CHAPTER 6: MATERIALS AND METHODS

With the advent of orbital imagery, remote sensing has become an increasingly important tool in vegetation research. In vegetation surveys involving large areas, remote sensing is now the most important perquisite. Remote sensing techniques are valuable in providing the basic pre-field framework of the study area.

Remote sensing data forms an essential component in almost all of the present day extensive vegetation mapping researches, particularly in the study of highly dynamic coastal vegetation landforms. Its utility in mangrove studies has already been described in previous chapters. Its high spatial resolution and multi-spectral characteristics combined with its capability of providing images of large geographic area and otherwise inaccessible areas make it an important factor in mangrove studies.

In the present study remote sensing data has been used to study the mangrove vegetation. Methodologies have been developed to use the remote sensing data to zone the mangroves at the community level.

6.1 MANGROVE COMMUNITY ZONATION

Remote sensing data forms an essential component of the present study. The flowchart of the methodology and steps involved in mangrove community zonation is given in Fig 6.1.

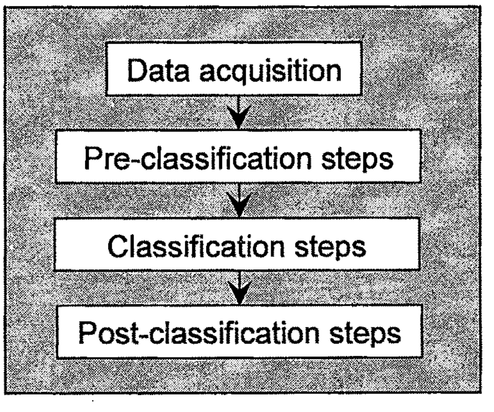

Figure 6.1 Flowchart of the various steps involved in mangrove community zonation.

6.1.1 Satellite Data

Digital remote sensing data of *Linear Imaging Self-Scanning Sensor* (LISS) III onboard IRS-1C/1D have been utilised to map the mangrove communities. The sun-synchronous IRS-1D satellite was sent to its orbit on 29th September 1997 nearly two years after launching of its predecessor IRS-1C satellite to provide continued remote sensing data to its large user community. Both the satellites are identical and have three sensors namely WiFS, LISS III and PAN that provide data on various spatial and spectral scales useful for varied applications. The WiFS data is useful for various large scale mapping and monitoring whereas the LISS III data is useful for medium scale mapping and monitoring of earth surface features and processes. Specifications of LISS III and PAN sensors have been presented in the tables 6.1 and 6.2 respectively. Panchromatic data provides high-resolution data in panchromatic mode and is able to provide stereo data for photogrammetric studies. The main reason of selecting the LISS III data was its availability, its resolution (both spatial as well as spectral) and to explore it's potential for mangrove community zonation studies.

Table 6.1 Major specifications of LISS III sensor

Specifications of LISS III sensor	
Spectral resolution Band-2 Band-3 Band-4 Band-5	0.52 – 0.59 µm 0.63 – 0.69 µm 0.77 – 0.85 µm 1.55 – 1.75 µm
Spatial resolution Band-2 Band-3 Band-4 Band-5	23.5 m 23.5 m 23.5 m 70.5 m
Swath Visible NIR SWIR	141 km 141 km 148 km
Radiometric resolution	7 Bits
Repeativity	24 days

Table 6.2 Major specifications of PAN sensor

Specifications of PAN sensor	
Spectral resolution	500-900 µm
Spatial resolution	5.8 m
Swath	141 km
Radiometric resolution	7 Bits
Repeativity	24 days

Presence of clouds in an image is a serious constraint in the optical remote sensing based studies, which significantly reduces the availability of the remote sensing data for the region of interest. Remote sensing based mangrove studies are also affected by the unavailability of data in the optical range due to the presence of could over the study area but another important factor that significantly affects the information content is the tidal height. Effects of tides on the remote sensing data are not adverse where there is a minimal differences between low and high tidal heights but in a macro-tidal region like the Gulf of Kachchh, where the tidal height generally crosses four meters, and submerges substantial portions of the fringe mangrove the thickness of water column is expected to significantly affect the information retrieval from the remotely sensed data. Presence of the water column within the mangroves during high tides modifies the signals coming from the mangrove forests; so, it was preferred to choose the data acquired at low tide and clear sky conditions. For the present study, remotely sensed data representing both the low and high tidal conditions over the forests were acquired in order to study the impact of tides on mangrove community zonation. Details of the LISS III scenes used for the purpose are presented in the Table 6.3.

6.1.2 Software and Hardware Used

Silicon Graphics O_2 workstation and IBM BULL Power PC having 24 bit display colour monitors were used to store and process the digital data. Both the systems work under their own versions of Unix operating system. ERDAS IMAGINE image processing software package (Version 8.3) was used for digital image processing of the remote sensing data and for on-screen digitization. The thematic maps were stored in vectorised format in GIS using *Environmental Systems Research Institute's* (ESRI) Geographic Information System (GIS) software ARC/INFO Version 7.2.

Table 6.3 Details of the remotely sensed data acquired for the study period

Satellite/Sensor	Path/Row	Date of Acquisition	Tidal condition
IRS-1C LISS III	090 / 056	27October 1998	Low Tide
IRS-1C LISS III	090 / 056	01 March 1999	High tide
IRS-1C LISS III	090 / 056	06 November 1999	High tide
IRS-1D LISS III	090 / 056	10 March 2000	Low tide
IRS-1D LISS III	090 / 056	15 November 2000	Low tide
IRS-1D LISS III	090 / 056	21 January 2001	Low tide

6.1.3 Classification system

The use of remotely sensed data for mangrove mapping is dependent fundamentally on the ability of the sensor and image processing technique to distinguish between mangrove vegetation and other habitats such as non-mangrove vegetation, bare soil and water. The applications of remote sensing falls into three broad categories

1. Mangrove inventory and mapping
2. Change detection
3. Management of aquaculture activities

Mangrove inventorying and mapping has been sought to gather information on the extent and distribution of mangrove habitats (Nayak *et. al.*, 1992) With the aims of the present work in mind, the classification system developed by Bahuguna *et. al.* (1997) has been adapted with minor modifications and has been given as table 6.4.. For the preparation of the mangrove habitat maps, the level III classification was selected while for the mangrove community zonation the Level IV was selected.

Table 6.4 Classification system for mangrove habitat and community zones of the study area.

Level I	Level II	Level III	Level IV
Non Vegetated	Mud/Tidal flat	High Tidal	
		Inter tidal	
		Sub tidal	
	Sand	Sand	
	Coral Reef	Reef Area	
Vegetated Wetland	Mangroves	Dense	*Avicennia*
			Rhizophora –Ceriops
			Mixed
		Sparse	*Avicennia*
			Rhizophora –Ceriops
			Mixed
		Back Mangroves	
		Defoliated	
		Degraded	
	Marsh Vegetation		
	Algae	Dense	
		Sparse	
	Mudflat	Mud with vegetation	
	Coral Reef	Reef Vegetation	
	Sand	Sand Vegetation	
Water Bodies	Creek		
Shore Land	Saline area		
	Terrestrial area		
Other landforms	High water Line		
	Low water Line		
	Salt Pan		

6.1.4 Pre-Classification Steps

It is essential to pre-process the remote sensing data prior to its analysis to remove some of the errors (both internal and external) occurred during data acquisition processes, which may degrade the quality of the remote sensing data (Jensen, 1986). Digital data from the IRS-1D LISS III sensor were acquired from the National Remote Sensing Agency (NRSA), Hyderabad. The data is provided in generic binary format and stored in band sequential (BSQ) format. The data was converted in to viewable two dimensional raster data with the help of image processing software for further processing. The pre-classification steps involved here are geometric and radiometric corrections (Fig. 6.2).

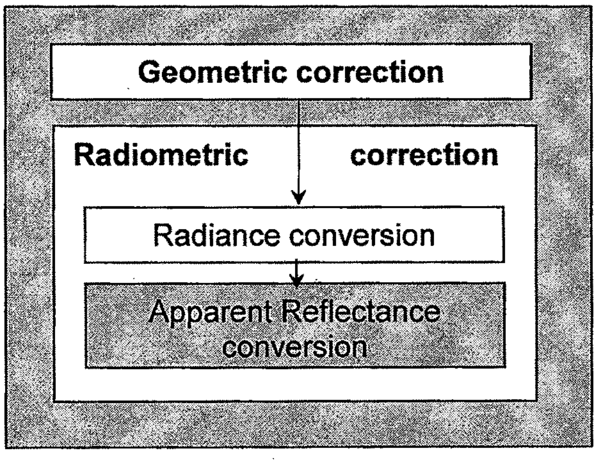

Figure. 6.2 Steps in pre-classification stage

6.1.4.1 *Geometric Correction*

The geometry of remote sensing images gets distorted by sensor's large angular field of view, orientation of the satellite, earth's rotation, instrument errors and satellite platform's instability. The images obtained had already been corrected for platforms instability, *etc.* They were then geometrically corrected in order to have the scale and projection properties of a map by identifying ground control points in the image and matching it with the Survey of India topographical maps.

The whole LISS III scene of March 2000 was geometrically corrected using the Survey of India topographical maps of 1:50000 scale. A total of 84 ground control points (GCPs) were identified on the SOI topographical maps. Almost all of the GCPs identified were land features since locating points on coastal and Gulf area was difficult. The points were chosen so as they were equally distributed in all parts of the image. Corresponding points were located on the image and second order polynomial equation was used to transform the geometry of image using nearest neighborhood resampling method. The nearest neighborhood resampling method was preferred because it transfers original data values without averaging them and therefore, the extremes and subtleties of the data values are not lost (ERDAS, 1999). The projection system and datum chosen for the conversion was the 'Geographic Lat/Long' and 'Modified Everest' respectively. The corrected image was used as a reference image for geometric correction of other images. The total root mean square error (RMSE) was observed about ±0.3 pixel for all the images.

6.1.4.2 *Radiometric Correction*

The intensity of EMR recorded by the remote sensing instruments is generally provided to the user in the form of digital numbers, which do not quantitatively correspond to physical units as they would be obtained at the earth's surface. For a sensor such as LISS III having 8 bit (resampled) radiometric resolution, the digital numbers vary from 0 to 255. These values are specific to the sensors and the conditions under which they were recorded. In order to obtain radiometrically comparable physical units, suitable for further processing, the integer digital values (DN) of the image were transformed into apparent spectral reflectance data. Radiometric correction involved the following two steps: radiance conversion and apparent reflectance conversion.

6.1.4.2.1 <u>Radiance conversion:</u>

First the digital numbers were converted to radiance using the spectral calibration coefficients with the help of 'Modeller' module available in ERDAS IMAGINE image processing software, and requires information on the 'gain' and 'bias' of the sensor in each band. The gain and bias provided in the header file in CD-ROM and used in the conversion are presented in table 6.5. The calibration is given by the following expression for satellite spectral radiance,

$$L_{rad} = \left\{ \left(\frac{DN}{Max\ grey} \right) \times \left(L_{max} - L_{min} \right) \right\} + L_{min}$$

where,

DN = Digital number of a pixel,

Max grey = maximum DN possible for a given data,

L_{min} and L_{max} = Lower and upper limits of the post calibration spectral radiance range for a given band.

Table 6.5 L_{max} and L_{min} for IRS-1D LISS III sensor

	L_{max} (mW cm^{-2} sr^{-1} µm^{-1})	L_{min}
Band 2	14.80	0.00
Band 3	15.66	0.00
Band 4	16.45	0.00
Band 5	02.43	0.00

6.1.4.2.2 *Apparent reflectance conversion:*

The pixel values were converted from radiance to unitless *apparent reflectance* (also called as *top of the atmosphere reflectance* or *exoatmospheric reflectance*). It takes into account the varying sun elevation angles at the time of image acquisition. The conversion formula used is expressed as:

$$\rho = \frac{\pi.L.d^2}{ESUN.cos(SZ)}$$

where,

ρ = at satellite reflectance,

L = spectral radiance at sensor aperture in mw cm^{-2} ster^{-1} um^{-1},

d^2 = Earth-Sun distance in astronomical units = [1 - {0.01674 cos(0.9856 (JD-4))}]^2 where JD is the Julian Day of the image acquisition,

$ESUN$ = Mean solar exoatmospheric spectral irradiance in mW cm^{-2} um^{-1}, and

SZ = sun zenith angle in degree at the time of image acquisition

6.1.5 Image Analysis And Classification Steps

The pre-processed images were subjected to certain image analysis steps prior to classification procedures. This stage involved four steps: unsupervised classification, field data integration, image analysis (including band ratioing) and development of classification system and supervised classification (Fig 6.3). Field data collection has been described as a separate heading after all the classification steps.

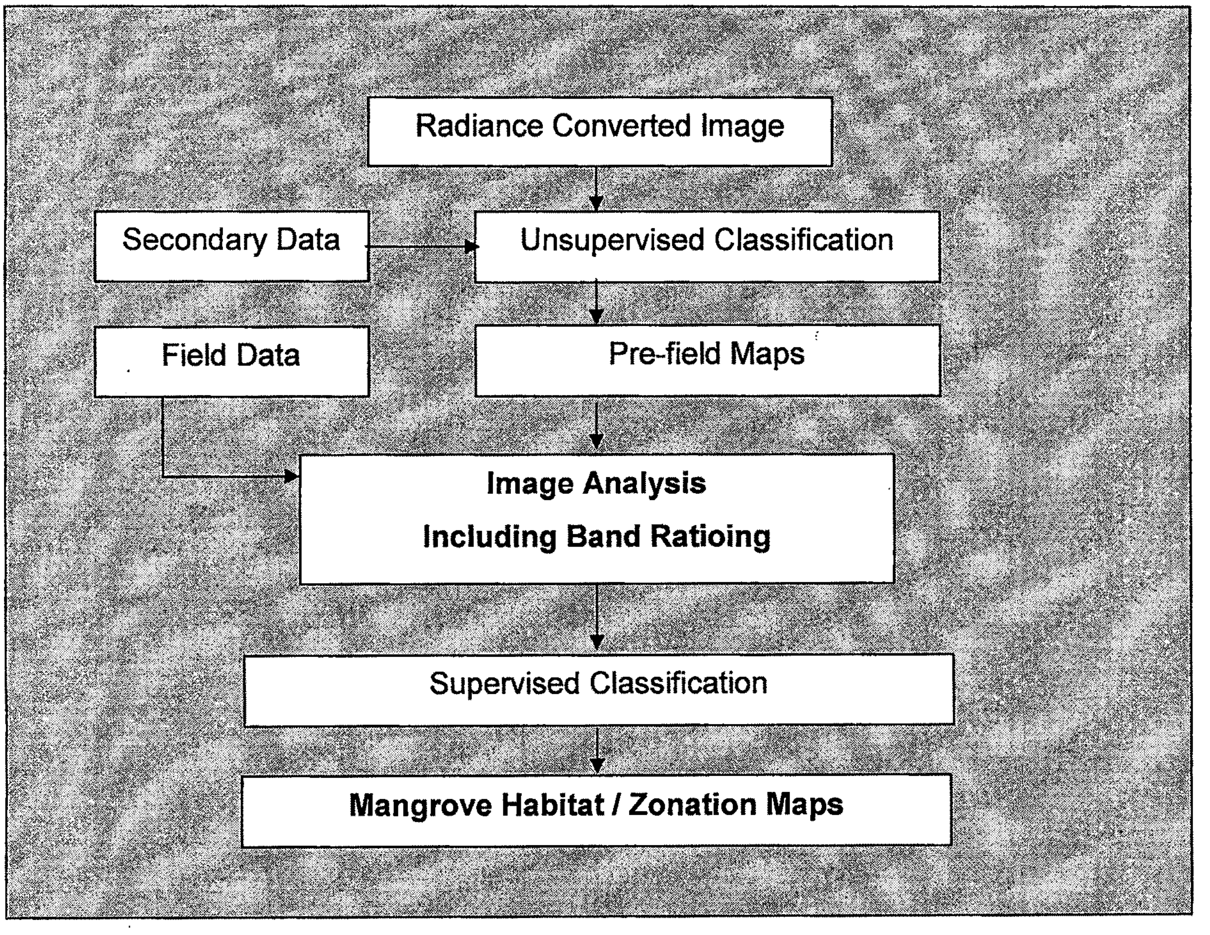

Fig. 6.3 Flow chart of the steps involved in the image analysis and classification stage.

6.1.5.1 Unsupervised Classification

Pattern recognition or *classification* is defined as the science of finding meaningful patterns in the image data. Human brain can automatically group the observed patterns into various groups based on their spatial and/or tonal characteristics. However, the pattern discrimination capability of human brain varies from person to person and is also restricted to very few numbers of patterns. For digital images, patterns are identified through some mathematical criteria, which largely rely on the spectral characteristics of various features within the image and can identify a much larger number of patterns than the human brain can. There are various pattern recognition / classification algorithms available, which can be grouped under two groups (*i.e.* unsupervised and supervised classification algorithms) based on their level of automation. Supervised classification is the procedure in which labelled training samples are used to design a classifier whereas unsupervised classification is the procedure in which unlabelled samples are used to form clusters of the input patterns (Jensen, 1986; Mather, 1987; Tso and Mather, 2001; Duda *et al.* 2001). Unsupervised algorithms require minimal input (*i.e.* number of classes to be identified) from the user whereas supervised classification algorithms require the spectral patterns of the classes being classified.

To generate the prefield map for ground truth studies unsupervised classification technique was adopted because there was limited information available about the mangrove environments. In order to reduce the processing time and avoid large data volume of the data a subset of the image covering the study area (632 X 906 pixels) was taken from the pre-processed large LISS III scene. The subset image was then subjected to unsupervised classification to find the 'natural groupings' within the image. The Iterative Self-Organising Data Analysis (ISODATA) clustering algorithm available in ERDAS IMAGINE image processing software was used for the purpose. Advantages of the ISODATA algorithm is that i) it is not geographically biased to the top or bottom pixels of the data file, ii) it is highly successful at finding the spectral clusters that are inherent in the data, iii) it creates a preliminary thematic raster layer, which is similar to minimum distance classifier, and iv) the created thematic layer can be used for analysing and manipulating the signatures before actual classification takes place (ERDAS, 1999).

The unsupervised classification was guided by the past field knowledge of the study area. The algorithm was first applied to the four band LISS III images of high and low tidal conditions belonging to years 1999 and 2000 respectively to understand the effect of tidal condition on retrieval of information from the remotely sensed data. The exercise was repeated with various numbers of classes until the classified image revealed major floristic habitats in the study area.

6.1.5.2 Image analysis

The maps that were prepared by unsupervised classification were subjected to detailed analysis on the basis of ground information collected thereafter. Categories and regions that were classified properly and those that were not classified properly were identified. Several pattern recognition techniques as well as statistical methods such as Principal Component Analysis (PCA) and haze reduction were tried out and then subjected to unsupervised as well as supervised classification. Several combinations of the above methods were tried out. The outputs were subjected to analysis again and the classification accuracy (this topic has been explained in detail later) was calculated.

Band ratios and vegetation indices like NDVI have been widely used in the classification of vegetation. Several combinations of band ratios, vegetation indices and the raw satellite bands were used and the resultant classified outputs were subjected to accuracy estimation. The results of the different techniques have been presented in chapter 8. The method, which showed the best results both in terms of number of classes identified as well as the accuracy achieved was band ratioing followed by supervised classification.

Band Ratioing

The process of dividing the pixels in one image by the corresponding pixels in the second image is known as ratioing. They are commonly applied to remote sensing data for the following two reasons, i) differences in the spectra of different surfaces can be emphasized and ii) the effects of variation in the topography can be reduced. It generates a ratio image in which the value at any pixel represents the ratio of the values of the two combined bands.

$$Y_{ij} = \frac{X_{ij1}}{X_{ij2}}$$

Where,

Y_{ij} = Output value of the pixel of the location (i, j)

X_{ij1} = Value of input pixel at the same location for band 1

X_{ij2} = Value of input pixel at the same location for band 2

Band ratios are not only generated by simple division of two images, their values may be subjected even to additions or subtractions before they are divided. Several combinations of the four LISS III bands were tried out.

6.1.5.3 Supervised Classification

The unsupervised classified map generated from the March 2000 image served as a prefield map for the initial field studies. As stated earlier, a number of sites were surveyed. The data collected during the survey included identification of major communities in the area, their component species, height, density *etc.* These sites were used as training sites for supervised classification to map various habitats in the region as well as major mangrove communities in the study area. Signature evaluation of the various features, observed on the field was carried out in the image-processing laboratory and supervised classification was carried out using *Maximum Likelihood Classifier.* The Maximum Likelihood decision rule was adopted for the supervised classification because it takes most variables into consideration. It takes into account the variability of classes by using the co variance matrix. The decision rule is based on the probability that a pixel belongs to a particular class. The equation assumes that these probabilities are equal for all classes, and that the input bands have normal distributions (ERDAS, 1999). The equation used for the maximum likelihood classifier in the image processing system is as follows:

$$D = ln(a_c) - [0.5\, ln(|Cov_c|)] - [0.5\,(X - M_c)T(Cov_c - 1)(X - M_c)]$$

where,

D = weighted distance (likelihood)

c = a particular class

X = the measurement vector of candidate pixel

M_c = the mean vector of the sample of class c

a_c = percent probability that any candidate pixel is a member of a class c (*i.e.* 1.0)

Cov_c = the covariance matrix of the pixels in the sample of class c

$|Cov_c|$ = determinant of Cov_c

$Cov_c - 1$ = inverse of Cov_c

ln = natural logarithm function

T = transposition function

6.1.5.3.1 Mangrove Habitat Mapping

The supervised classification was conducted on a number of different combinations of the four LISS III bands, their band ratios and NDVI,. The generated mangrove habitat maps were then evaluated for their accuracy. The two methods that were giving the highest accuracy were then selected and the remaining data was then analysed using the selected methods to generate mangrove habitat maps annually. In order to avoid merging between the land and the mangrove vegetation on one hand and the mangrove-marsh vegetationd and reef vegetation on the other hand it was decided to separate the two region and classify them separately and then mosaic them into the final mangrove habitat map.

6.1.5.3. Mangrove community Zonation

It was carried out on the image (consisting only the study area) of the year 2000. As the main emphasis was on the different mangrove communities found in the area, the terrestrial regions as well as the reef regions were masked out and only the mangrove regions were selected. After carrying out supervised classification, mangrove community zonation map were generated.

6.1.6 Post-classification Steps

The classified mangrove habitat maps as well as the mangrove zonation maps were then subjected to post classification steps. The post classification steps involved area estimation and assessment of accuracy are presented in Fig. 6.4

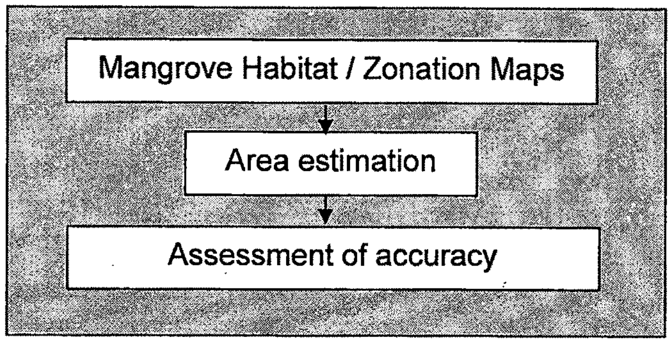

Figure 6.4 Steps involved in post-classification stage.

6.1.6.1 Area estimation

The Geographic Lat/Long projection of the classified image does not allow direct estimation of the area from the classified image. To overcome this, the projection of the images was converted to Polyconic while keeping the spheroid constant. After carrying out this change in projection, the area for various categories was calculated from the classified image in hectares.

6.1.6.2 Accuracy assessment

Accuracy of the classification process is determined through several statistical measures. For the purpose, points were randomly plotted on the classified maps using the image processing software. The plotting of points was stratified by excluding water category. The accuracy of the mangrove habitat maps were calculated using 75 points while for the mangrove community maps 125 points. The points were located in the field during the April-May 2002 survey with the help of the same Magellan NAV DX Global Positioning instrument used during the earlier field surveys. Accuracy of the mangrove zonation maps was determined from the *error matrix* (*i.e.* a tabular arrangement of rows and columns representing classification and reference categories respectively) derived from the classification and reference data. Three measures (viz., user accuracy, overall accuracy and kappa coefficient) used in the present study for accuracy assessment of the classified maps are being described below:

i) *User accuracy* is considered more pertinent in a management context (Green *et al.* 2000). Congalton, (1991) defines the user accuracy as the probability of a classified pixel's actually representing the same category on the ground. It is used to assess the accuracy of individual categories and is calculated by the following formula:

$$User\ accuracy = \frac{N_c}{T_r}$$

where,

N_c = Number of correctly classified points, and

T_r = Total no. of points in that row.

ii) *Overall accuracy* is the most common way of describing the accuracy for the whole map across all categories. It is considered to describe the overall degree of agreement in the error matrix. Following relation is used in deriving the overall accuracy:

$$Overall\ accuracy = \frac{N_{dc}}{T}$$

where,

N_{dc} = Total number of correctly classified points (diagonal points), and

T = Total no. of points used for accuracy assessment

iii) *Kappa analysis* is another way of presenting the collective accuracy of a map. It is a measure of overall agreement based on discrete multivariate analysis (Bishop *et al.* 1975). *Khat statistics* or *Kappa coefficient* is generated incorporating the off-diagonal values of an error matrix, which is ignored in the calculation of overall accuracy. The Kappa coefficient K represents the proportionate reduction in error generated by a classification process compared with the error of a completely random classification (Bishop *et al.* 1975). It is also suggested that Kappa statistic theoretically deflates the accuracy statistics based on chance occurrence of correct classification. The mathematical relation from which the K is calculated, is expressed as:

$$K = \frac{N\sum_{i=1}^{r} X_{ii} - \sum_{i=1}^{r} (X_{i+}.X_{+1})}{N^2 - \sum_{i=1}^{r} (X_{i+}.X_{+1})}$$

where,

r = total number of rows (*i.e.* classes) in a matrix,
X_{ii} = total number of points in row *i* and column *i*,
X_{i+} = marginal total in row *i*,
X_{+i} = marginal total in column *i*, and
N = total number of points used for accuracy assessment.

The value of Kappa coefficient, K (value ranging from 0 to 1) is less than the overall accuracy unless the classification is exceptionally good (Green *et al.* 2000).

6.2 FIELD DATA COLLECTION

Remote sensing data is valuable in providing the basic prefield framework of the study area, but it does not replace the field exercises. Rather a complete, accurate and detailed vegetation mapping requires extensive ground survey. Also the present spatial resolutions of the satellite sensors do not permit the identification of vegetation to the species level in heterogenous communities. The ground survey is required in remote sensing studies for a variety of reasons such as plant community composition, atmospheric correction, identification of spectral signatures, characterization of the surface features and accuracy assessment.

In the present study, ground survey has been carried out with the following aims;

(1) To identify training sites pertaining to different mangrove communities in the area to help classification of the area at habitat and mangrove community levels.

(2) To make an inventory of the higher plants growing in the area.

(3) To study the phytosociology of the mangrove genera of the area

(4) To estimate the accuracy of the maps produced.

A preliminary survey of the area was carried out during March-April 2000 to identify the different habitats in the area. During this survey various locations on Jindra and Chhad were visited. Existing coastal land use maps and Survey of India topographic sheets available at Space Applications Centre (ISRO), Ahmedabad were used as base maps to carry out the survey. Information on the mangrove as well as associated species growing in the area, height of different species, the principal mangrove community zones and physiognomy was collected. This information was then used to plan further field data collection. The overview of the field survey methodology has been given in fig 6.6

6.2.1 Identifying Training Sites

The prefield maps prepared after unsupervised classification showed a number of heterogenous classes in the area. Using information from the preliminary survey it was decided that to identify training sites for mangrove community zones a detailed field survey was to be carried out at Pirotan, Jindra, Chhad, Bhains Bid, Chiriya Tapu, Pathe Pir ka Bela, Amudi Bela and the area south of Hadde Creek. These different areas had shown a variation in their spectral reflectances, which could translate in variation in the community structure. Areas showing different spectral properties on the image were visited and the community at the location was identified. Using this information, sufficiently large sites of each community were identified and visited. Such sites were then used as training sites to be used in supervised classification. Pure patches covering large areas were selected in order to avoid mixed patches and in such a way that these 'pure pixels' patches could be identified on the remote sensing images. Field data collected during the survey included identification of the mangrove community, species composition, vegetation height, percent cover, *etc.* Geographic co-ordinates of field data collection points were determined with the help of a hand held GPS device. The projection used for the field survey was

Geographic Lat/Long while the spheroid selected was WGS84. This projection was selected because it gave higher positional accuracy.

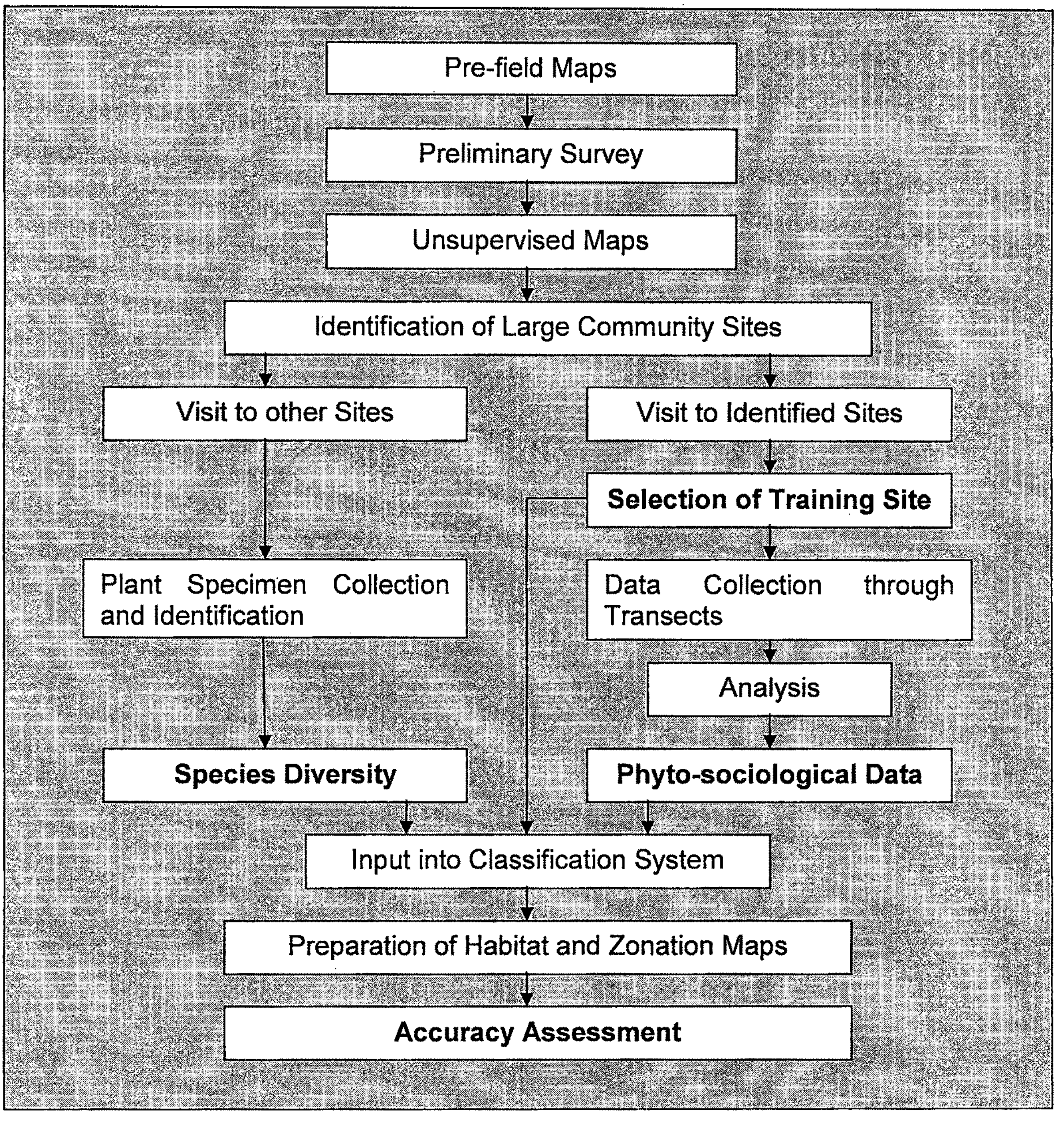

Fig 6.6 Overview of the Field Survey Methodology. The main aims of the field survey have been highlighted

6.2.2 Diversity Survey

For the purpose of making an inventory of plants growing in the study area it was decided to visit all the islands as well as the adjoining regions on the mainland. Plant specimens from the field were collected and pressed to make herbarium specimens. The specimens that were collected were then compared with various floras and a list of species present in the area was prepared.

6.2.3 Phytosociological data collection

During a detailed survey on Narara Island in July-August 2000, different sampling techniques were attempted to collect phytosociological data. The quadrats were put on randomly selected transects which started from the edge of the creek or the seaward margin of the mangrove to the landward margin of the mangrove vegetation. Similarly belt and segmented belt transects were also laid down in the same manner. A review of literature had revealed the Point Center Quadrat Method (PCQM) is best suited for studying mangrove vegetation (Cintron and Novelli, 1984; Satyanarayana *et. al.*, 2001). In the study area, the segmented belt transect as well as the PCQM was found to give similar results. Along the margins of the creek, where the height as well as density of the mangrove vegetation was more, both the methods performed well with the PCQM being easy to use but as we reached towards the land ward margin, the vegetation became sparse and stunted and at such an area this method was a bit difficult to follow. On the other hand the segmented belt transects did not face this problem but needed more care, time and manpower. Considering the resources of time and manpower available it was decided to collect data using the PCQM. The calculation of density has been done using the formula given by Cintron and Novelli (1984). The formula has been given below

Overall Density $D = \frac{1}{d^2}$

Where d = Mean distance of the plants from the centre point.

Density of individual species = $D \times \frac{r_1}{R}$

Where D = Overall density

r_1 = Number of Individuals of the species

R = Total number of Individuals of all species

6.2.4 Field Survey for accuracy Estimation:

In order to evaluate the classification accuracy, ground checks were made all over the study area while keeping in mind the fact that areas used as training sites were not used during the accuracy estimation.

Filed investigations were carried out in December 2000, May 2001 and November 2001. The field visit for accuracy assessment was carried out in April-May 2002.

6.3 SPECTRAL STUDIES FOR DOMINANT MANGROVE COMMUNITIES

The reflectance properties of vegetation in the different spectral bands are collected to produce spectral signatures for the component vegetation in an area. The spectral reflectance of different mangrove communities found in an area can be compared using the raw or DN values. However such values are not comparable to the reflectance values obtained for the same communities at a different location. To allow comparison of reflectance properties of the same communities at different locations several imaging parameters like time of image acquisition, sun elevation angle etc. have to be taken into consideration and the changes in the reflection due to them have to be nullified. The conversion of DN values to apparent reflectance values takes care of most of these changes.

Using ground based information, large patches of different communities in the study area were identified and their spectral reflectance properties were analysed. For each community type at least five locations were identified and used to generate the set of spectral signatures. The results have been discussed in chapter 7.

6.4 CHANGE DETECTION STUDIES

Change detection studies have been one of the major applications of remote sensing technology to mangrove studies. The synoptic viewing capacity of remote sensing technology has been the major factors behind this. With more than 30 years of satellite earth observation, a great repository of data of the earth has been accumulated. With environmental change proceeding at an ever-faster rate, this repository has the ability to give the direction of environmental change if analysed properly.

Change detection studies can be broadly divided into two major types. The first type is the pre classification change detection and the second is the post classification change detection. In the first type the analysis involves the use of the image data before they have been subjected to classification into thematic maps. While in the second type, the analysis is conducted after the image data have been classified into thematic maps.

The present study aims to look into the changes in the mangrove area in the past 40 years. The data used for this change detection study has been enumerated in table 6.6. The steps involved in the study have been depicted in the figure 6.7.

Table 6.6 Maps used in the Change detection study

Year	Map Type	Source
1966	Traced Mangrove area map	SOI Toposheet
1975	Coastal Landuse Map	Landsat TM data
1990	Coastal Landuse Map	Landsat TM data
1998	Mangrove Habitat Map	IRS LISS III data
2001	Mangrove habitat Map	IRS LISS III data

6.4.1 THEMATIC DATA USED

Thematic maps of five different dates have been used for the purpose of this study. The details of each map including their origin has been give below.

Mangrove Map 1966.

This map has been derived from the SOI topographical sheets (41 fF/14, 41 F/15 and 41 J/2). This map has been selected as it shows the status of the mangroves in the area before the advent of satellite imagery. This map gives the location and the areal extent of the mangroves in the area. It does not have any information on the type or the density of the mangroves. The map has been represented in plate 6.1

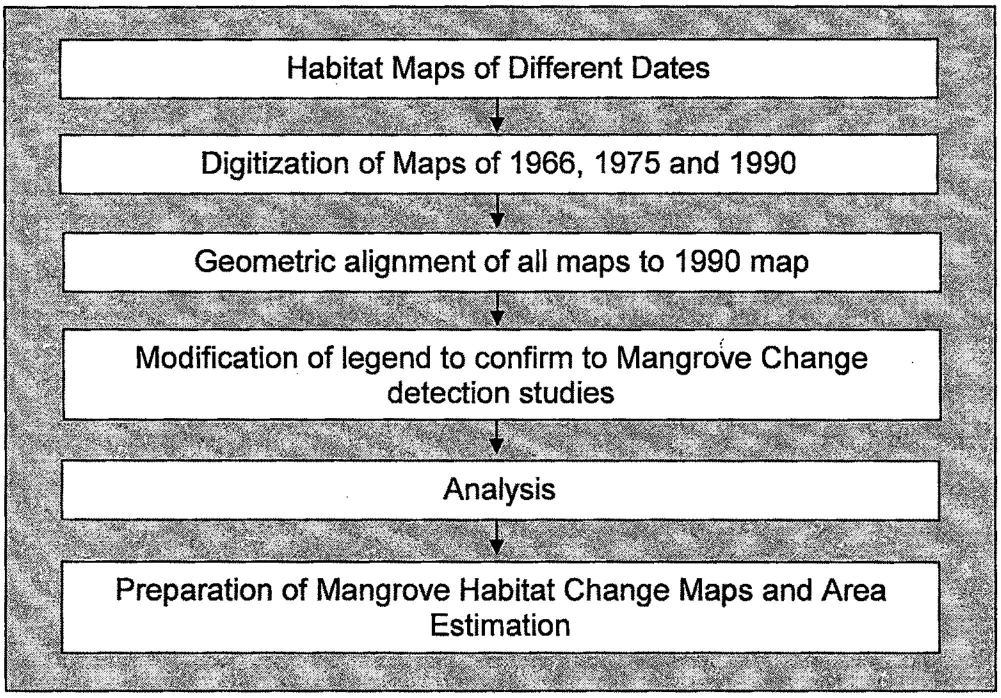

Fig 5.7 Steps involved in change detection studies

Coastal Land-use Map 1975

This map has been derived from the Landsat MSS Diazo colour composite data of 16th February 1975. Only a small part of the original map, which was prepared at 1:50,000 scale has been used for the present study. It has been prepared by visual interpretation of the data. The accuracy of the map has been pegged at 83% at 90 % confidence level (Nayak et al. 1988). This is one of the earliest maps of the area based on satellite data. It has been represented in plate 6.2

Coastal Landuse Map 1990

This map is again a very small part of the map that was prepared using Landsat TM data of 1990. The original map had several categories which were not there in the other maps and for this reason several categories were merged into one or more inclusive categories e.g. built-up area, port, roads were merged into one single category terrestrial area. Detailed information on the class that have been finally used has been given later. The map has been depicted in plate 6.3.

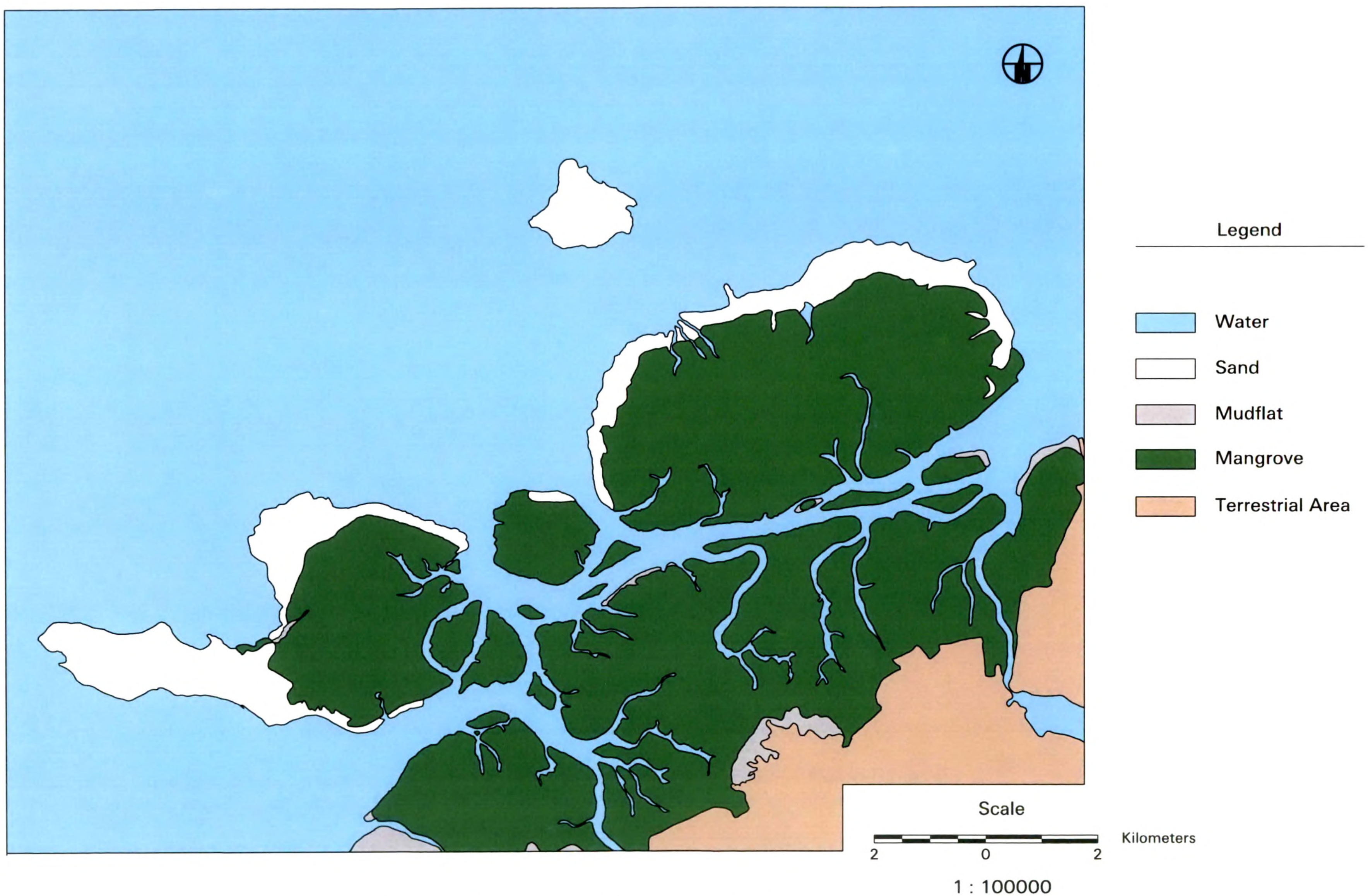

Plate 6.1 Mangrove habitat map 1966

Plate 6.2 Coastal Landuse map 1975

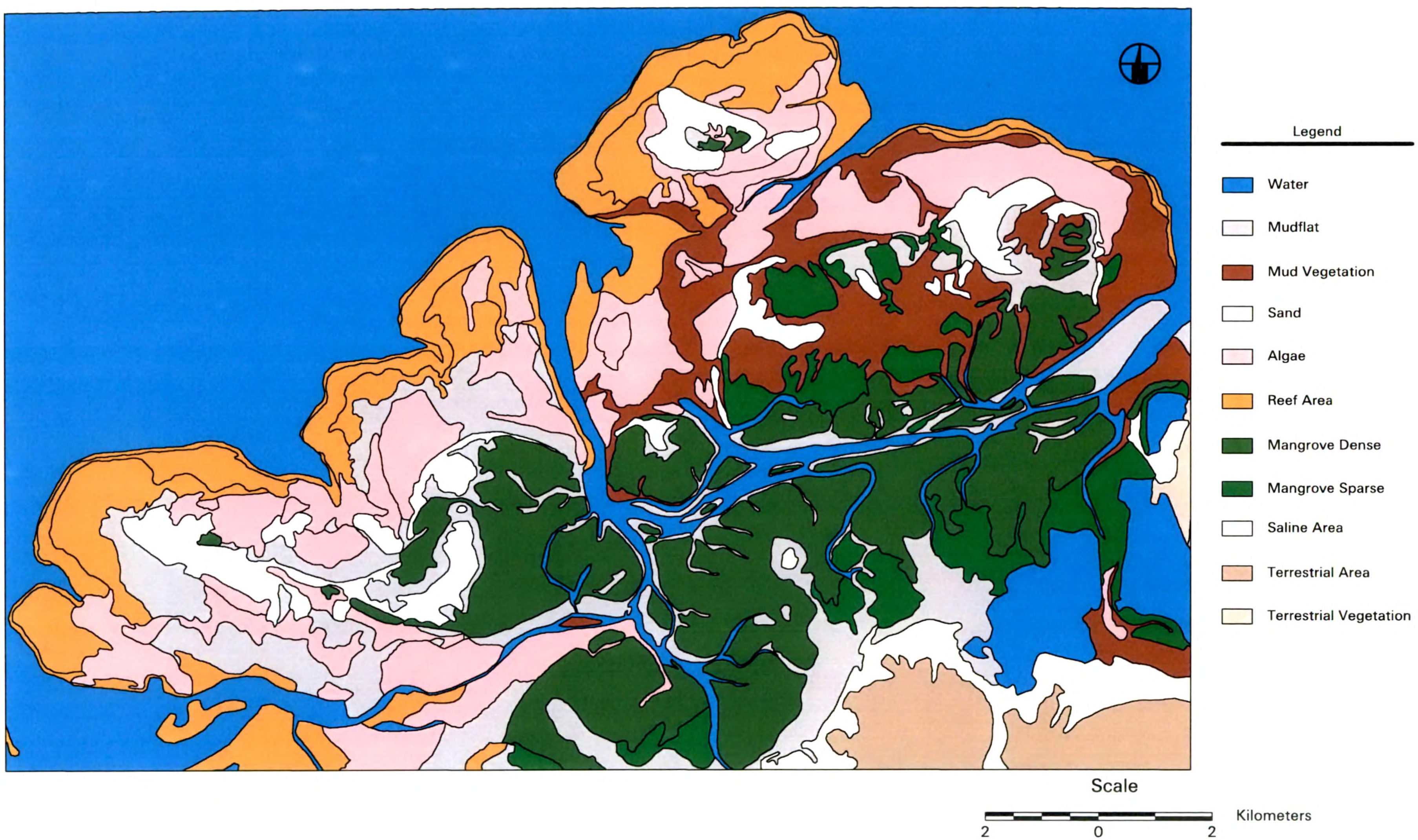

Plate 6.3 Coastal Landuse Map 1990

Mangrove Habitat Maps 1998 and 2001

These maps have been prepared using digital interpretation. The methodology of their preparation as well as other information about them have been given in detail in chapter 8. As they were created in raster form their conversion to vector format led to the formation of several polygons of very small size. The conversion of the 1998 map led to the formation of a vector layer with more than 9,000 polygons of which more than half were of less than 1,500 m^2 size (less than 3 pixels in LISS III data) This further created problems in the change detection process in which polygons of even smaller sizes were created. So all polygons smaller then 1,500 m^2 were merged with neighboring polygons with which they shared their longest boundary.

6.4.2 Geometric Correction

As all the maps were generated at different times they were subjected to geometric correction. This was necessitated due to errors of location in the different maps that showed the same place having different geographical coordinates in two different maps. The 1990 map was taken as the basis for the geometric correction as this map has been a major input for the Coastal Regulatory Zone Information System (CZIS) for Gujarat.

Using at least 15 GCPs each maps were then geometrically aligned to the 1990 map. This was carried out using the same procedure as has been explained in geometric correction explained earlier in the chapter but for the fact that the process was carried out using the ESRI ArcInfo software instead of ERDAS Imagine.

6.4.3 Legend Standardization

As all the maps were created at different times, they had legends which did not conform to each other. To overcome this problem a set of 23 classes was defined and the legends of all the maps were then converted to it. Each class was then assigned a three-digit code to help in the change detection analysis. The classes and the codes were not arbitrarily chosen but they are part of the classes and codes being used in the coastal ecosystem modeling experiment at SAC. The maps for 1966 and 1975 had fewer categories and thus were easily converted. The 1990 map had several categories, which were not very useful in the present exercise that was concentrating on the mangrove vegetation. Thus several categories were merged into classes that sufficed the present objectives. The categories and the codes assigned to them have been given in the table 6.7.

Table 6.7 Classes and Codes standardized for change detection analysis

Sr. No.	Category	Code
1.	Sea	110
2.	Water Body	120
3.	Mud	200
4.	Intertidal Mudflat	220
5.	Hightidal Mudflat	230
6.	Mud vegetation	240
7.	Marsh	260
8.	Sand Beach / Patch	310
9.	Sand Vegetation	320
10.	Reef area	410
11.	Mud over Reef	430
12.	Reef Vegetation	460
13.	Rocks	500
14.	Mangrove Dense	610
15.	Mangrove Sparse	620
16.	Mangrove Degraded	640
17.	Standing Dead Mangrove	670
18.	Back Mangrove	680
19.	Salt Pan	820
20.	Saline Area	830
21.	Terrestrial Area	950
22.	Terrestrial Vegetation	970
23.	Habitation	990

6.4.4 Change Detection Analysis

The change detection analysis was carried out using ESRI's ArcInfo software. Each map was compared with its preceding as well as the map of the next date. This resulted in the development of 4 mangrove change maps. The steps involved in this analysis have been detailed in fig 6.8.

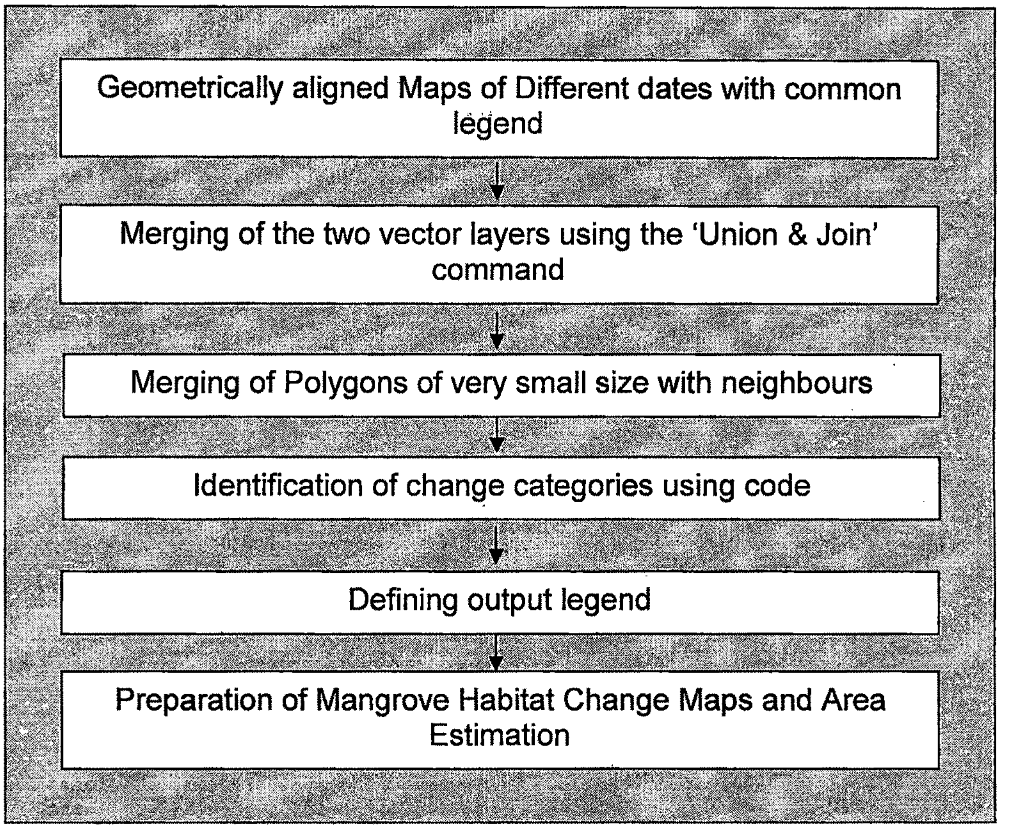

Fig 6.8 Steps involved in change detection Analysis

6.4.4.1 Merging of vector layers

Each vector layer has several attributes in its Polygon Attribute Table (PAT) file. When two vector layers are subjected to analysis (either union or intersect) based on the output required information from both the PAT may be required. As the present analysis needed information of the categories in both the vector layers they were merged using the 'union and join' command.

6.4.4.2 Dissolving polygons of very small size.

The output map generated in the above process had a large number of polygons out of which there were several polygons of very small size. These polygons were then merged with the neighbouring polygons with which they shared their longest boundary. In this way polygons measuring less than 1500 m^2 (this area would cover less than 3 mm^2 in a 1:25,000 scale map) were merged.

6.4.4.3 Identification of Change Categories

Each polygon that is generated in the merged map will have information about that region from both the input maps in its Polygon Attribute Table (PAT) file. Using the category codes of the two different dates a new item (a new column in the tabular PAT file) is added to the file. This new item is generated in such a way that it has information on the earlier as well as the latter category. A part of a PAT table is illustrated below (Fig. 6.9) for ease in understanding.

ion#	Polygon ID	Code1990	Code1998	ChangeCode	Perim
	1440	610	620	610620	
	1441	620	220	620220	

Fig 6.9 Part of Polygon Attribute Table showing codes

In the above figure a look at the ChangeCode of polygon 1440 will reveal that area has changed from dense mangrove (610) in 1990 to sparse mangrove (620) in 1998 while polygon 1441 has changed from dense mangrove to intertidal mudflat (220) during the same period. The ChangeCode for each polygon has thus been derived from the category codes of both the years.

6.4.5. Defining Output Legend (Map Composition)

The number of output classes in each of the change detection analysis is different as this is based on the number of input classes and their respective locations. The total possible number of output classes crosses 400. Even if only the mangrove changes were taken into consideration it was observed that a large number of output classes were been formed in the 1998 to 2001 analysis more than 55 classes were obtained. This decreased the clarity of the map and then it was decided to have only three output classes in the output map while the change statistics will be given in a tabular form. The classes in the mangrove vegetation change map are, no-change areas (which indicated that no change in the category has occurred), improving areas (indicating areas where either mangroves have colonized or the status has improved) and degrading areas (indicating areas where mangroves have vanished or their status has deteriorated). The results of the change detection study have been given in chapter 10.