CHAPTER - 3
METHODOLOGY

3.0 Methodology

The methodology has been channelized into four different groups as follows (Figure 2) :

- Visual interpretation of satellite data imageries.
- Field Studies
- Digital analysis of satellite data and
- Geographical Information System (GIS) Analysis.

3.1 Visual Interpretation

The following steps were undertaken to identify, delineate and monitor the forest cover: data collection, preliminary interpretation, ground truth verification & final interpretation which has been discussed separately.

3.1.1 Data Collection

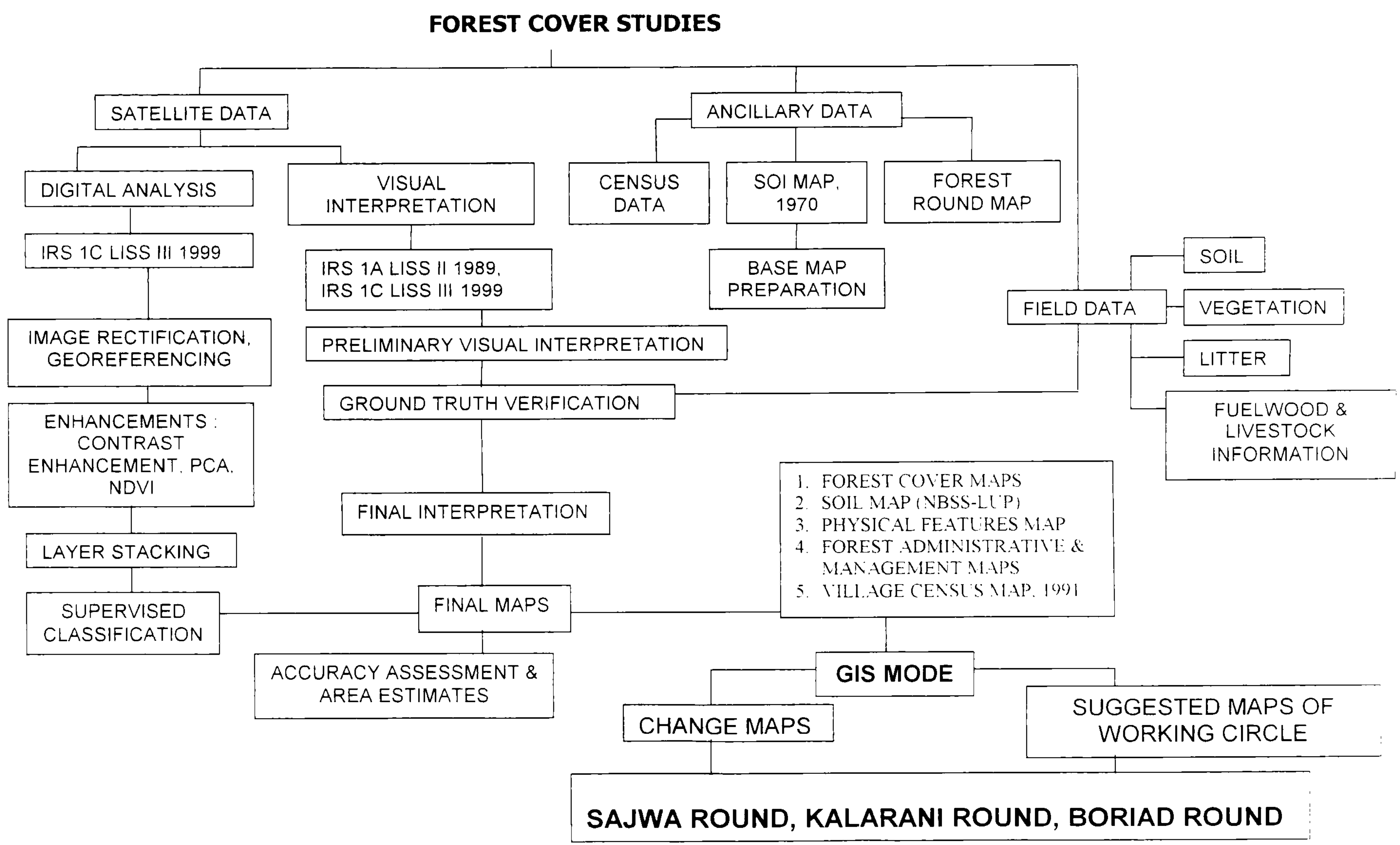
The three different data sets were taken for analysis as follows:

3.1.1.1 Satellite data

Forest cover monitoring was done using multitemporal satellite images of 1989 and 1999 geocoded paper print acquired from the National Remote Sensing Agency (NRSA), Hyderabad. The higher resolution images were obtained to have micro level information in forest cover mapping. Accordingly, the scale and minimum mapping unit of the map was finalized. The details of the data used are:

Satellite	Sensor	Bands	Year	Scale	Path/Row
IRS 1C	LISS III	2,3,4	1999	1:50,000	94/56

Figure 2: Methodology Flow Chart



3.1.1.2 Ancillary data

It consisted of Survey of India (SOI) topographical maps at 1:50,000 scales which were used as the base map. Round maps and Forest management maps acquired from the Forest Department on 1:63,360 (2"= 1mile) were also used. Reports & records from the Forest Department and other repositories have also been referred to for information on forest management and climatic aspects.

3.1.1.3 Field data

A quick reconnaissance survey of the study area was carried out to get a feel of the entire ground area which can aid in the preliminary interpretation of the data.

3.1.2 Preliminary interpretation

Base maps of the study area were generated at 1:50,000 scale. Data of IRS I A and IC were used for visual interpretation on these base maps. The forest round map, at 1:63,360 scale was enlarged to 1:50,000 scale with the help of ORE (Optical Reflecting Enlarger). Considering the basic elements of interpretation such as tone/colour, size, shape, texture, pattern, location, association, shadow, aspect and resolution along with ground truth and ancillary information collected during the preliminary reconnaissance survey, a photointerpretation key for different classes was developed (Table 12).

The preliminary image interpretation was done based on the interpretation key and the field survey data.

3.1.3 Final Interpretation

A detailed ground survey was carried out to check the discrepancy of the interpreted data. The random points plotted were

Table 12: Photointerpretation Key

No.	Classes	Tone	Texture	Shape	Size	Pattern
1	Closed Teak Forest	reddish	Smooth	Contiguous	large	Irregular
2	Closed Mixed Forest	Red	Smooth to medium	Contiguous	Medium	Irregular
3	Open Mixed Forest	Greenish red	Rough	Contiguous	Small	Irregular
4	Degraded Forest	Light pink	Rough	Contiguous	Large	Irregular with grains
5	Scrubs	Bluish red	Rough	Contiguous	Large	Irregular with lines
6	Scrub with Coppice forest	pink	Smooth	Contiguous	Medium	Irregular
7	Sparse Tree Cover	Bluish white with scattered brown grains	Rough	Contiguous	Large	Irregular
8	Plantation - Acacia	Pinkish green	Rough	Regular	Small	Regular
9	Plantation - Eucalyptus	Dark red	Smooth to medium	Regular	Small	Regular- square to rectangle. Flat land
10	Agriculture	Bright red	Smooth to rough	Regular patches	Small to Medium size	Irregular-rectangular
11	Sparse Tree Cover with Agriculture	Bluish white with scattered brown grains and scattered bright red to pink colour patches	Rough	Contiguous	Large	Mixed
12	Wasteland	Yellowish white	Smooth	Contiguous	Large	Irregular
13	River	White and blue	Smooth	Linear	Medium	Regular
14	Stony waste	Greenish blue	Smooth	Contiguous	Small	Irregular

checked using the Global Positioning Systems (Table 13). The confusion matrix was prepared to assess the overall classification accuracy and mapping accuracy. The KAPPA analysis yielding a K_{hat} statistics (an estimate of KAPPA) that is measure of agreement or accuracy was calculated. The following formulas were used to calculate the accuracy.

Overall Classification Accuracy = $(\Sigma N_i / \Sigma T_i) \times 100$

Where,

ΣN_i = Total number of correctly classified points,

ΣT_i = Total number of points checked on ground.

Overall Mapping Accuracy = $\Sigma N_i / \Sigma N_i + \Sigma E_i \times 100$

Where,

ΣN_i = Total number of correctly classified points

ΣE_i = Total number of erroneous points

$$K_{hat} = \frac{N \sum_{i=1}^{r} X_{ii} - \sum_{i=1}^{r} (X_{i+} \times X_{+i})}{N^2 - \sum_{i=1}^{r} (X_{i+} \times X_{+i})}$$

Where,

r = numbers of rows in the matrix,

X_{ii} = number of observations in row i and column i,

X_{i+} and X_{+i} = marginal totals for row i and column i, respectively,

N = the total number of observations.

In addition, for final accuracy testing, different points were visited to find out the precise correlations between the classes delineated on the spatial data with the ground.

3.2 Field Studies

For this, stratified random sampling technique was adopted. The plant soil and litter samples were collected from different random

Table 13: GPS Readings

Sr. No.	Spots	Class	Latitude	Longitude
1	Sajwa RF	Scrub	22° 09.485 N	73° 55.754 E
2	Panchwadha RF	Degraded Forest	22° 10.410 N	73° 54.017 E
3			22° 10.353 N	73° 53.950 E
4	Phenaimata RF	Closed Teak Forest	22° 08.205 N	73° 52.363 E
5			22° 08.159 N	73° 52.084 E
6			22° 08.219 N	73° 52.064 E
7	Panchwadha RF	Closed Teak Forest	22° 10.215 N	73° 50.243 E
8			22° 10.157 N	73° 50.276 E
9			22° 10.152 N	73° 50.276 E
10			22° 09.989 N	73° 50.404 E
11	Jamli RF	Scrub with Coppice Forest	22° 00.583 N	73° 51.198 E
12	Bagalia RF	Scrub with Coppice Forest	22° 01.246 N	73° 55.430 E
13	Kalarani RF		22° 14.014 N	73° 51.282 E
14			22° 13.900 N	73° 51.281 E
15			22° 13.948 N	73° 50.916 E
16			22° 14.048 N	73° 51.270 E
17	Degala RF	Closed Mixed Forest	22° 13.851 N	73° 58.916 E
18			22° 13.956 N	73° 58.982 E
19			22° 14.307 N	73° 58.906 E
20	Wadtalav	Teak Plantation	22° 15.134 N	73° 46.931 E
21	Sajwa	Agriculture	22° 09.681 N	73° 51.284 E
22	Bagalia	Riverine	22° 01.246 N	73° 55.430 E
23	Jhanpa	Wasteland	22° 12.079 N	73° 47.385 E
24			22° 11.958 N	73° 47.388 E
	VILLAGES			
1	Boriad		22° 02.927 N	73° 50.323 E
2	Sengpur		22° 02.536 N	73° 53.369 E
3	Gajara		22° 14.472 N	73° 53.371 E
4	Kosum		22° 13.703 N	73° 53.712 E
5	Bhaisa		22° 16.148 N	73° 57.238 E
6	Bordha Beat Office		22° 14.711 N	73° 56.201 E

points. Care was taken to see that the points visited correlated with the visually interpreted. Microlevel studies were then carried out on the spots visited. These studies covered phytosociological parameters, soil physicochemical features and details of the litter from different sample plots. In addition to this, villages of different rounds were visited to understand the livestock status and fuelwood requirement of the villages. The different studies carried out are described separately.

3.2.1 Phytosociological Studies

Quadrat plot was laid in triplicate at each spot visited. Density, frequency, abundance and dominance and their relative values were calculated along with IVI values (Ambasht, 1990 and Odum, 1983). The basal area was calculated by formula using diameter at breast height (Ravindranath & Premnath, 1997). Secondary analyses like different indices were calculated using this primary data. These indices include:

- Index of dominance (Simpson, 1949),

  $C = \sum ni\ (ni-1) / N\ (N-1)$

  Where, C = Index of dominance,

  ni = number of each species,

  N = Total number of each species
- Index of diversity (Shannon & Wiener, 1949),

  $H = -\ 3.3219\ \sum(ni / N) \log (ni / N)$

  Where, H = Index of diversity,

  ni = number of each species,

  N = Total number of each species.
- Similarity index (Soranson, 1948),

  $S = 2C / A+B$

Where, A = number of species in sample A, (at one level)

B = number of species in sample B, (at another level)

C = number of species common to both samples,

- Evenness index (Pielous 1966) and

  $E = H / \log S$

  Where, H = Index of diversity,

  S = number of species

- Species richness index (Menhinick, 1964)

  $Sr = S / N^{1/2}$

  Where, S = number of species,

  N = number of individuals.

3.2.2 Soil Physicochemical Studies

The top soil and soils at one feet layer collected from each of the quadrats, was then brought to the laboratory for analysis. Selected physical and chemical tests such as colour, texture, field capacity, pH, EC and macronutrients like Nitrogen, Phosphorus and Potassium (N, P & K respectively) and some of the micronutrients such as Zinc, Iron, Manganese and Copper (Zn, Fe, Mn, and Cu respectively) were determined.

The soil colour was determined with the help of Munsell Chart (Piper,1950) and the texture by field method (Black,1968). Soil water content was found by taking the known weight of air dried soil and noting the relative difference in mass after oven drying the soil and thereafter calculating the percentage (Rowell, 1994).

A saturated extract (1:2) of the soil was made for the determination of pH and EC (Jackson, 1967). Soil organic carbon was extracted and assayed colorimetrically. (Datta et. al. 1962). The available phosphorus in the soil was determined by Olsen's method, colorimetrically (Olsen et. al. 1954). The determination of available potassium was done on a flame photometer (Ghosh et. al. 1983).

The micronutrients Zn, Fe, Mn, Cu were determined on an atomic absorption spectrophotometer (AAS) following the method of Lindsay and Norvell (1978).

3.2.3 Litter analysis

Litter of dominant, associated or common species was collected from all the classes thrice in a year i.e. during winter, pre monsoon and post monsoon periods.

Litter nitrogen analysis was done by digesting the plant material and determining the concentration through titration method (Jackson 1973). The determination of phosphorus was done spectrophotometrically (Ghosh et. al. 1983).

3.3 Digital analysis of satellite data

Digital analysis of the data was carried out through the following steps:

- Data input.
- Image rectification.
- Image enhancement & spectral signature generation.
- Image classification and accuracy assessment.
- Data output.

3.3.1 Data input

Data of two types were imported to the system i.e. satellite data and ancillary data.

3.3.1.1 Satellite data

The satellite data, acquired from NRSA, Hyderabad, i.e. IRS 1D LISS III 1999, in band sequential format (BSQ) was imported to the system by the ERDAS 8.5 software data. Information such as number of pixels, rows, columns and bands was filled up while importing data.

3.3.1.2 Ancillary data

The base map prepared from the Survey of India topomap and the forest round maps were imported to the ERDAS system.

3.3.2 Image rectification

The study area portion on the digital data was mosaiced. The mosaiced raw data was to be corrected geometrically. Geometric rectification of the images was done by registering it to the Survey of India topographical maps through identification of Ground Control Point (GCP), which are the common points between the map and the image. The output image was obtained by the nearest neighborhood interpolation technique.

3.3.3 Image enhancement & spectral signature generation

Image enhancement was done to improve the image visualization and to highlight the information required on forest classes. The different band combinations (24 permutation combination of three bands) were tried and the best band observed was selected for vegetation analysis. Other enhancements such as contrast adjustments were tried. The spectral enhancement such as normalized difference vegetation index (NDVI) and principle components analysis were also attempted.

The spectral signatures of different visually interpreted classes were also generated.

3.3.4 Image classification and Accuracy assessment

Four different images viz. Red band of LISS III and the near infra red band of LISS III, NDVI and Principal component were merged to further enhance the image features. Finally the supervised classification was attempted using ground truth information to precisely classify the forest classes.

The accuracy assessment was done on the final classified image by plotting random points on the image. Overall mapping accuracy and classification accuracy was calculated. KAPPA analysis was also performed on the classified output.

3.3.5 Data Output

The classified scene generated was assigned pseudocolours for the purpose of easy discernability. The forest round map was then overlayed on the classified image which was then clipped. The final layout was generated in the Arcinfo 8.1 software.

3.4 GIS Analysis

3.4.1 Change Detection Study

The visually interpreted map was brought to the GIS environment and change analysis was done wherein the following steps were followed:

- Creation of spatial database.
- Area analysis
- Change analysis

3.4.1.1 Creation of spatial database

Maps generated by visual interpretation were rasterized. Using subset utility, the unwanted image portion was removed. Georeferencing was done on the remaining portion. The image was then converted into a vector format using ArcInfo 8.1 software. The spatial features of the map thus got converted into digital format. The vector map data included a number of errors caused during digitization, like undershoot, overshoots, missing arc, missing label, etc. These errors were removed through editing. A spatial relationship between features was created by building up topology.

The topology building generates the attribute table in the system. To this attribute table, the change classes' fields were added so as to generate the symbology for change classes.

Map projection (polyconic) and transformation was done so as to convert the map to real world co-ordinates.

3.4.1.2 Area analysis

Area and perimeter of different polygons on digital coverages were generated during the construction of topology. The area and perimeter of each polygon along with its id code was thus obtained.

3.4.1.3 Change analysis

Forest maps prepared from the SOI toposheets of 1970 were taken as a base year map. Other forest maps were generated using 1989, 1999 satellite data of IRS 1A, LISS II and IRS 1C, LISS III respectively.

A composite map of all these three maps was generated to understand changes that have occurred from 1970 to 1999. These changes in the class and area of the forest were then represented by a change matrix.

3.4.2 Geographical Information System (GIS) for sustainable development of forest

Integration of all the data generated was done using GIS module for which the following methodology was adopted.

- Database generation
- Data digitization and processing
- Data analysis / output generation

3.4.2.1 Database generation

This process included collection of spatial and nonspatial data from different sources. Spatial database was generated for five different types of maps, viz.

(i) Forest cover map prepared by visual interpretation of satellite data (1999).

(ii) Soil map collected from the National Bureau of Soil Survey (NBSS, 1994).

(iii) Physical features map such as roads, rivers, elevation, etc. generated from SOI toposheet.

(iv) Forest department administrative and management map and

(v) Village boundary map from census, 1991.

The non-spatial database was generated in a tabular form, i.e. attribute information. This included information generated through local information collected through questionnaires during field survey, which included socio-economic data, phenological, phytosociological data, soil physicochemical and litter nutrient data.

3.4.2.2 Data digitization and processing

The spatial data in the form of visually interpreted thematic map of 1999, soil map and physical feature map was digitized with the help of ArcInfo 8.1 software, to transform map data into machine editable form. Topology was built up after error correction. Attributes were assigned to different classes. All the maps were brought to the same projection system i.e. polyconic. Transformation was done so as to convert the map co-ordinates to real world co-ordinates.

3.4.2.3 Data analysis and output generation

The attribute data and the spatial data were merged for further analysis. This analysis was based on the parameters such as forest density, forest cover/species, river and road proximity, slope, soil type and condition and the species' diversity and dominance.

Different spatial data were overlaid on each other and the attribute data table and the database fields were attached to the final coverage. This coverage was then subjected to several queries using query builder for generating a final coverage. The queries included the basic parameters and conditions fixed for a forest-working circle. Based on this, the existing forest working circles were then further categorized into different working circles looking at different conditions for further improvement of the working circle. After categorization of this working circle, the old and the suggested were overlaid to notice the change. Thereafter the final outputs were generated for each round.