

Chapter 3

Materials and methods

3.0 Materials & Methods:

A step wise detailed methodology adopted for the present research work to meet the objectives are discussed and shown in the form of methodology charts in this section. It includes development of spatial and attribute database, thematic map generation using toposheets and high resolution satellite imagery, and based on the identification of sensitive areas with respect to forest, an ecologically sustainable development plan is generated. Till date, no such type of research except few dissertation or unpublished reports, is carried out in this area. Hence this research work is considered to be a pioneer study using geospatial technology. In the following sections the acquired materials and adopted methodology, to generate the ecologically sustainable development plan for Pavagadh forest area is described.

3.1. Materials

3.1.1. Topographical data

Topographical maps at 1:50,000 scale series of 46F06, 46F07, 46F10 & 46F11 have been collected from Survey of India (SoI). Each of them comprised of all the topographical details like, road, rail network, water bodies, forest boundaries, administrative boundaries, drainage, settlements, forest areas, scrubs/waste lands, bridges crossing etc. These toposheets were used as a base map and they were considered for the rectification of the other spatial and non spatial data.

3.1.2. Field Survey/ Reconnaissance survey

A reconnaissance survey was carried out to get acquainted with the general pattern of vegetation of the study area which can aid in preliminary interpretation of the

satellite data. At the same time, Ground Control Points (GCPs) of the forest and other distinct topographic features of the study area were collected. These GCPs were used during the rectification of the data. Field survey was also carried out for enumeration of ecological parameters. The results of the classified output was then validated by carrying out post classification verification.

3.1.3. Ancillary Data

Demographic information of the Halol Taluka was obtained from the District Census of 2001. This information included Village profile regarding its Population, available aerable land, Recorded Forest area, village boundary, & available education facilities in that village. Other information like Total forest area, their distribution, soil, geology, air pollution and ground water status of the study area were gathered from the Working Plan published by the Gujarat State Forest Department in the year 2008. This information was collected in the form of scanned images. These images were rectified and digitized in GIS environment to prepare a particular theme like road, drainage, slope & aspect, Forest cover, Population, Aerable land etc.

3.1.4. Remote Sensing Data

A freely available CARTOSAT data was procured from the BHUVAN, NRSC website to generate the contours of the study area. It was used to generate the thematic map of slope and aspect. Other spatial data of IRS-LISS-IV-MONO of the year 2007 and 2012, were procured, processed and analyzed for generation of different thematic maps of the forest like, Forest density map, forest type map, Change detection map, etc.

3.2. Softwares

The various soft wares were utilized during the application of this methodology which are described as following.

ERDAS IMAGINE 11: This has the raster graphic editor capabilities. It is mainly used for geospatial raster data processing and it allows the user to prepare, display and enhance digital images for mapping use in GIS . In this research work it was exploited for the assessment of the different forest parameters.

ARC GIS 10 : Arc GIS is software consisting of a group of GIS System Software products like Arc Reader, Arc View, Arc Editor, Arc Info etc. which in turn was utilized for data integration and manipulation with respect to ecologically sustainable development plan.

The soft wares have the capabilities to process the spatial as well as non spatial data and at the same time they can integrate this processed information as per the user's interest also. Considering their ability, the following soft wares were used for the present study.

3.3. Methods

Methodology employed for the assessment of different objectives has been discussed in the following section.

3.3.1. Generation of Base Map/Reference Map

The acquired SoI toposheets were rectified using GCPs and were mosaiced. The taluka boundary was overlaid on this mosaiced images using the reference of this

boundary, the Area of Interest (AoI) with appropriate projection was extracted from the toposheets. This served as a base map for the rectification of the spatial and incorporation of non spatial data for generating respective base maps of different themes.

3.3.2. Generation of Thematic map

Area development planning often requires a number of thematic maps on appropriate scale as well as a variety of attribute / non spatial information. The thematic information comprises of spatial data on natural resources, topography and infrastructure / communication network whereas the non spatial information, mainly comprised of the demographic patterns, socio economic profiles of the area and ground ecological attributes. Thus, basically three types of thematic maps were generated viz.,

- a) Thematic Map generation using ancillary/attribute/field/ non spatial data
- b) Thematic maps generation of ecological parameters
- c) Thematic map generation using spatial data

3.3.2.1. Thematic Map generation using ancillary/attribute/ field/ non spatial data

This type involved generation of thematic maps using either ancillary or non spatial data. Following thematic maps were generated under this.viz,

- 1. Roads,**
- 2. Slope & Aspect,**
- 3. Drainage pattern**
- 4. Village,**
- 5. Population,**
- 6. Arable land,**

7. Soil

8. Air pollution & Ground water status

The major and minor roads were digitized from the toposheets. The CARTOSAT data for the study area was downloaded from the BHUVAN, NRSC website for generation of thematic map of contour. Taking this map as a base, Slope & aspect Map were generated using Spatial Analyst Tool of Arc Map 10 software. The drainage pattern of the study area was digitized from the toposheets to generate the thematic map of drainage. The taluka map from the District Census, was procured. The village boundaries were digitized from this Taluka map in order to produce thematic map of village. All the other required information regarding village like population, available land, land use pattern, education facilities etc. was acquired from the Census data. It was stored in the form of attribute data of the village map for generating the thematic maps of Population, per capita availability of arable land, recorded forest area. Thematic Map of soil was made from the district soil map of Forest Working Plan. Data from unpublished records were collected regarding ground water and different gases of atmosphere. The thematic maps of Air pollution status were generated in the form of concentration of SO_2 , NO_x , CO in the atmosphere. Whereas thematic maps of ground water quality were generated in the form of level of Ph, EC, & TDS of ground water. The data for Air pollution and ground water quality was analyzed with reference to CPCB standards.

3.3.2.2. Methodology for Thematic map generation of forest

SoI toposheets & Census Data of year 2001 were used as a source to generate the Thematic map of forest area.

1. **Reserve Forest area** : The reserve forest area boundary were digitized from the SoI map, and thus thematic map of forest area was created.
2. **Census Data 2001:** Information available for the forest area of each village was used from the Census Data, to generate another thematic map of the forest area.

3.4. Thematic map of Forest Ecology:

Sustainable development of forest requires understanding of its vegetation composition in relation to other forests, the effects of past impacts on the present status of this vegetation and the present relationship of the forest with surrounding land uses. (Geldenhuys & Murray 1993). The Ecological Assessment of the study area has taken this fact into consideration and so the Primary and Secondary vegetation Analysis and diversity analysis have been carried out. The methodology of each component has been described separately.

3.4.1. Primary Vegetation Analysis

It provides a database about the number and status of the species existing in that region and becomes essential Primary Vegetation Analysis. The ground inventory was carried out wherein, the size and number of quadrates were determined by species –area curve. A random sampling method was applied and quadrates of 10×10 mt & 1×1 mt. were laid for Tree layer and Understorey respectively. Each quadrant was systematically analyzed and species identification was done using Flora of Gujarat (Shah, 1978) and Bombay Flora (Cooke, 1958) during this enumerations. The vegetation data were quantitatively analyzed for frequency, abundance, density, basal area, relative density, relative frequency and relative dominance. (Phillips, 1959). The

Importance Value Index (IVI) for each species was determined as the sum of the relative frequency, relative density and relative dominance. (**Curtis and Cottam, 1956**).

- 1) **Species Frequency (%)** = Frequency tells about the occurrence of the species in a community. It is calculated as follows:

$$\text{Species Frequency (\%)} = \left(\frac{\text{No. of sampling units in which the species occurred}}{\text{Total no. of sampling units studied}} \right) \times 100$$

- 2) **Density (D)** = Frequency alone does not give correct idea of the distribution of any species, unless it is correlated with other characters, such as density etc. Density represents numerical strength of a species in the community and gives an idea of competition. It is calculated as follows:

$$\text{Density (D):} = \frac{\text{Total no. of individuals of the species in all the sampling units}}{\text{Total no. of sampling units studied}}$$

- 3) **Abundance (A)**: It is the number of individuals of any species per sampling unit of occurrence. It is calculated as follows:

$$\text{Abundance} = \frac{\text{Total no. of individuals of the species in all the sampling units}}{\text{No. of sampling units in which the species occurred}}$$

- 4) **Basal area (BA)** = It refers to the ground actually penetrated by the stems and is readily seen when the leaves and stems are clipped at the ground surface. This is usually a measurement taken at 2.5 cm above ground level.

$$BA = \pi r^2$$

Basal area (BA) of individual tree and Total Basal Area (TBA) of the forest sites were calculated as follows (**Ravindranath, 2000**);

$$BA \text{ (cm}^2\text{)} = (GBH/2\pi)^2 \times \pi; \quad \text{where GBH is Girth at breast height}$$

$$TBA \text{ (in m}^2\text{ per ha)} = \sum BA/10,000$$

- 5) **Dominance**: = Total basal area value for a species /Area sampled
- 6) **Relative density (RD)** = (Density of the species/Total density of all species) x 100.
- 7) **Relative frequency (RF)** = (Frequency of the species /Total frequency of all species) x 100.
- 8) **Relative dominance (RDo)** = (Basal area of the species/Total basal area for all species) x 100.
- 9) **Importance Value Index (IVI)** This index is used to determine the overall importance of each species in the community structure. The Importance Value Index (IVI) for the tree layer was determined as the sum of the relative frequency, relative density and relative dominance for each species.

3.4.2. Secondary vegetation assessment

Based on the primary vegetation analysis, secondary analysis was carried out and it involved analysis of different diversity indices and measurement of growing stock in the form of Standing woody biomass (SWB).

3.4.2.1. Diversity Analysis

The basic idea behind the diversity index was to obtain a quantitative estimation of biological variability that can be used to compare biological entities, composed of discrete components, in space or in time. It provides important information about rarity and commonness of species in a community which give an idea of the community structure. The following different diversity indices were assessed for Pavagadh forest area.

1) Shannon-Wiener diversity index / -H Diversity Index/ Information Index:

Shannon and Wiener independently derived the function which is known as Shannon index of diversity. This index assumes that individuals are randomly sampled from an independently large population. This can be calculated using the formula given by Magurran (1988):

$$H' = - \sum_{i=1}^S p_i \ln p_i$$

Where, p_i = relative abundance of each species, calculated as the proportion of individuals of a given species to the total number of individuals in the community: ($p_i = n_i/N$)

* n_i = The number of individuals in each species; the abundance of each species

N = total number of all individuals

S = number of species. Also, called as species richness

This information index takes into account the evenness of the species distribution as well as the absolute number of the species. (**Hurlbert, 1971; Martin & Rey, 2000; Southwood & Henderson, 2000; Magurran, 2006**).

2) Evenness (E): Evenness index quantifies the equality of species abundances, whereas maximum value (1.0) of evenness is reached in the case of an equal distribution of species abundances, and more the relative abundances of species differ, lower is the evenness. It is also an important component of the diversity indices. This expresses how evenly the individuals are distributed among the different species.

Using Species Richness (S) and the Shannon- Wiener index (H), we can also compute a measure of evenness:

$$E = H / \log(S)$$

Evenness (E) is a measure of how similar the abundances of different species are. When there are similar proportion of all subspecies then evenness is one, but when the abundances are very dissimilar (some rare and some common species) then the value increases.

2) Species Richness: Species richness or variety index (d) is the mean number of species per sample and determined using the formula of **Margalef (1958)**.

$$d = S / \sqrt{N}$$

Where, S = number of species, N = number of individuals of all species.

4) **Simpson's dominance index, c (Simpson, 1949):**

Simpson's this index is also called as a dominance index . It is affected primarily by few dominant species. It is denoted by 'c'. It is relatively insensitive to sampling variability if sample is adequate to represent dominant species. It was calculated by following equation.

$$c = \sum_{i=1}^S \left(\frac{n_i}{N} \right)^2$$

where n_i = number of individuals in the 'ith' species

N = total number of individuals

S = total number of species

3.4.2.2. **Methodology for Biomass**

Basal area per hectare is an indicator of growing stock of the forest, the approximate size of trees and standing biomass. The growing stock was calculated using the following regression equation given by **Ravindranath, 1995**.

Standing woody biomass (SWB)

$$\text{SWB (t/ha)} = -1.689 + 8.32 \times \text{BA}$$

where,

$$\text{SE of coefficient} = 1.689$$

$$R^2 = 0.5$$

BA = Basal Area in m^2/ha

3.5. Thematic Map generation using spatial data:

The thematic maps of Land use were generated by the spatial analysis of the remote sensing data for the identification of forest and other land use classes. For this, LISS-IV image of remote sensing data of the year 2007 & 2012 were used to generate the Land use Map of both years. Using NDVI values, the change detection analysis was done and the change occurred in each land use class, including forest, was noted. The steps followed are described as follows:

3.5.1. Image Analysis

The procured remote sensing images were rectified and a supervised classification was performed individually for each image to delineate the different land use and forest classes of the study area and to quantify the change in area if any. The images were interpreted both digitally and visually.

3.5.2. On-Screen Visual Interpretation:

In addition to digital classification an interactive visual interpretation of satellite image was achieved using the image characteristics. The basic elements comprising tone/colour, size, shape, texture, pattern, location, association and shadow have played a vital role in interpreting and drawing the vector boundaries using the on screen digitizing option. Considering these basic elements of interpretation along with ground truth and ancillary information collected during the preliminary reconnaissance survey, an interpretation key for different classes was developed (**Table 12**). Preliminary image interpretation was done based on the interpretation key and field survey data. The vector layer generated was edited for removing the errors and correspondingly pre-decided

class assignment/polygon-id was attributed to each polygon. The subjectivity of human intelligence and knowledge by the interpreter due to pre field familiarity and post field improvements enhanced the accuracy of the image. This was done for the LISS-IV remote sensing images of the year 2007 & 2012 and the thematic maps of LU-LC along with different forest classes were prepared. Area statistics was obtained for forest as well as other land use classes for each year. This was followed by attempting the change detection techniques on images of 2007 and 2012 .

In digital techniques different training sets were identified based on the reconnaissance survey. In visual techniques interpretation was based on the basic element of interpretation along with the inputs from ground truth survey.

Table 12. Key for visual interpretation of different land use classes

| No. | Classes | Tone | Texture | Association |
|-----|-----------------|------------------------------|----------------|-----------------------------------|
| 1. | Dense forest | Deep red | Coarse | Irregular |
| 2. | Open forest | Pinkish | Smooth | Irregular |
| 3. | Degraded forest | Greenish-white | Smooth/ Coarse | Irregular with grains |
| 4. | Agriculture | Mosaic of red and deep green | Coarse | Irregular-rectangular to squarish |
| 5. | Canal | Cyan-whitish | Smooth | Regular |
| 6. | River | White-deep blue | Smooth | Regular |

3.5.3. Accuracy Assessment:

At the end of completion of image interpretation, area statistics were obtained representing the different forest classes of Pavagadh. 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. In addition to the final accuracy testing, different points were visited to find out the precise correlations between the classes delineated on the spatial data with the ground.

3.6. Identification of Ecologically sensitive area

The entire methodology used in the identification of ESA is shown in flowchart (**Figure 6**). Different steps used are as follows:

1) Generation of suitability model:

2) Identification of ESA

1) Generation of suitability model: Suitability model was generated using methodology given by **FAO, 1993 and 1985 and Gurmessa & Nemomissa, 2013**. This whole suitability analysis process was carried out in GIS mode. Steps followed in suitability analysis were:

- a) Selection of thematic layers
- b) Reclassifying the values
- c) Running the model using weighted values

a) Selection of thematic layers

First step involved in the suitability measurement was selection of several thematic layers that represent relevant factors for the site suitability model development. Thematic layers selected for the present analysis were LULC, Slope of the area, Available arable land, Available Forest area, Demographic data, Groundwater EC, Air pollutants namely CO and SO₂, Road and Drainage.

b) Reclassifying the values

Each selected thematic data layer was then reclassified on a scale of 1 to 5, with 5 being the most suitable and 1 being the least suitable.

c) Running the model using weighted values

In the real world, certain features are more relevant than others in a suitability model. Thus instead of giving equal weight to the factors, weighted values were used in accordance to the factors' relevancy. The weighted model was run using Raster Calculator in ArcGIS Spatial Analyst tool. In this model, the maximum weightage was given to the available forest area, than to LULC and available arable land so that these factors will have the most influence. Once the model was run, then final reclassification was done into 5 classes namely S1, S2, S3, N1 & N2.

2) Identification of ESA

For identification of ESA from generated suitability model, following steps were followed.

a) Determining Preference

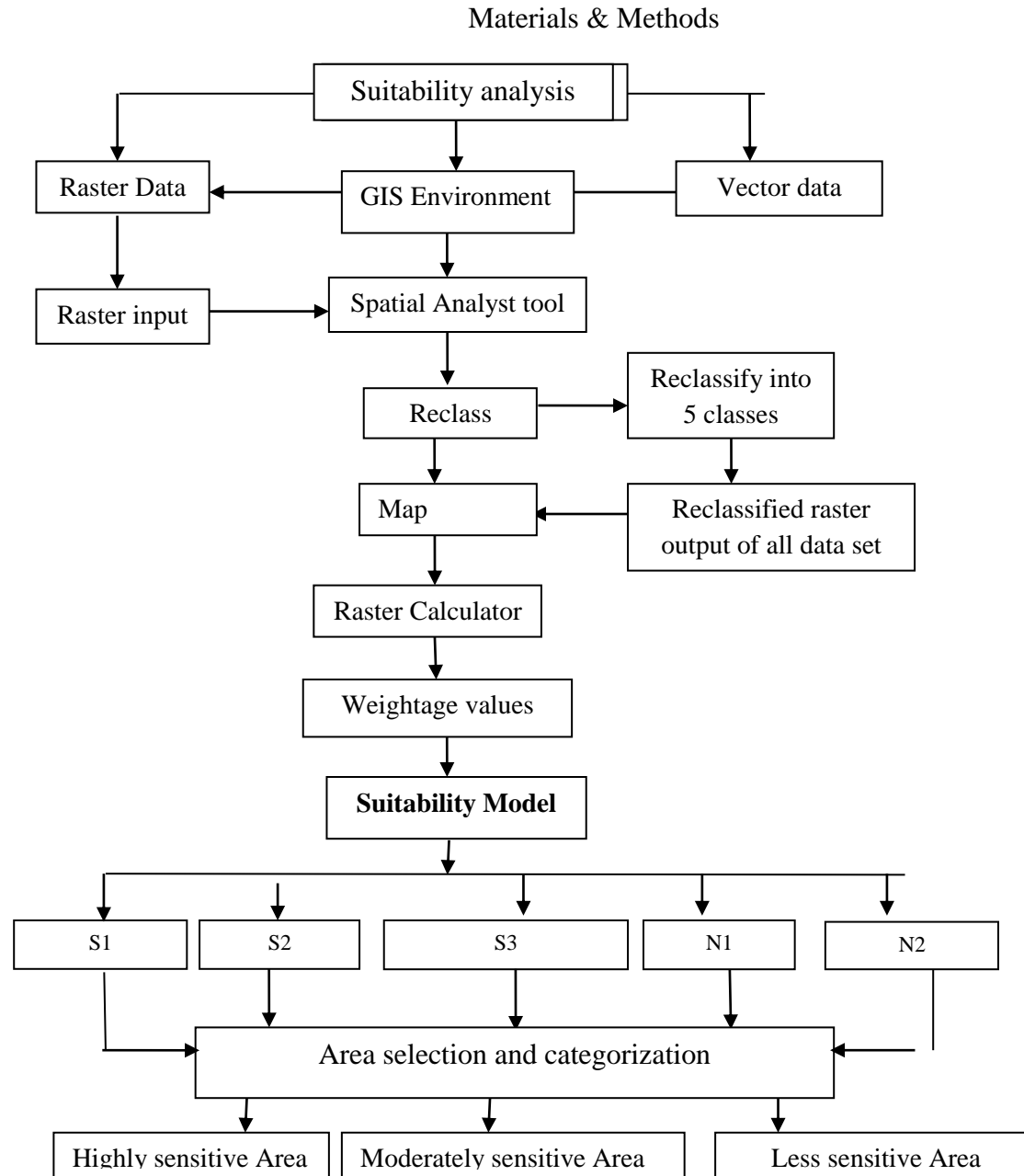
Under each suitability category, 13 different sites were selected for the delineation of ESA

b) Selection of Sites for consideration of ESA

The sites for consideration of ESA were selected from the suitability categories with the different land use themes. According to their land use type they were categorized into Highly sensitive, Moderately sensitive & Less sensitive. The sites falling under forest, agriculture, & wasteland/scrub types of land use were

considered as highly sensitive, moderately sensitive & less sensitive areas respectively.

Figure 6: Methodology flowchart for identification of ESA



3.7. Methodology for Ecologically sustainable development plan:

Various conceptual methods have been employed for generation of ecologically sustainable development plan. These methods were based on analysis characteristics, actual conditions and data availability in the study area. In this study, after the identification of sensitive areas, the criteria and indicators formulated under Bhopal- India Process, have been considered. Besides these, other criteria like per capita arable land, population density and soil erosion status, suitability status and Sensitivity status of identified ESA sites have also been taken into consideration. (**Table 13**). Based on these, the ESD Plan has been generated at micro level for a village namely, Champaner. A detailed plan for this village has described separately.

Table 13. Selected C& I of Bhopal-India Process used for Ecologically sustainable development plan:

| Sr.No. | Criteria | Indicators |
|--------|--|--|
| 1 | Increase in the context of forest and tree cover | Per capita forest area |
| 2 | Maintainance , conservation & enhancement of biodiversity | Variety of plant species |
| 3 | Maintainance & enhancement of forest resource productivity | Production of fuel wood (Biomass) & Basal area |
| 5 | Others | per capita arable land |
| | | soil erosion status |
| | | Population density |
| | | Suitability status |
| | | Status of ESA sites |

The following Criteria were taken into consideration for the generation of Ecologically Sustainable Development plan of Champaner village (**Table 14**).

Table 14 Criteria considered for generation of ecologically sustainable development plan for Champaner

| Sr. No. | Criteria |
|----------------|--|
| 1 | Slope |
| 3 | Distance from the road |
| 4 | Soil fertility status |
| 5 | Tourist pressure |
| 6 | Status of Sp. Diversity, Basal area & Biomass |
| 7 | Drainage pattern to locate the ideal place for check dam |
| 8 | Status of ESA sites of Champaner |