Less turbid water near the circular portion off Marmugoa.

The image shows some percentage of noise. In the fourth image (PC4), there is mostly covered by noise & nothing is noticable.

False Color Composite image is generated from the first three principal component images **(Figure.15)**, & is interpreted on the basis of tone, color & texture. Various features like the shoreline, estuaries, intertidal zones, mangrove vegetation, dense & sparse vegetation, deep & shallow turbid water bodies are extracted from the composite image. The red color indicates the beach stretch all along the coastal area. The pink color indicates the barren land & pink with red dots indicates very sparsely vegetated areas. Mangroves are seen in green color. Dense vegetation is noticed by yellowish green color. Deep waters are seen in blue color while the shallow, highly turbid waters are noticed by black color. The image shows highly turbid waters off the Terekhol coast, Zuari estuary, Colva beach stretch & Sal River moving in the southeasterly direction & down south they form an eddy pattern.

Image differencing

In the image difference map **(Figure.16)**, the brighter areas (white color) indicate clearing of the cultivated or forest land. This can be clearly seen in the Baga area, Divar Island, along the linear stretch of the Salcete area & around the Chandranath hills. While the darker areas (black color) indicate that the region has increased in the forest area or the region has become wet. This is noticed in some parts of the Chorao Island, along the Sal River channel & the Khushvati River in Salcete. In the highlighted difference image **(Figure.17)**, the red spots indicate the changes over the region.

Unsupervised classification

As this classification is a spectral classification, the computer does the job of assigning pixels to the classes based on the signatures. The classification with the minimal number of classes carried out for both the images did not provide any useful information about the area. A total number of 16 classes provided the image that closely resembles the original image **(Figures.18 &.19).**

Comparing the two images, it is seen that the thick vegetation cover in March 2001 image has decreased & the moderate vegetation & mangrove vegetation have increased. The barren land & the waterlogged area of Cumbarjua have increased in March 2001 image.

Supervised classification

The FCC image was classified using the supervised classification to show the land use classes. The resultant classified image of land use shows seven classes **(Figures.20 & 21)** namely: Dense vegetation (dark green), Moderate vegetation (light green), Low-lying areas (light brown), Settlement areas (pink), Inland water (light blue), Estuarine water (dark blue) & Marshy areas (greenish brown).

From these resultant classified images, it is observed that the thick vegetation cover has decreased in March 2001 image & the moderate vegetation cover; settlement areas & marshy areas have increased when compared with the January 1999 image. In January 1999 classified image, major portion of the area is occupied by thick vegetation & settlement areas & in March 2001, classified image major portion is occupied by moderate vegetation & settlement areas.

CONCLUSIONS

From the study, it is concluded that for the entire Goa region:

- There is an increase in the barren area within the mining belt in March 2001 as shown by the ratio images. The color composites of band ratio images show the changes in the Tiswadi area in more detail.
- There is an overall decrease in the thick vegetation (category) shown by the vegetation index images & the difference grayscale map.
- In the classified image the settlement areas, moderate vegetation, low-lying areas & area covering estuarine water shows an increase in March 2001.
- The black & white principal component images depict lineaments & to some extent the land use features like vegetation cover, low-lying areas, etc. The imagery can be used to map the location, density & pattern of lineaments. The color composite image of PC1, PC2 & PC3 show the actual land use units.
- The highly turbid water in the northern region indicates active sedimentation along the coast. These sediments then move in the southeasterly direction. The Mandovi & Zuari Rivers show heavy sediment transport.

The above-mentioned changes were the results obtained by the various enhancement techniques. However if more temporal data was available for number of years, seasons then more detailed study could have been possible & with help of GIS it could have been done in more accurate manner.

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Table 1. Identification of coastal features using elements of interpretation

As in Fig-3	Category	Tone/ Color	Shape	Texture	Location	Remarks
A	Tidal flat	Brown	Irregular	Smooth	Along lowest waterline	Silty & clayey vegetation may be present
B	Sandy beach	White	Linear	Smooth	Adjacent to coast on land water boundary	Made up of fine silt particles, broken shells, etc.
C	Estuary	Dark	Funnel	Smooth	Connection with sea & land	Semi enclosed body. Part of river course affected by mingling of salt water with fresh water
D	Bay	Blue	Semi circular	Smooth	Adjacent to coast	-
E	Coastal dune	White	Linear	Smooth	Behind the beach on landward side	-
F	Mangrove	Bright red if dense, pale red if sparse	Irregular	Smooth	Intertidal areas along creeks & low-lying flats	Grows on substrate mud
G	Saltpans	Light blue, white	Rectangular, square	Smooth	Near high tide limits	Dry saltpans appears white
H	Reclai-med area	Dull white	-	Rough	May be connected to water body	Agriculture is the prime use
I	Creek	Blue	Meandering	Smooth	Intertidal area	Intricate networks of narrow inlets
J	Spit	White	Linear may be curved at the end	Smooth	Part of the beach extending in the sea	Narrow embankment of land

Figure 1. A Map covering Goa region. Inset shows study area.

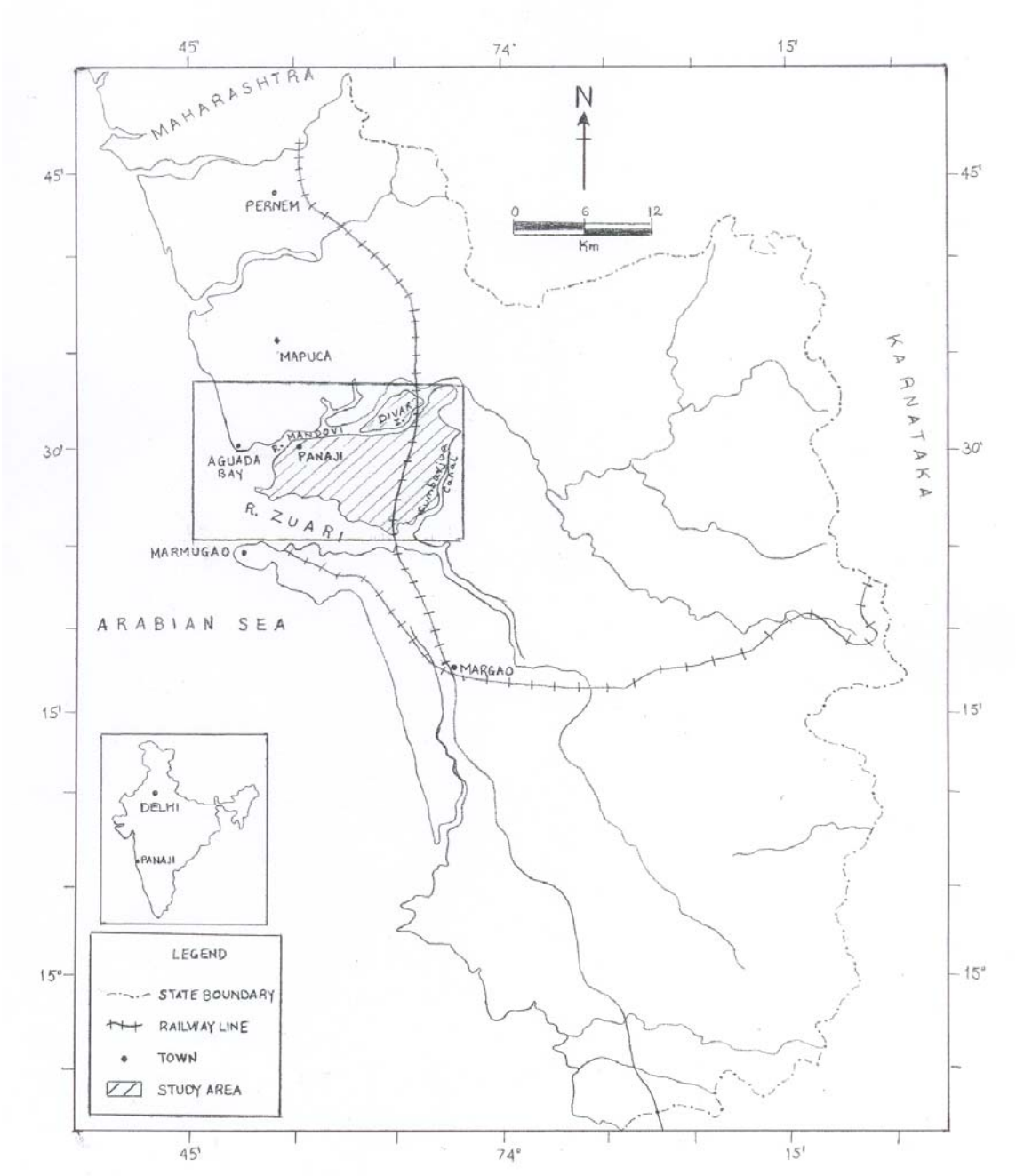


Figure 2. Field photographs

Figure 2A. Thick Vegetation in Tiswadi

Figure 2B. Mangrove Vegetation

Figure 2C. Low lying area in Tiswadi

Figure 2D. Saltpans at Kalapur, Tiswadi

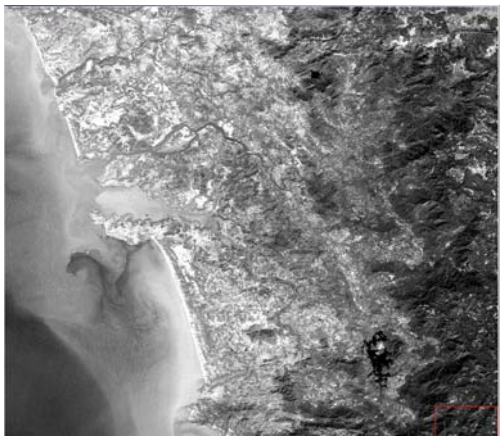
Figure 2E. Settlement areas in Tiswadi Tiswadi

Figure. 2F. Marshy land in Cumbarjua canal,

Figure 3. FCC image showing Coastal Features

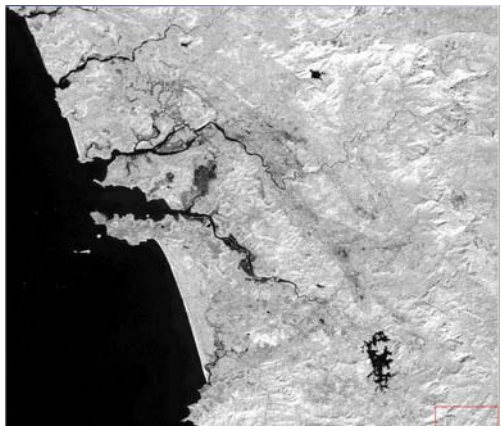
A) Tidal flat
B) Sandy beach
C) Estuary
D) Bay
E) Coastal dune
F) Mangrove
G) Saltpans
H) Reclaimed area
I) Creek
J) Spit
K) Estuary island
L) Offshore island
M) Headland
N) Turbid waters

Figure.4. IRS image in four spectral bands



Band 1

Band 2



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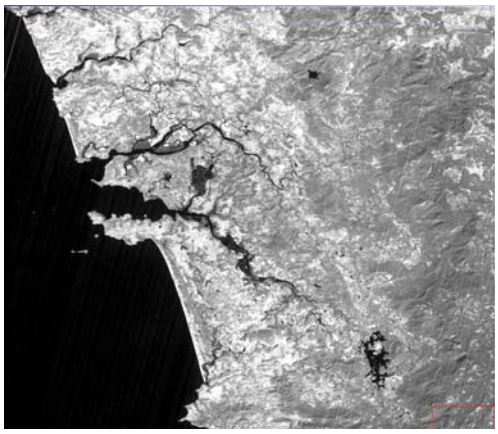


Band 4

Figure.5. Band Ratio 1/2 for the entire Goa region for January 1999.

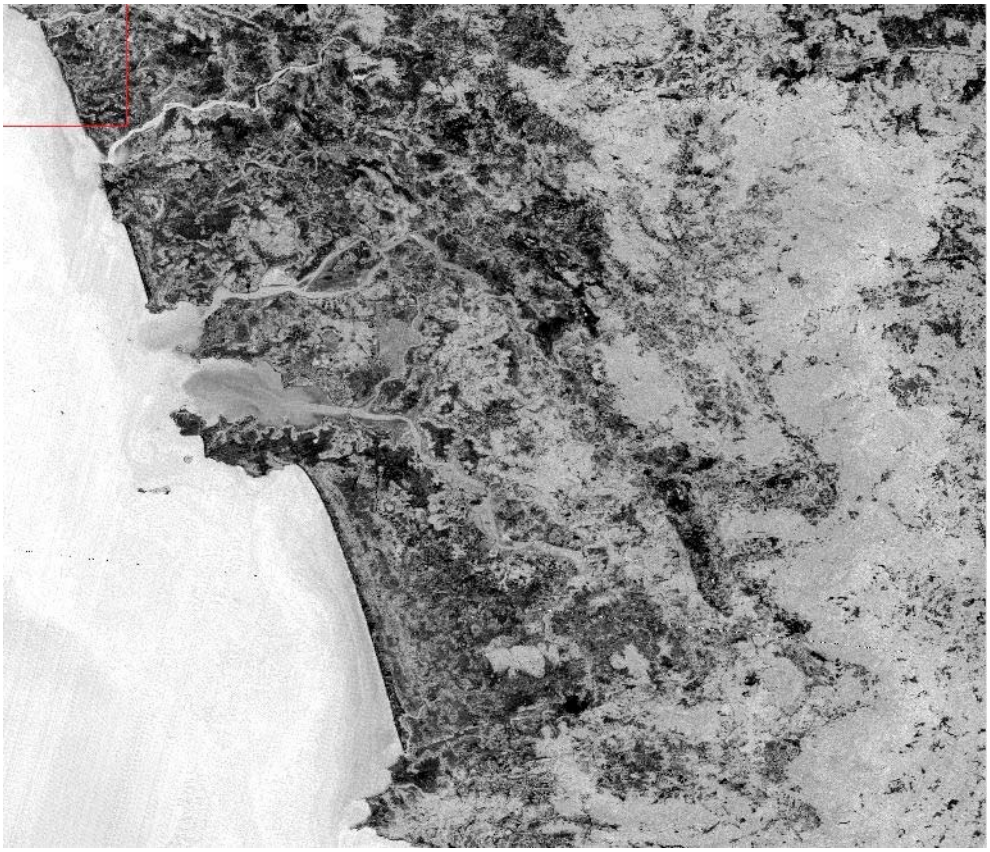


Figure.6. Band Ratio 1/2 for the entire Goa region for March 2001.

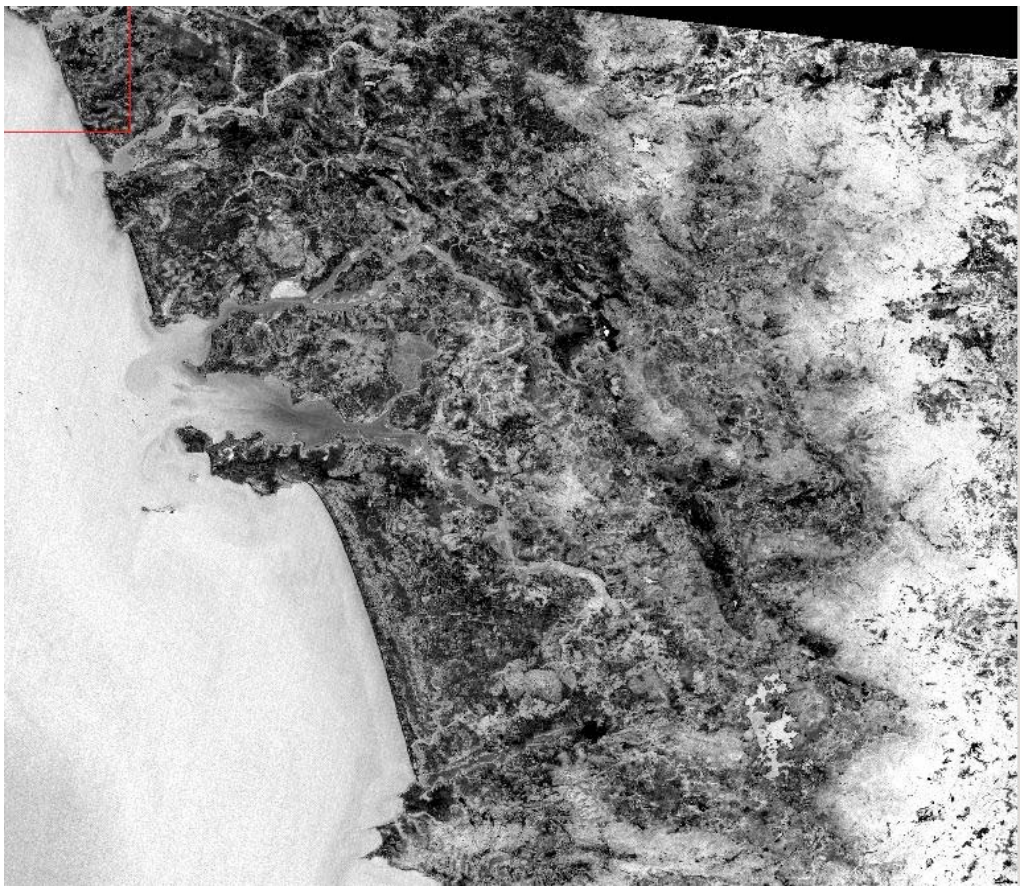
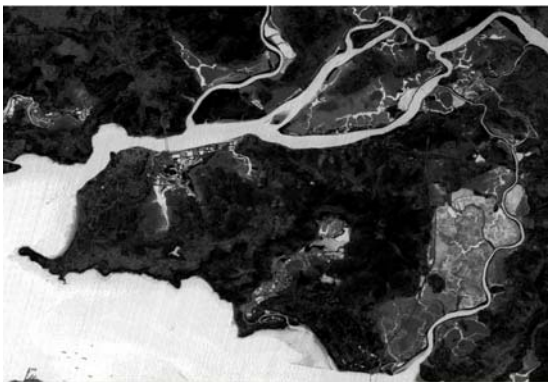
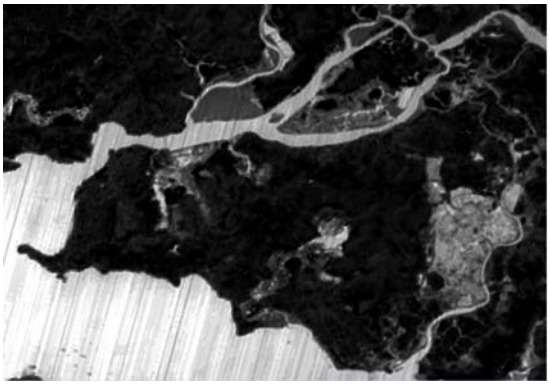


Figure.7. Band Ratio images for year January 1999.

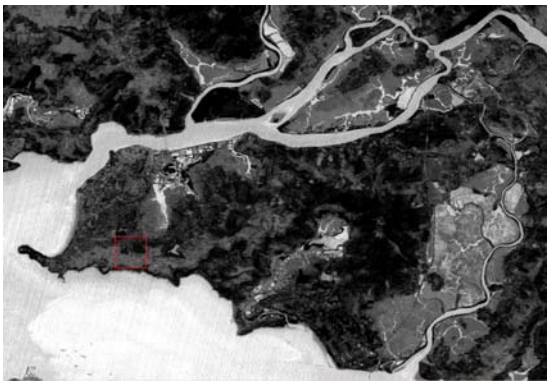
Band 1/2



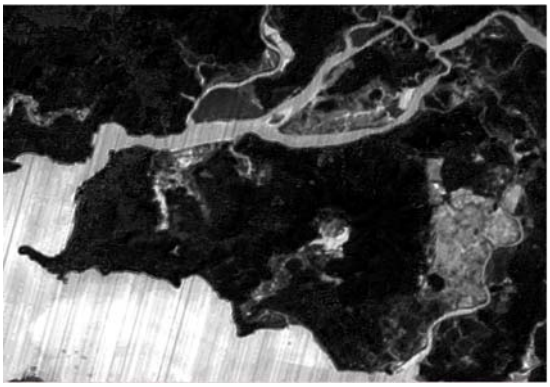
Band 1/3



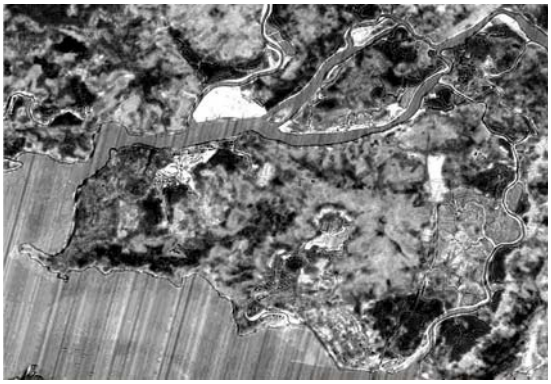
Band 1/4



Band 2/3



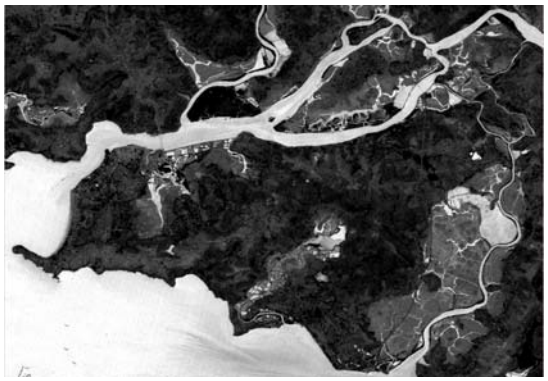
Band 2/4



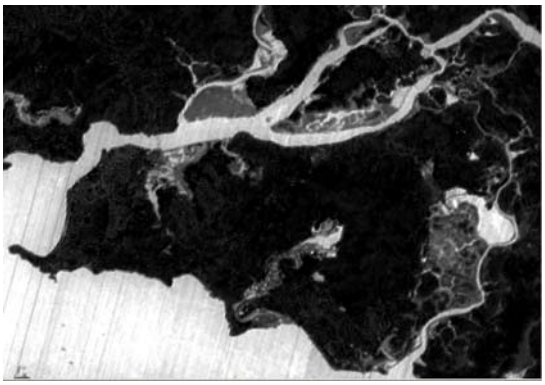
Band ¾

Figure.8. Band Ratio images for year March 2001.

Band 1/2



Band 1/3



Band 1/4

Band 2/3

Band 2/4

Band 3/4

Figure.9. FCC of Band Ratio 3/4, 2/3 & 1/3 in RBG for Tiswadi area for January 1999.

Figure.10. FCC of Band Ratio 3/4, 2/3 & 1/3 in RBG for Tiswadi area for March 2001.

Figure.11. Edge Detection map

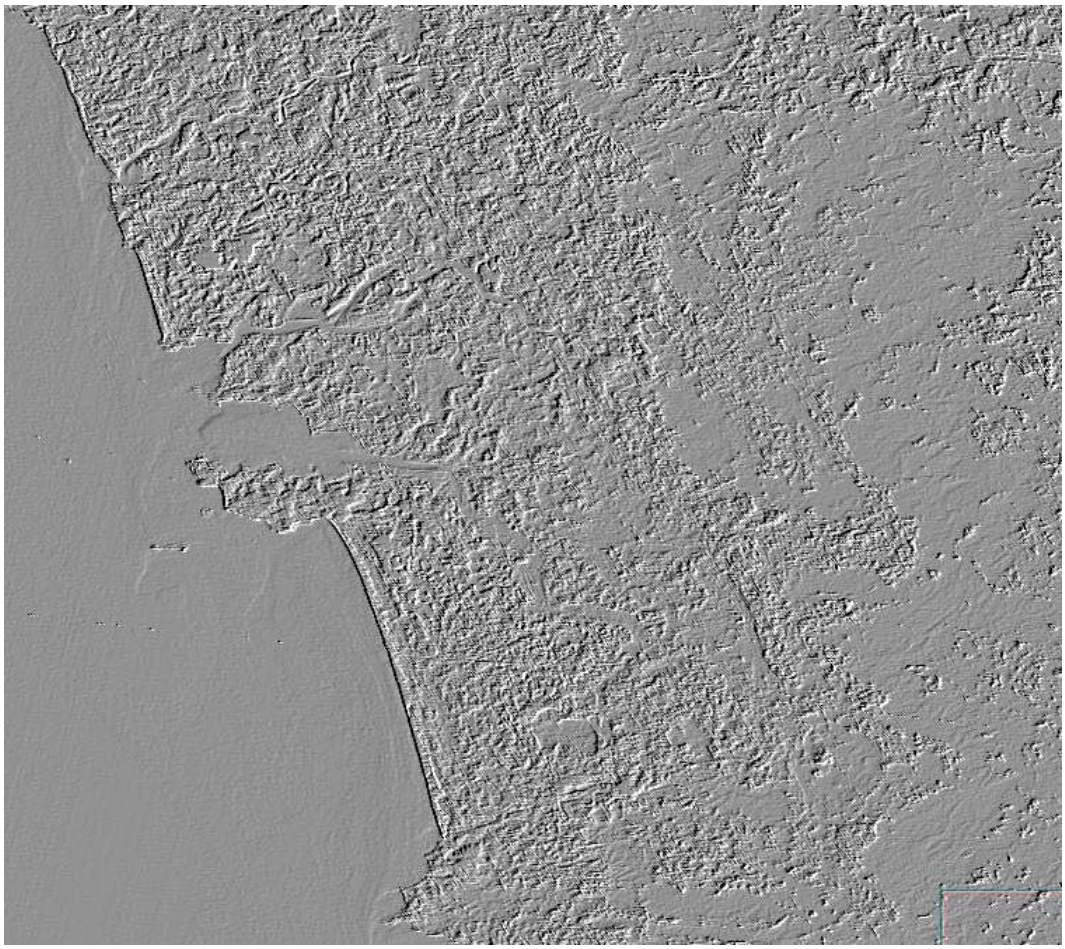


Figure.12. Vegetation Index for Goa region for January 1999.

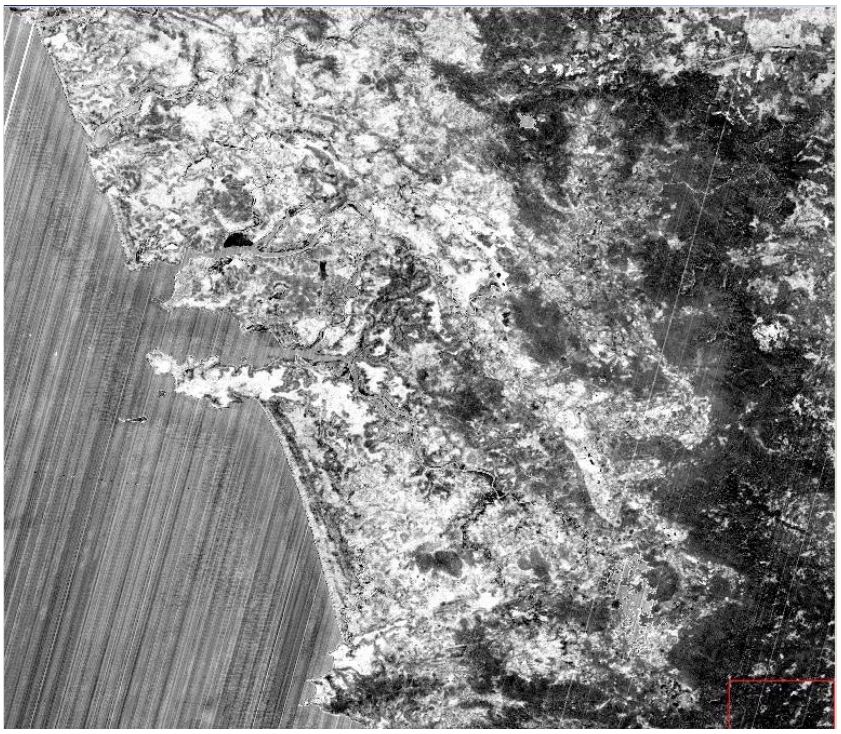


Figure.13. Vegetation Index for Goa region for March 2001.

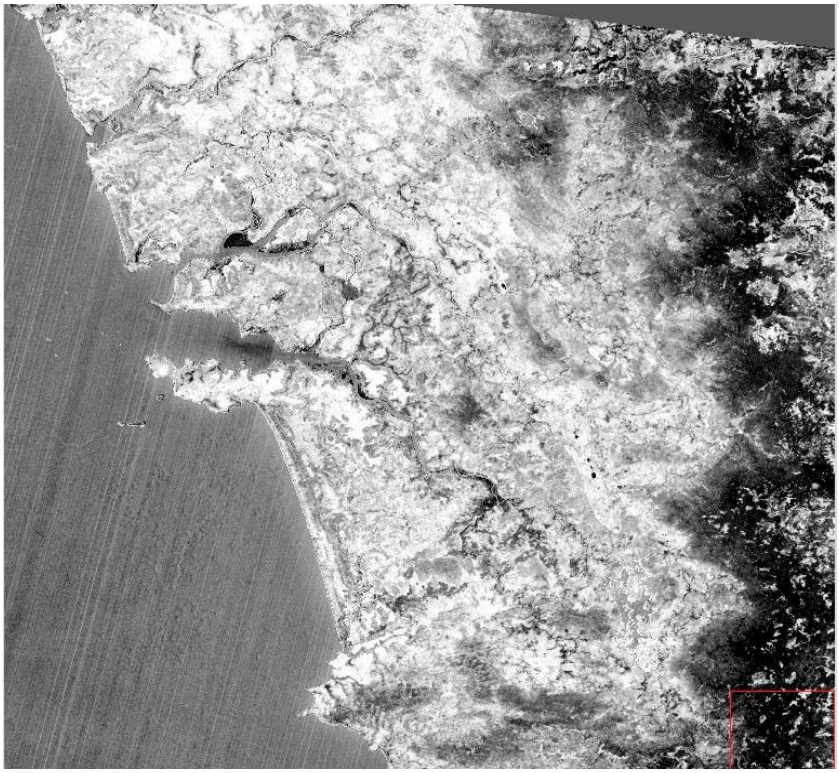
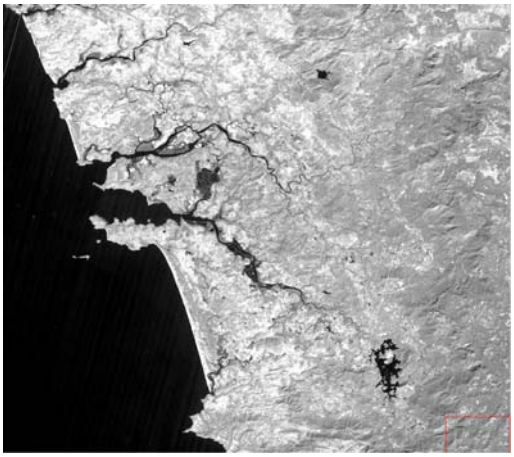
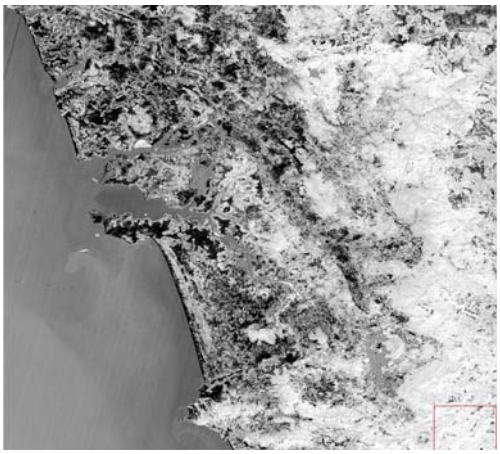


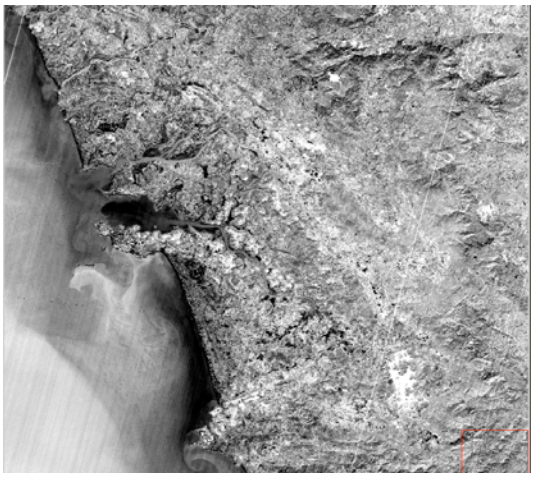
Figure.14. Principal Component Analysis images for the entire Goa region.



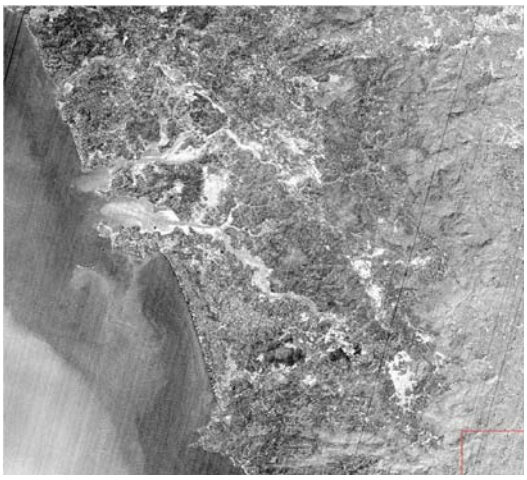
PC 1



PC 2



PC 3



PC 4

Figure.15. FCC of Principal Component Analysis images for entire Goa region.

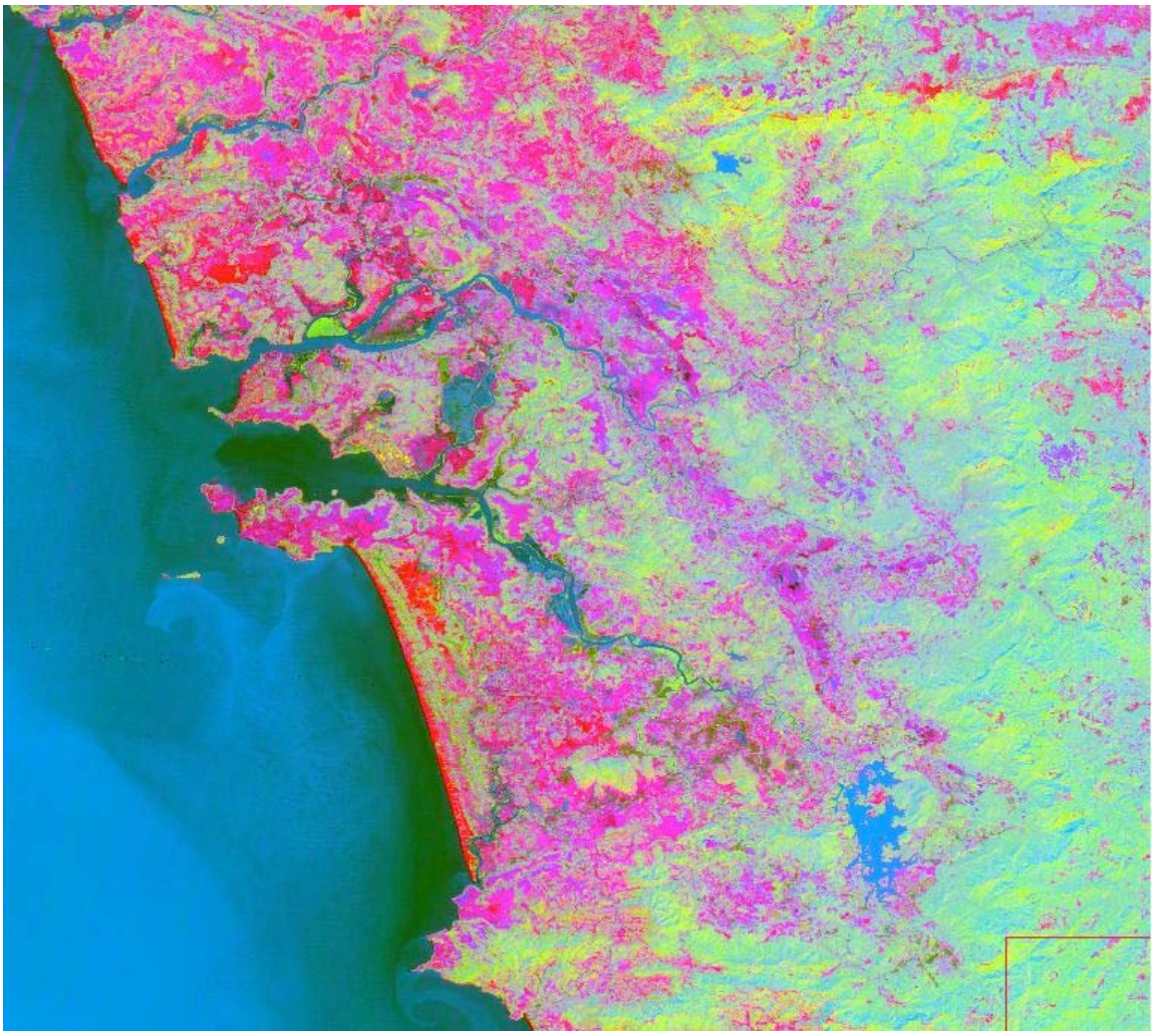


Figure.16. Image Difference (Grayscale) map.

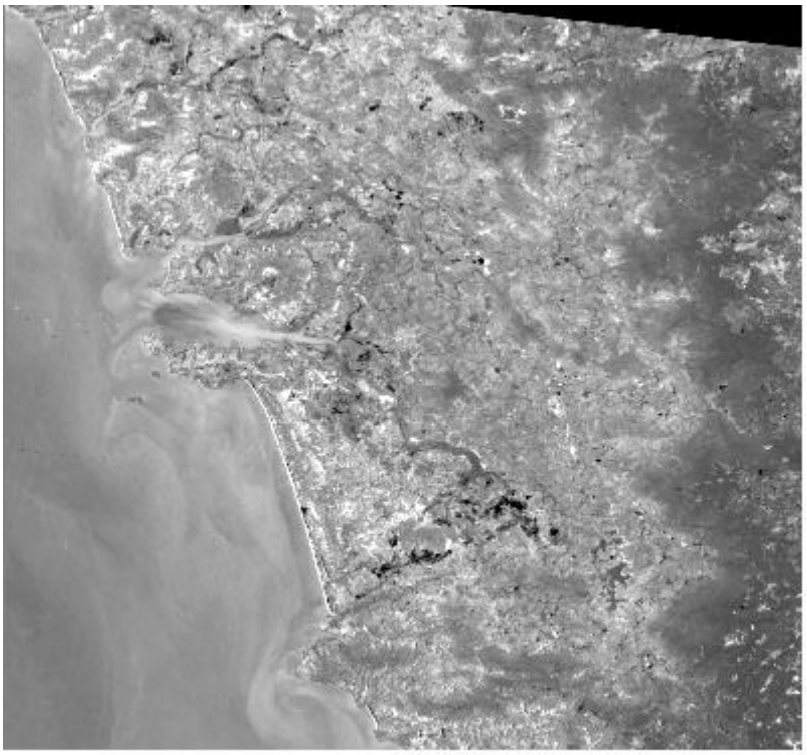


Figure.17. Highlight Difference image.

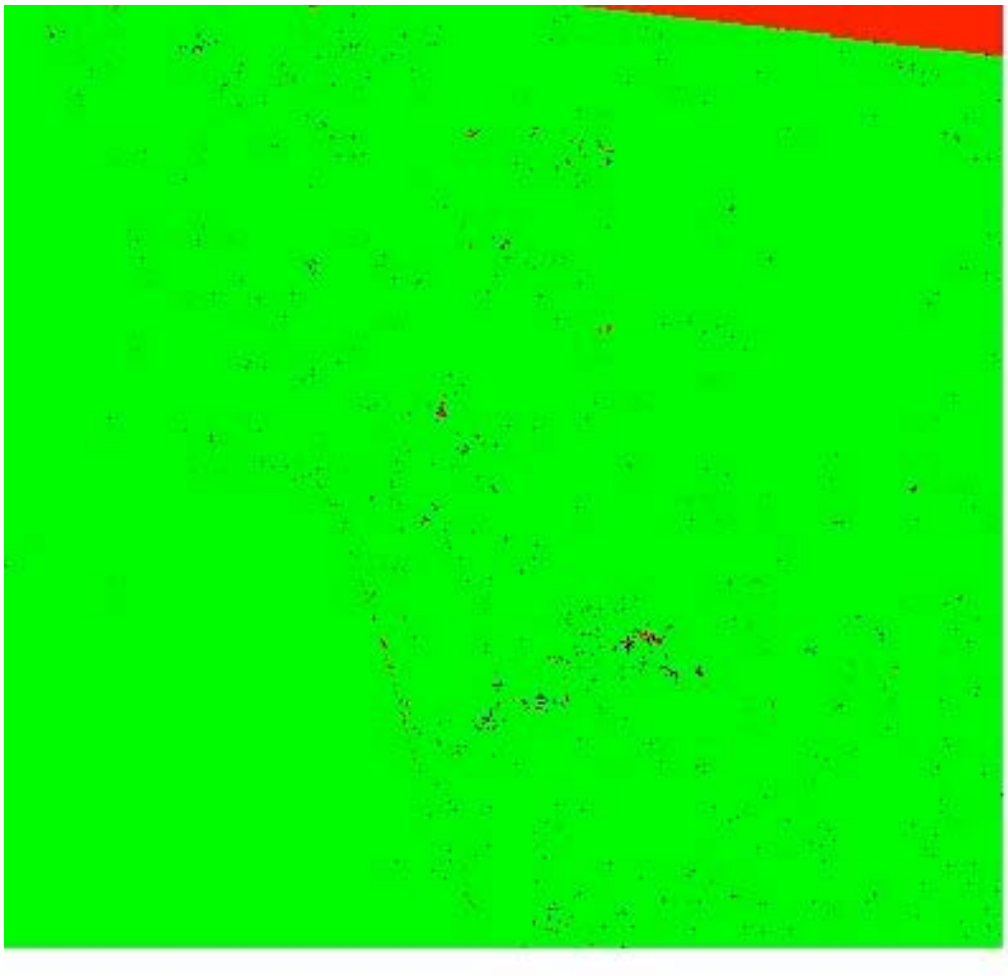


Figure.18. Unsupervised classified image of Tiswadi area for January 1999.

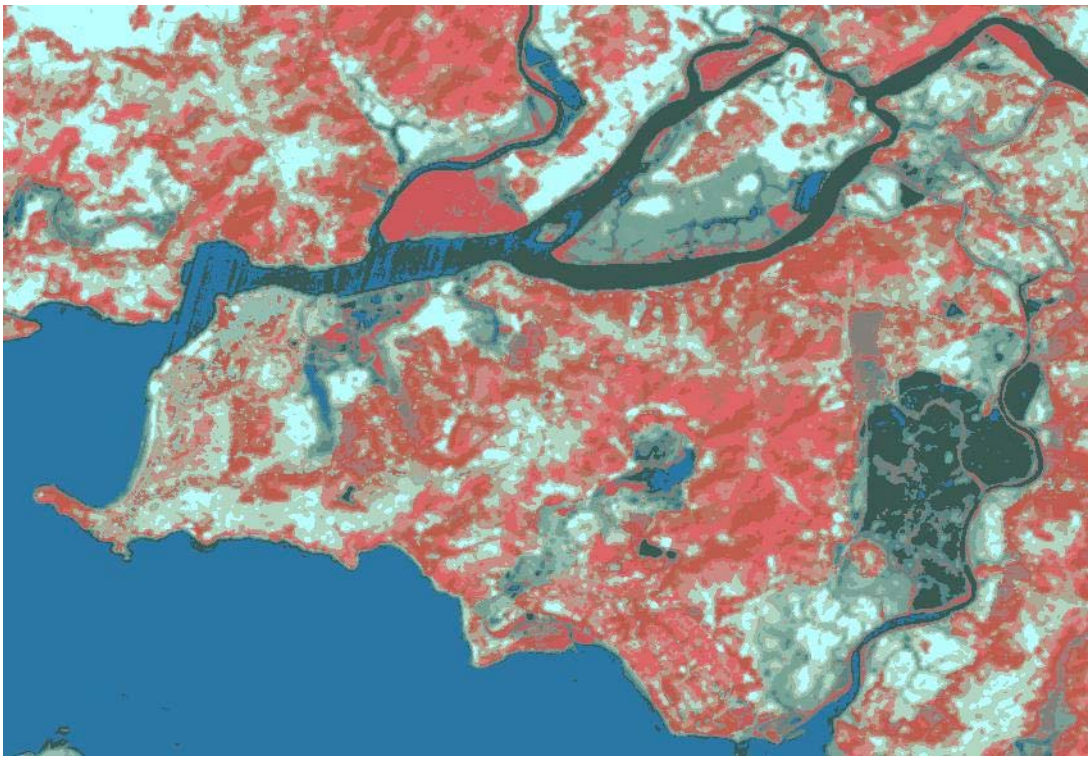


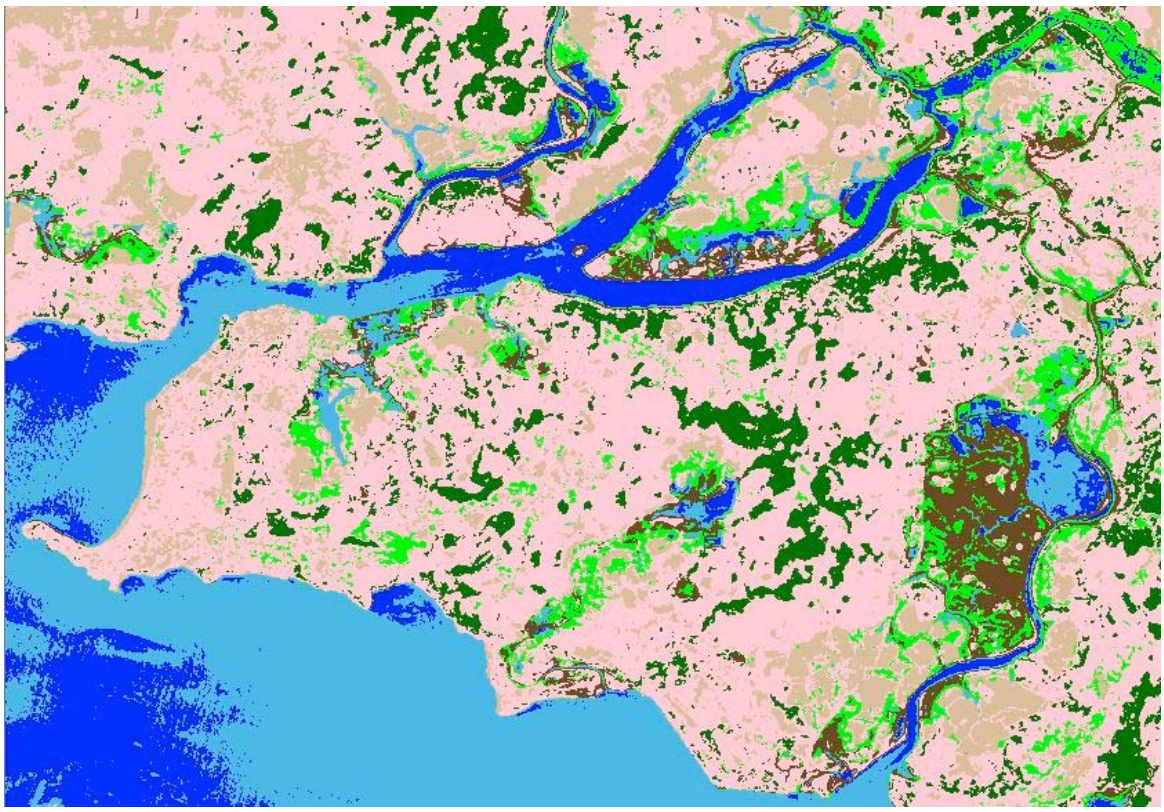
Figure.19. Unsupervised classified image of Tiswadi area for March 2001.

Figure.20. Supervised classified image of Tiswadi area for January 1999.

Legend

Row	Histogram	Color	Red	Green	Blue	Opacity	
0	0		0	0	0	0	Unclassified
1	56824		0	0.392157	0	1	dense vegetation
2	26634		0	1	0	1	moderate vegetation
3	30387		0.823529	0.701961	0.54902	1	lowlying area
4	235630		1	0.752941	0.796078	1	settlements
5	78187		0.2	0.588235	0.784314	1	inland water body
6	46096		0	0	1	1	estuarine water
7	24605		0.215686	0.227451	0.0117647	1	marshy area

Figure.21. Supervised classified image of Tiswadi area for March 2001.



Legend

Row	Histogram	Color	Red	Green	Blue	Opacity	
0	0		0	0	0	0	Unclassified
1	37564		0	0.392157	0	1	dense vegetation
2	32392		0	1	0	1	moderate vegetation
3	50556		0.823529	0.701961	0.54902	1	lowlying area
4	220669		1	0.752941	0.796078	1	settlements
5	81404		0.243137	0.67451	0.87451	1	inland water body
6	40362		0	0	1	1	estuarine water
7	25351		0.34902	0.235294	0.105882	1	marshy area