Chapter 5

NATURAL RESOURCES DATABASE GENERATION
5.1 Introduction

The ever increasing population, combined with the need for better standard of living, leads to indiscriminate use of natural resources like forest, minerals etc. without having intimate knowledge about ecological backlashes. A planner must look into the fact that an unplanned development breaks ecological as well as civil laws. Therefore, there is need to have inventory, mapping and monitoring of the natural resources on a regular basis. A detailed database on natural resources is a pre-requisite to prepare any action plan keeping in view the underlying concept of sustainability as stated in the preceding chapters. This is the primary data on which all secondary or derived output depends such as prioritisation for soil conservation, site suitability analysis, land capability, ground water prospect, forest fire risk map, infrastructure development and many more. In other words, preparation of various thematic maps gives a way to assess the environmental and geo-resources condition by integrating various themes in geographic information system. The disposition of natural resources of the two priority subwatersheds, namely Gorna and Baghari Subwatersheds is discussed in this chapter. In order to demonstrate the use of natural resource database, ground water prospect modelling and forest fire risk modelling using natural resource database has been attempted, which are being discussed in the subsequent chapters.

Generation of different thematic maps such as lithology, landforms, soils, drainage, slope, land use, etc. of the study area has been done by interpreting satellite imagery along with field studies. The detailed description of various thematic maps for Gorna and Baghari Subwatershed are discussed in the present chapter.
5.2 Objectives

The objective formulated here is to assess the natural resources of the Gorna and Baghari Subwatersheds through preparation of following primary thematic maps, viz., Land use / Land cover, Forest type, Slope, Soils, Landforms, Roads, Settlement, Drainage, Surface water bodies, Lineament etc.

5.3 Study Materials

5.3.1 Data

Following primary and secondary data have been used to accomplish the present study:

(i) Primary Data

(a) Satellite : IRS - 1D  
Sensor : LISS III  
Data Product : Geocoded Standard FCC (432) of (64 E 6/7)  
Date : 7th May 1999

(b) Satellite : IRS - 1D  
Sensor : LISS III (Band 2,3,4,5)  
Data Product : Digital data in CD-ROM  
(Path/Row 101/055 & 056)  
Date : 7th May, 1999

(c) Satellite : IRS - 1D  
Sensor : PAN  
Data Product : Digital data in CD-ROM  
(Path/Row 101/055 D & 056 B)  
Date : 18th March, 1999

(ii) Secondary data

(a) Survey of India toposheet no.64 E/6, E/7, E/10 on 1:50000 scale;  
(b) Working plan report of North Shahdol forest division (M.P.);  
(c) Rainfall and temperature data from Land record dept. Shahdol, (M.P.);  
(d) Census record book of Shahdol district (M.P.), 1981 & 1991;
5.3.2 Instruments

(i) Optical Pentagraph;
(ii) Interpretation Light table;
(iii) Curvimeter and Planimeter;
(iv) ERDAS 8.3.1 software to perform digital Image processing.

5.4 Database Preparation

This involves study area extraction, image enhancements and transformations. The following techniques have been discussed here in brief which has helped in mapping of thematic details for various purposes in this chapter.

5.4.1 Map to image registration

After loading the data from CD-ROM into hard disk, map to image registration was necessary in order to extract study area from the image. It is a fundamental step for creating a mask. Toposheets of 1:50,000 scale of the study area was used for this purpose. Twelve ground control points (GCPs) were assigned to develop map to image model.

5.4.2 Image to image registration

LISS III data possess multispectral information (Figure 5.1), while PAN data contains higher spatial information (Figure 5.2). To avail both the entities, there is need to merge these data using suitable technique. Since the resolution of LISS III image and PAN image is different, image to image registration is needed. LISS III image was taken as reference image and PAN
image was taken as input image. Nine GCPs distributed over entire area were used to perform the image registration. After this, resampling has been performed which resulted in a output image (Figure 5.3) as a FCC image with the same dimension and scale as the PAN (high resolution). This merged product provides more information than a standard FCC obtained by LISS III bands.

5.4.3 Study area extraction
Watershed boundary of study area was delineated from SOI toposheet (64 E/6, E/7 & E/10) using contour and drainage information. It was digitized in ARC/INFO and a mask was created. Area under mask was extracted from both LISS III and PAN data (Figure 5.1 & 5.2).

5.4.4 Enhanced data generation
To enhance the IRS LISS III and PAN data towards extraction of thematic details with more contrast and clarity, a set of enhancement techniques have been performed. The details of the same are discussed below.

i) Image stretching
In its basic form the linear contrast stretching involves mapping of pixel values from the observed range to the full range of display device. Linear stretch was used while preparing color composites using different bands.

ii) Principal component analysis
Principal component analysis (PCA, also called as Karhunen - Loeve analysis) is a method of multivariate analysis used to produce uncorrelated variables from original correlated bands. It is transformation of the raw remote sensor data that results in new principal component images that are often more interpretable than original data (Kaneko 1978, Byrne et al, 1980). PCA can
Figure 5.1 IRS 1D Standard FCC of the study subwatersheds

Gorna Subwatershed

Baghari Subwatershed

LISS III BAND
Figure 5.2 IRS 1D PANCHROMATIC Image of the study subwatersheds
Figure 5.3 IRS 1D LISS III & PAN merged image of the study subwatersheds
also be used to compress the information content of number of bands i.e. it has ability to reduce dimensionality. The first output variable contains the largest possible amount of total variance and the rest account for remaining variance in descending order.

Band 1, 2 & 3 of LISS III were used to create 3 principal components. First principal components have large percent of the total variance present in original three bands of LISS III scene. The variances of principal components are known as eigen values, which was computed for all three principal components (Table 5.1). The first principal component accounts for 86.23 % of the variance in the entire data set. Component 2 accounts for 12.47 % of the remaining variance. Cumulatively, these first two principal components account for 98.70 % of the variance. The third component accounts for another 1.29 % bringing the total to 100 % of the variance explained by the three components. Thus the three-band data set might be compressed into just one new principal component image. Table 5.2. stands for factor loading elements which shows that how each band 'loads' or is associated with each principal components. High correlations (i.e. factor loading) were found for all the band of LISS III for principal component 1. This suggests that PC 1 is having information of all the bands. Conversely, principal component 2 provides very little information of value with no loading above 0.374. Component 3 accounts for very little of the variance but is easy to label since it loads heavily (0.610) on the NIR (band 3).

PC 2, PC 1 and PC 3 have been additively filtered with red, green and blue filter respectively to create a principal component color composite. PC 1 has the highest information, so whole image looks green, due to PC 1 has been kept on green plane. (Figure 5.4). This colour combination has brought out the clear distinction between forest, agriculture and wasteland.
Figure 5.4 False color composite of combination PC2, PC1 & PC3

Gorna Subwatershed

Baghari Subwatershed
### Table 5.1: Eigen values for the three bands of LISS III scene

<table>
<thead>
<tr>
<th>PRINCIPAL COMPONENTS</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>EIGEN VALUES</td>
<td>715.08</td>
<td>103.41</td>
<td>10.73</td>
</tr>
<tr>
<td>% VARIANCE</td>
<td>86.23</td>
<td>12.47</td>
<td>1.29</td>
</tr>
<tr>
<td>CUMMULATIVE % VARIANCE</td>
<td>86.23</td>
<td>98.7</td>
<td>100</td>
</tr>
</tbody>
</table>

TOTAL VARIANCE = 829.22

### Table 5.2: Degree of correlation between bands & Principal component

<table>
<thead>
<tr>
<th>BANDS</th>
<th>PRINCIPAL COMPONENTS</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>LISS III-1</td>
<td>0.584</td>
<td>0.195</td>
<td>-0.787</td>
<td></td>
</tr>
<tr>
<td>LISS III-2</td>
<td>0.697</td>
<td>0.374</td>
<td>0.610</td>
<td></td>
</tr>
<tr>
<td>LISS III-3</td>
<td>0.414</td>
<td>-0.906</td>
<td>0.082</td>
<td></td>
</tr>
</tbody>
</table>

### iii) IHS transformation

The potential of IHS coding in remote sensing image enhancement has been demonstrated by Haydn et al. (1982). This method can be more easily understood by considering the Munsell color system. The color space is conceived as a cylinder where hue is represented by the polar angle, saturation by the radius and intensity or brightness by the vertical distance on the cylinder axis. The coding of remote sensing images using this coordinate system is called IHS transform.

LISS III (Band 1, 2 & 3) data were used to create IHS transformation. FCC was generated using hue, intensity and saturation images (Figure 5.5).

### iv) Normalised difference vegetation index

Ratio images are often useful for discriminating spectral variation in a scene that are masked by the brightness variations in images from individual
spectral bands or in standard colour composites. It is used to reduce the variable effects of illumination condition and topography. Considering the unique spectral behavior of different objects (Figure 2.2), various vegetation indices has been developed so far. They have been termed as 'robust' mathematical treatment to the spectral band to discriminate vegetation from non-vegetation surfaces (Richardson et al., 1977). In this series, Rouse et al. (1973) developed normalised difference of brightness values from infrared and red band for monitoring vegetation. Extensive research has shown that NDVI can be used for accurate assessment of vegetation phenology, estimating net primary production, effective monitoring of rainfall and drought situations (Justice et al., 1989, Franklin & Hiernaux, 1991, Srivastava et al., 1994, Thiruvengadachari & Gopalakrishna, 1994). This is most popular vegetation index, called as normalised difference vegetation index (NDVI).

\[
\text{NDVI} = \frac{\text{IR band} - \text{R band}}{\text{IR band} + \text{R band}}
\]

NDVI operation has been applied here on LISS III IR & R bands (Figure 5.6), which highlights the vegetation status. NDVI classification has been also attempted for better discrimination between vegetation classes based on band ratio values (Figure 5.7). The various colours red / yellow through dark green to blue to light green - indicates increasing leaf area and biomass. The figures adjacent to the various colour bars are vegetation index values. Forest cover is assumed to have NDVI values higher than 0.

v) FCC Image Formation

Various FCCs of different band combination were tried and it was found that the combination PC 1, intensity image and IR band of LISS III data gives better discrimination of land use / land cover features (Figure 5.8).
Figure 5.6 NDVI image of the study subwatersheds

Gorna Subwatershed

Baghari Subwatershed
Figure 5.7 Classified NDVI image the study subwatersheds

- SAL (> 0.1)
- SAL & BAMBOO (0.1 - 0.05)
- DRY MIX (0.05 - 0)
- CROPLANDS (0 - -0.04)
- NON CROPLANDS (-0.04 - -0.09)
Figure 5.8 False colour composite of PC1, Intensity and LISS III BAND 3

Gorna Subwatershed

Baghari Subwatershed
5.5 Land use / Land cover

Land is the most important natural resource which embodies soil, water and associated flora and fauna involving the total ecosystem (Vink, 1975), whereas land use refers to "man’s activities and the various use which are carried on land". Land cover refers to "natural vegetation, water bodies, rock / soil, artificial cover and others resulting due to land transformations". Information on land use / land cover is essential for effective management of the natural resources. Systematic and comprehensive compilation of land use / land cover maps and data is necessary for planned development of agriculture, forests, grasslands, rural settlements, urban spread, industries and a host of other land-based programmes and activities. The need for optimising land use in an integrated manner has become particularly relevant in recent years as a consequence of competing and conflicting demands of growing population, increasing land degradation and a sharply declining man land ratio. Today, degradation in various forms and intensities has extended to cover nearly 175 million hectares or more than half the geographical area of the country (NRSA, 1990).

5.5.1 Methodology (Figure 5.9)

(i) Pre-Field Work

(a) Preparation of base map:
Base map of the study area was prepared using SOI toposheet on 1:50,000 scale. Permanent details of feature like road, settlement, river etc. were transferred on it.

(b) Demarcation of forest boundary:
This has been done with the help of forest stock map of North Shahdol Forest Division on 1:15000 scale. Forest boundary in our study area has been demarcated by using optical pentagraph.
Figure 5.9 Approach for land use / land cover mapping
(c) Preliminary visual interpretation:
IRS-1C LISS III geocoded FCC of May 1999 were interpreted visually based on image interpretation elements like tone, texture, association, pattern, location etc. and map showing broad land use / land cover has been prepared. FCC formed by hue, intensity and saturation (Figure 5.5) has been used here for mapping the agricultural and forest land.

(ii) Field Work
This was a survey to collect various informations regarding the area. A bird’s eye view of the whole area was acquired during fieldwork. With the help of imagery and toposheet, broad land use / land cover classes were located. The training sets were generated completely during the reconnaissance survey. Classification scheme was also prepared during fieldwork (Table 5.3).

(iii) Post Field Work
Final interpretation key was prepared based on field observation and its relationship with tone, texture, association, pattern, location etc. Then the interpretation was finalised based on classification scheme and interpretation key (Table 5.4). Transfer of details was also done on to the base map of 1:50000. On the basis of above factors, land use / land cover map of the Gorna and Baghari Subwatershed has been prepared (Figure 5.10).

<p>| Table 5.3: Classification Scheme |</p>
<table>
<thead>
<tr>
<th>No.</th>
<th>CLASSES</th>
<th>LEVEL I</th>
<th>LEVEL II</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Agricultural land</td>
<td>Crop land</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fallow land</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Plantation</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Forest</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>Wasteland</td>
<td>Land with scrub</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Land without scrub</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rocky area</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>Water body</td>
<td>River / Tank</td>
<td></td>
</tr>
</tbody>
</table>
### Table 5.4: Interpretation key for land use / land cover mapping

<table>
<thead>
<tr>
<th>NO.</th>
<th>CLASS NAME</th>
<th>TONE</th>
<th>TEXTURE</th>
<th>LOCATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Crop land</td>
<td>Muddy white &amp; Pink</td>
<td>Smooth</td>
<td>Foot hills and Flat areas</td>
</tr>
<tr>
<td>2.</td>
<td>Fallow land</td>
<td>White</td>
<td>Smooth</td>
<td>Flat areas</td>
</tr>
<tr>
<td>3.</td>
<td>Agricultural Plantation</td>
<td>Red</td>
<td>Coarse</td>
<td>Flat area</td>
</tr>
<tr>
<td>4.</td>
<td>Forest</td>
<td>Deep Red to Light Red</td>
<td>Smooth</td>
<td>Mainly Hills</td>
</tr>
<tr>
<td>5.</td>
<td>Land with scrub</td>
<td>Blue-Gray</td>
<td>Smooth</td>
<td>Ridges and Plains</td>
</tr>
<tr>
<td>6.</td>
<td>Land without scrub</td>
<td>Muddy White</td>
<td>Smooth</td>
<td>Flat areas</td>
</tr>
<tr>
<td>7.</td>
<td>Rocky area</td>
<td>Greenish White</td>
<td>Coarse</td>
<td>Hills</td>
</tr>
<tr>
<td>8.</td>
<td>River / Tanks</td>
<td>Blue</td>
<td>Smooth</td>
<td>Hills and Plains</td>
</tr>
</tbody>
</table>

#### 5.5.2 Description of land use / land cover classes

The various categories identified and their detailed description is given below (Table 5.5).

1. Agricultural land

It is defined as the land primarily used for farming and for production of food, fibre, and other commercial and horticulture crops. It includes land under crops (irrigated and unirrigated), fallow, plantations etc.

a) Crop Land - It includes those lands with standing crop (per-se) as on the date of the satellite imagery. The Croplands are sub classified as

- Kharif - it includes standing crops during June to September
- Rabi - it includes standing crops during October to February
- Kharif + Rabi - Area sown during both the seasons

Here satellite data of May season has been used. It is the time when Rabi crops have been harvested. While mapping, enough care has been taken to delineate cropland with and without vegetation, which includes all the above subclasses of croplands.
b) **Fallow Land** - It is described as agricultural land which is taken up for cultivation but is temporarily allowed to rest, un-cropped for one or more seasons, but not less than one year. These lands are particularly those, which are seen devoid of crops at the time when the imagery is taken of both seasons.

c) **Plantations** - It is described as an area under agricultural tree crops, planted adopting certain agricultural management techniques. It includes ukayliptus and horticultural nurseries.

**Table 5.5: Area of various land use / land cover classes**

<table>
<thead>
<tr>
<th>NO.</th>
<th>CLASS NAME</th>
<th>GORNA SUBWATERSHED</th>
<th>BAGHARI SUBWATERSHED</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Area (Km²)</td>
<td>% Area</td>
</tr>
<tr>
<td>1.</td>
<td>Crop land</td>
<td>38.40</td>
<td>28.59</td>
</tr>
<tr>
<td>2.</td>
<td>Fallow land</td>
<td>0.07</td>
<td>0.05</td>
</tr>
<tr>
<td>3.</td>
<td>Agricultural Plantation</td>
<td>0.46</td>
<td>0.34</td>
</tr>
<tr>
<td>4.</td>
<td>Forest</td>
<td>85.47</td>
<td>63.57</td>
</tr>
<tr>
<td>6.</td>
<td>Land without scrub</td>
<td>0.73</td>
<td>0.55</td>
</tr>
<tr>
<td>7.</td>
<td>Rocky area</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>8.</td>
<td>River / Tanks</td>
<td>0.13</td>
<td>0.10</td>
</tr>
</tbody>
</table>

2. **Forest**

It is an area (with in the notified forest boundary) bearing an association predominantly of trees and other vegetation types capable of producing timber and other forest produce (FAO, 1981). It includes dry deciduous forest, scrub forest, forest blank and forest plantations.
Figure 5.10 Land use / Land cover map of the study subwatersheds

LEGEND

- CROP LAND
- FALLOW LAND
- PLANTATION
- FOREST
- LAND WITH SCRUB
- LAND WITHOUT SCRUB
- ROCKY AREA
- WATER BODIES

GORMA SUBWATERSHED

BAGHARI SUBWATERSHED
3. Wastelands
It is described as degraded land which can be brought under vegetative cover with reasonable effort, and which is currently under-utilised and land which is deteriorating due to lack of appropriate water and soil management and on account of natural causes.

a) Land with scrub – It is predominated by scrubs, which is stunted tree or bush / shrub. It is the result of both biotic and abiotic influences. This occupies higher topography like uplands or ridges with scrub. These lands are generally prone to erosion or degradation.

b) Land without scrub – This is relatively undulating terrain area having very poor soil and ground water characteristics.

c) Rocky areas – It is defined as rock exposures of varying lithology often barren and devoid of soil cover and vegetation. It occurs as isolated hills.

4. Water bodies
It is an area of impounded water, areal in extend and with a regulated flow of water. It includes man-made reservoirs / lakes / tanks besides natural rivers / streams, which is a small stream to a big river.

5.6 Forest Type
Importance of forest cover cannot be underestimated because our long-range ecological security is inter-twisted with it. Judicious management through appropriate prescription for improving the forest stock of any area requires identification of various vegetation types and status in real time. Remote sensing techniques because of synoptic coverage, repetitive data acquisition capability, spatial information, real time data collection and computer
compatibility are extremely useful in forest monitoring (Sharma et al., 1989; Botkin et al., 1984; Lent, 1983; Singh, 1987). Forest type is defined as a unit of vegetation which is possessing broad characteristics in physiognomy and structure sufficiently pronounced to permit of its differentiation from other such units (Champion and Seth, 1968). The major groups are further divided into sub-types of geographic basis because these forest types vary with locality owing to differences in floristic composition, minor variations in climate and other environmental factors. Visual interpretation techniques has been widely used for forest cover mapping (Anon, 1995 and Porwal et al., 1994). However, the visual interpretation technique is subjective and depends on the field knowledge and aptitude of the interpreter. In order to improve the classification, results from digital image processing has been also integrated. Image ratioing mainly normalised difference vegetation index (NDVI) has been used here to stratify vegetation and non-vegetation areas.

5.6.1 Methodology
The methodology for forest type map preparation is same as land use / land cover map preparation. The emphasis has been given on mapping of the forested area. Considerable help has been taken from NDVI image for classifying forest and croplands (Figure 5.6). Further this image has been classified into five classes depending upon the NDVI ratio values (max. = 0.237 & min. = - 0.09) over the image (Figure 5.7). Based on the ground truth collection and interpretation key (Table 5.6), the forest type map of the Gorna and Baghari Subwatershed has been prepared (Figure 5.11). Description of all the classes has been given below.
Table 5.6: Interpretation keys for forest type mapping

<table>
<thead>
<tr>
<th>NO.</th>
<th>CLASS</th>
<th>TONE</th>
<th>TEXTURE</th>
<th>LOCATION</th>
<th>DOMINANT SPECIES</th>
<th>OTHER INFORMATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>SAL</td>
<td>Brown</td>
<td>Fine &amp; Medium</td>
<td>Flat &amp; undulating terrain</td>
<td>Sal</td>
<td>Mostly on the top of Dhandha Pahar and along the streams</td>
</tr>
<tr>
<td>2.</td>
<td>SAL &amp; BAMBOO MIX</td>
<td>Lighter Red</td>
<td>Coarse</td>
<td>Undulating &amp; hilly areas</td>
<td>Sal &amp; Bamboo</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>DRY MIX</td>
<td>Pale brown</td>
<td>Coarse</td>
<td>Hill top &amp; slopes</td>
<td></td>
<td>On southern aspect of hills</td>
</tr>
<tr>
<td>4.</td>
<td>MOIST MIX</td>
<td>Reddish Brown</td>
<td>Fine</td>
<td>Undulating and near water bodies</td>
<td></td>
<td>Low lying areas</td>
</tr>
<tr>
<td>5.</td>
<td>BAMBOO MIX</td>
<td>Light Red on land &amp; Bluish on hills</td>
<td>Fine</td>
<td>Hill slope &amp; flat areas</td>
<td>Bamboo</td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>BAMBOO DEGRADED</td>
<td>Light Grey to White</td>
<td>Coarse</td>
<td>Sites with low moisture</td>
<td>Bamboo</td>
<td>Open areas</td>
</tr>
<tr>
<td>7.</td>
<td>PLANTATION</td>
<td>Dark Brown</td>
<td>Fine</td>
<td></td>
<td>Eucalyptus</td>
<td>Regular shape</td>
</tr>
<tr>
<td>8.</td>
<td>FOREST BLANK</td>
<td>Dull White</td>
<td>Coarse</td>
<td>Inside forest</td>
<td></td>
<td>Irregular</td>
</tr>
</tbody>
</table>

1. **Sal forest**: It constitutes 38.22% of forested area of Gorna Subwatershed and 8.26% of forested area of Baghari Subwatershed and mostly found on the sandstone hills having density more than 40%. The main species found in this forest type are: *Shorea robusta, Terminalia tomentosa, Anogeissus latifolia, Cassia fistula, Lagerstromia parviflora, Boswellia serrata, Accacia pinnata, Terminalia arjuna*, etc.

2. **Sal Bamboo mix**: It constitutes 19.63% of forested area of Gorna Subwatershed and 39.64% of forested area of Baghari Subwatershed and mostly found on the hill slope having density more than 40%. The
Figure 5.11 Forest Type map of the study subwatersheds

Gorna Subwatershed

Baghari Subwatershed

LEGEND
- FOREST LAND
- SAL
- SAL & BAMBOO MIX
- DRY MIX
- MOIST MIX
- BAMBOO MIX
- BAMBOO DEGRADED
- FOREST PLANTATION
- FOREST BLANK
- NON FOREST LAND
- AGRICULTURE
- WASTELAND
- WATER BODIES

Kilometers
main species found in this forest type are: *Shorea robusta*, *Boswellia serrata*, *Buchanania lanzen*, *Terminalia arjuna*, *Ficus glomerata*, *Syzygium cummuni*, *Accacia pinnata*, *Terminalia tomentosa*, *Anogeissus latifolia*, *Cassia fistula*, etc.

3. **Bamboo mix**: This type of forest constitute 14.97 % and 19.93 % of forested area of Gorna Subwatershed and Baghari Subwatershed, respectively, having density more than 40%. The main species found in this forest type are: *Boswellia serrata*, *Shorea robusta*, *Tectona grandis*, *Madhuca indica*, *Dyospros malanoxylon*, *Zizyphus nummularira*, *Cassia fistula*, *Bauhinia retusa*, *Terminalia tomentosa*, *Dendrocalamus strictus*, etc.

4. **Bamboo degraded**: This constitutes 4.7 % and 11.82 % of the forested area of Gorna Subwatershed and Baghari Subwatershed respectively, having density less than 40%. The main species found here are: *Boswellia serrata*, *Tectona grandis*, *Madhuca indica*, *Dyospros malanoxylon*, *Zizyphus nummularira*, *Cassia fistula*, *Bauhinia retusa*, *Terminalia tomentosa*, *Dendrocalamus strictus*, etc.

5. **Moist mix**: It constitutes very small part, 5.17 % and 3.94 % of forested area of Gorna Subwatershed and Baghari Subwatershed respectively. The main species found are: *Accacia catechu*, *Cymbopogon martini*, *Cassia fistula*, *Woodfordia fruticosa*, *Butea superba*, *Bauhinia vahlii*, *Asparagus racemosus*, *Bauhinia malabarica*, etc.

6. **Dry mix**: This type of forest constitute 9.12 % and 7.11 % of forested area of Gorna Subwatershed and Baghari Subwatershed respectively and it is mainly confined to southern aspect of the hills. The main species are:
**Terminalia tomentosa, Anogeissus latifolia, Diospyros melanoxylon, Achyranthes aspera, Zizyphus mauritiana, Adina cardifolia, Madhuca indica, Garuga pinnata, Dendrocalamus strictus, etc.**

7. **Forest blank**: It is described as openings amidst forests without any tree cover. It includes openings of assorted size and shapes as seen on the imagery. It constitutes 4.3 % of forested area of Gorna Subwatershed and 6.9 % of forested area of Baghari Subwatershed.

8. **Forest plantation**: It constitutes 3.9 % and 2.35 % of the forested area of Gorna Subwatershed and Baghari Subwatershed. It is described as an area of trees of species of forestry importance and raised on notified forest lands. It includes plantation of eucalyptus, bamboo, etc.

**5.7 Soil Resources**

Soils are our most precious resource. Maintaining soils in a state of high productivity is important for providing people with their basic needs on a sustainable basis (Abrol, 1990). The information on nature, extent and spatial distribution of soils is pre-requisite for optimal land planning for agriculture and other usage. Conventional surveys using topographical sheets and cadastral maps have been hitherto carried out for generating aforesaid information on soils. Synoptic coverage of a fairly large area in discrete spectral bands and at regular interval provided by the orbiting satellites enable generating soil resources map in a timely and cost-effective manner. Most of the studies on soils using IRS 1A/1B data were confined to visual interpretation approach (NRSA, 1994). Mapping of soils was carried out upto 1:50,000 scale using IRS 1A/1B LISS II, Landsat TM and SPOT data and soils were classified at the level of association of soil series (Rao and Dwivedi, 1990 and Rao et. al., 1993). However a few studies were also

Soils have characteristics spectral response in the visible and infrared range of the electromagnetic spectrum. The reflectance pattern of radiant energy provides important clues about the soil classes. The variations in surfacial features of the soils, like color, texture, moisture content, concretions, organic matter, etc. which are partly diagnostic of soil classes, are registered on the imagery. Land use and vegetation are both indicative and obstructive to soil identification depending upon the physiographic unit and expression of other image elements. In view of this, a correlative approach involving image elements and the physiographic system has been adopted in the present study.

5.7.1 Methodology

Based on the image characteristics and other collateral information like geology, landform, landuse and vegetation, a tentative pre-field image analytical legend was formed. While making the soil maps, FCC formed by PC2, PC1 and PC3 was found useful after knowing the tentative soil classes. Based on all the soil mapping units present in the study area, one profile / minipit has been evacuated in each class. The morphological characteristics of each class were examined in detail. In course of the field work, relationship between image interpretation units and soil classes was progressively established (Table 5.7). The detailed description of each soil type and area constituted by them in both the subwatersheds is given in Table 5.8. Based on the relationship thus established, pre-field interpretation map was refined and transformed into the soil map (Figure 5.12).
Table 5.7: Interpretation keys for soil type mapping

<table>
<thead>
<tr>
<th>NO.</th>
<th>SOIL TYPE</th>
<th>TONE</th>
<th>TEXTURE</th>
<th>LOCATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Type 1</td>
<td>Dark gray</td>
<td>Coarse</td>
<td>Doleritic ridge</td>
</tr>
<tr>
<td>2.</td>
<td>Type 2</td>
<td>Deep brown</td>
<td>Smooth</td>
<td>Hills</td>
</tr>
<tr>
<td>3.</td>
<td>Type 3</td>
<td>Light red</td>
<td>Coarse</td>
<td>Hill top</td>
</tr>
<tr>
<td>4.</td>
<td>Type 4</td>
<td>Bright white</td>
<td>Coarse</td>
<td>Fallow land</td>
</tr>
<tr>
<td>5.</td>
<td>Type 5</td>
<td>White</td>
<td>Smooth</td>
<td>Flat areas</td>
</tr>
<tr>
<td>6.</td>
<td>Type 6</td>
<td>Gray green</td>
<td>Smooth</td>
<td>Flat areas</td>
</tr>
<tr>
<td>7.</td>
<td>Type 7</td>
<td>Gray black</td>
<td>Coarse</td>
<td>Flat areas</td>
</tr>
<tr>
<td>8.</td>
<td>Type 8</td>
<td>White</td>
<td>Smooth</td>
<td>Flat areas</td>
</tr>
<tr>
<td>9.</td>
<td>Type 9</td>
<td>Light red</td>
<td>Smooth</td>
<td>Foot hills</td>
</tr>
<tr>
<td>10.</td>
<td>Type 10</td>
<td>Muddy white</td>
<td>Smooth</td>
<td>Low lying near river</td>
</tr>
<tr>
<td>11.</td>
<td>Type 11</td>
<td>Deep red</td>
<td>Smooth</td>
<td>Near to tank, ponds</td>
</tr>
</tbody>
</table>

Table 5.8: Area statistics and description of soil types

<table>
<thead>
<tr>
<th>NO.</th>
<th>Soil Types</th>
<th>General Characteristics Observed in the Field</th>
<th>% of Area</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Gorna Subwaters hed</td>
</tr>
<tr>
<td>1.</td>
<td>Type 1</td>
<td>Shallow, dark reddish brown to reddish brown, gravelly sandy clay loam surface and subsurface with stones and outcrops on surface having 15-25% slope on elongated dykes, well drained, severely eroded</td>
<td>0.7</td>
</tr>
<tr>
<td>2.</td>
<td>Type 2</td>
<td>Moderately deep, reddish brown, gravelly sandy loam surface and subsurface having lithic contact with stones and rock outcrop on surface having 10-15% slope, well drained, severely eroded</td>
<td>21.6</td>
</tr>
<tr>
<td>3.</td>
<td>Type 3</td>
<td>Shallow broom to reddish brown, gravelly sandy loam surface and subsurface having lithic contact with stores and rock outcrop on surface with steep slopes on hills, well drained, severely eroded on upper portion of the hills.</td>
<td>8.6</td>
</tr>
<tr>
<td>4.</td>
<td>Type 4</td>
<td>Shallow, reddish brown to dusky red, sandy clay loam surface and subsurface with stones and rock outcrops on 3-5% lower slopes of sedimentary hills, severely eroded, well drained</td>
<td>2.8</td>
</tr>
</tbody>
</table>
Figure 5.12 Soil Types map of the study subwatersheds

LEGEND
TYPE 1
TYPE 2
TYPE 3
TYPE 4
TYPE 5
TYPE 6
TYPE 7
TYPE 8
TYPE 9
TYPE 10
TYPE 11

GORNA SUBWATERSHED

BAGHARI SUBWATERSHED

1 0 1 2 Kilometers
<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
<th>Soil Depth</th>
<th>Color</th>
<th>Texture</th>
<th>Slope</th>
<th>Erosion</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.</td>
<td>Type 5</td>
<td>Shallow, yellowish red, gravelly clay loam having lithic contact with stones and rock outcrops on surface on 3-8% slope well drained on stony area, severely eroded</td>
<td>0.2</td>
<td>2.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>Type 6</td>
<td>Moderately deep, reddish brown surface and subsurface, gravelly sandy loam surface to gravelly clay loam subsurface with stones and rock outcrops on surface having 5-10% slope on brand valley low lying area, severely eroded</td>
<td>-</td>
<td>7.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7.</td>
<td>Type 7</td>
<td>Moderately deep, very dark gray to very dark grayish brown, clay throughout with surface and subsurface cracks on 1-3% slope, moderately well drained, severely eroded</td>
<td>3.8</td>
<td>35.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8.</td>
<td>Type 8</td>
<td>Shallow, reddish brown, sandy loam surface and subsurface with stones and rock outcrops on surface having 1-3% slope on moderate pediplain surface, well drained, severely eroded</td>
<td>5.1</td>
<td>9.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9.</td>
<td>Type 9</td>
<td>Deep, yellowish brown to brown, loamy sand surface to sandy clay loam subsurface on 1-5% slope on shallow pediplain surface, moderately drained and eroded</td>
<td>21.1</td>
<td>7.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10.</td>
<td>Type 10</td>
<td>Very deep, brown to strong brown, sandy loam surface to sandy clay loam subsurface on 1-3% slope on moderate pediplain surface, moderately well drained and moderately eroded</td>
<td>34.9</td>
<td>27.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11.</td>
<td>Type 11</td>
<td>Deep, grayish brown to light brown, sandy loam surface on 1-3% valley, acquic condition, slight erosion, moderately well drained and eroded</td>
<td>1.1</td>
<td>-</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 5.8 Landforms

Geomorphology, which is concerned with landform, materials and their related processes, is pertinent in all aspects of environmental management involving these physical phenomenon. Significant advances in the mapping of a land's geomorphological characteristics have added another invaluable tool in assessing the potential of land for development and in providing a valid
Natural resources database generation

basis for sustainable land use planning. However, the potential for applying geomorphological knowledge depends not only on the problem but also on the willingness of the environmental manager to appreciate the value of this knowledge (Cooke and Doornkamp, 1974). Geomorphic processes are the result of complex interaction between agents of geology, climate, hydrology, topography, soils and organisms. While few of these properties can be measured directly, previous studies have shown that remotely sensed data can provide useful surrogate information (McKean et al., 1991, Mc Dermid and Franklin, 1994).

With the advent of remote sensing techniques, acquiring synoptic information covering beyond visible range, application of geomorphology in recent years has gained in status (Young and White, 1984). Satellite data are found particularly useful in the mapping of landform as (i) they reduce the time required for reconnaissance; (ii) due to the vantage point, they reveal large scale landform patterns that are often not visible on the ground, i.e. providing synoptic view; (iii) they can record features which are at times obscured by the vegetation cover or cultural setting etc. They depict the diversified landform elements of units and their spatial relationship. They gives enough scope for visualising the whole complex of natural environment and landscape ecology in the context of intricate interrelationships which exist between landforms, rocks and soils, ground & surface water, climatic condition, vegetation and land utilisation (Verstappen, 1983). Keeping this in view, an attempt has been made in the present study to map and analyse the landform features in Gorna and Baghari Subwatersheds.

5.8.1 Methodology

For the preparation of the landform map of the area, hard copy of IRS 1D LISS III satellite image and digital data of LISS III and PAN together with SOI
toposheets were used for interpretation and delineation of landform units. During the exercise, the interpretation key has been generated to delineate the various landform units (Table 5.9). During the field visit, landform features were verified and re-judged in order to update the pre-field landform map. Results obtained from LISS III and PAN merged image (Figure 5.3) is also carefully incorporated which shows clear distinction between buried pediment classes with different tones. Light blue and white on image shows buried pediments (medium), green shows buried pediment plains covered with black soils, pink shows buried pediment plains (shallow) and red shows denudational hills.

5.8.2 Description of landform units
The different types of landforms present in the subwatersheds can be generally grouped into (i) valley fills (ii) buried pediplains (iii) denudational hills (iv) ridges (Figure 5.13). The specific characteristic of each of the landform mentioned above vary greatly in terms of shape, size, dimension, thickness of the overburden material, permeability, porosity, etc., depends on the underlying rock type, structural control, climate and vegetative cover. The general description of the landforms are detailed below:

(i) Valley fills: The valley fill is identified as an unconsolidated sediment consisting of both colluvial and alluvial materials ranging in size from fine silt to coarse sand and pebbles deposited so as to totally fill or partly fill a valley. As the term itself indicates, valley fill is a depositional landform formed by the processes of relief reduction followed by sedimentation. This unit is characterised by the high porosity and permeability, which result in high infiltration rate.
Table 5.9: Interpretation keys for landform delineation and its areal extent

<table>
<thead>
<tr>
<th>NO.</th>
<th>Landforms</th>
<th>Tone</th>
<th>Other Characteristics</th>
<th>% of Area</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Gorna SW</td>
</tr>
<tr>
<td>1</td>
<td>Valleys Fills</td>
<td>Dark red</td>
<td>Along with streams, Low lying plain area</td>
<td>1.5</td>
</tr>
<tr>
<td>2</td>
<td>Buried Pediplain (Shallow)</td>
<td>Red</td>
<td>Flat to gently undulating plain of vast aerial extent with shallow over burden, good vegetation</td>
<td>18.6</td>
</tr>
<tr>
<td>3</td>
<td>Buried Pediplain (Moderate)</td>
<td>Muddy White</td>
<td>Flat to gently undulating plain with moderate overburden – less vegetation</td>
<td>50.9</td>
</tr>
<tr>
<td>4</td>
<td>Buried pediplain covered with black soils</td>
<td>Greenish with coarse texture</td>
<td>vast aerial extent, cultural area, black soil area, generally habitation / agricultural lands</td>
<td>1.0</td>
</tr>
<tr>
<td>5</td>
<td>Denudation Hills</td>
<td>Dark red</td>
<td>Gently dipping, undulating hills with moderate to high relief developed over Gondwana Sandstones</td>
<td>26.7</td>
</tr>
<tr>
<td>6</td>
<td>Ridges</td>
<td>Gray</td>
<td>Linear ridges, doleritic rocks</td>
<td>1.3</td>
</tr>
</tbody>
</table>

(ii) Buried Pediment Plain:

In general, a pediment is a broad, flat or gently sloping rock-floored erosional surface or a plain of low relief, developed due to the process of denudation by the subaerial agents including running water in an arid or semi arid region at the base of an abrupt mountain front of plateau escarpment (Fairbridge, 1968). A pediplain is such a surface of large areal extent, normally formed by the coalescence of several pediments. During the process of weathering and erosion, the sloping surface of the pediment gets gradually covered with a mantle of soil and colluvial materials, thereby the pediment is buried. When the pediment is covered under a thick weathered mantle, it is termed as buried pediment (Bhattacharya & Chakroborthy, 1980).

On the basis of thickness and composition of weathered mantle, the pediment plains have been classified into three categories:-
Figure 5.13 Landform map of study subwatersheds

LEGEND
- Denudational Hills
- Buried Pediment Plains (Medium)
- Buried Pediment Plains (Shallow)
- Buried Pediment Plains (black soils)
- Dykes/Linear Ridge
- Valley Fills
Natural resources database generation

a) Buried Pediplain (Shallow)

b) Buried Pediplain (Moderate)

c) Buried Pediplain covered with black soils

(iii) Denudational Hill

Denudational hills are formed due to differential erosion and weathering, so that a more resistant formation or intrusion stand as mountains / hills. It is developed over Gondwana sandstones in the study watersheds. Dhanda Pahar is classified as denudational hill (Figure 3.6).

(iv) Ridges

Linear landmass occurring as relict body is seen in northern and eastern portions of the Gorna Subwatershed. It is mainly doleritic dykes having E-W trend.

5.9 Lithology

The geological maps for Gorna and Baghari Subwatersheds have been prepared based on the visual interpretation of standard FCC of IRS 1D LISS III and published geology map by Geological Survey of India on 1:250,000 scale. A standard interpretation key such as tone, texture, etc. has been utilised while interpreting the photographic products (Table 5.10). The detailed description of lithological classes found in the study watersheds has been already discussed in the previous chapter. Based on standard FCC and PAN data interpretation, the study watersheds has been classified into four lithological classes (Figure 5.14):

1. Basalt
2. Dolerite
3. Sandstone intermixed with Clay
4. Sandstone intermixed with Shale
Figure 5.14 Lithological map of the study subwatersheds

LEGEND
- Red: Dolerite
- Gray: Basalt
- Orange: Sandstone intermixed with clay
- Blue: Sandstone intermixed with shale

GORNA SUBWATERSHED

BAGHARI SUBWATERSHED

2 0 2 4 Kilometers
### Table 5.10: Interpretation keys for lithological mapping

<table>
<thead>
<tr>
<th>NO.</th>
<th>Litho-units</th>
<th>Tone</th>
<th>Other Characteristics</th>
<th>% of Area</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Gorna SW</td>
</tr>
<tr>
<td>1.</td>
<td>Basalt</td>
<td>Dark Gray</td>
<td>Black soil area, generally habitation / agricultural land</td>
<td>9.6</td>
</tr>
<tr>
<td>2.</td>
<td>Dolerite</td>
<td>Light Gray</td>
<td>Linear Dykes, no vegetation</td>
<td>1.0</td>
</tr>
<tr>
<td>3.</td>
<td>Sandstone intermixed with Clay</td>
<td>Deep red</td>
<td>Mainly forest area, hills, thick vegetation</td>
<td>87.5</td>
</tr>
<tr>
<td>4.</td>
<td>Sandstone intermixed with Shale</td>
<td>Greenish white</td>
<td>Flat area, agricultural land, but vegetation is not visible due to harvested</td>
<td>1.9</td>
</tr>
</tbody>
</table>

### 5.10 Lineament

A lineament is a mapable linear or curvilinear feature of a surface whose parts align in a straight or slightly curving relationship that may be the expression of a fault or other line of weakness. Lineaments assumed to be the location of joints and fault. The surface features that make a lineament may be geomorphic or tonal. Straight stream valleys and aligned segments of valleys are typical geomorphic expressions of lineaments. A tonal lineament may be a straight boundary between contrasting tone or a stripe against a background of contrasting tone. Differences in vegetation, moisture content and soil or rock compositions account for most tonal contrasts (Sabins, 1987).

Lineament traces has been visually interpreted and delineated from the satellite data (IRS LISS III FCC and digitally enhanced images). Many linear features are not continuous but have been extended in the interpretation. Lineament map for the entire subwatersheds is shown in **Figure 5.15**. As
Figure 5.15 Lineament map of the study area
Figure 5.16 Transport Network and Settlement locations map

LEGEND
- Metalled Road (Black Top)
- Metalled Road (other than Black Top)
- Unmetalled Road (Foot Path)
- Unmetalled Road (Cart Track)
- Settlement
many as 80 number of lineaments have been mapped. The general trend of the lineaments has been found NW-SE & NE-SW.

5.11 Road network & settlement locations
Settlement area is defined as an area of human habitation developed due to non-agricultural use and that which has a cover of building, transport, communication, utilities in association with water, vegetation, and vacant lands.

The transparent tracing film has been placed over the 1:50,000 scale toposheet and with the help of light table, all the categories of roads has been drawn. On the imagery, the physical size of the built up land and the connectivity by road network has been used for its identification. Help has been taken from the existing village revenue map obtained from Land record department, Shahdol. Road network and settlement location map for the entire subwatersheds is shown in Figure 5.16.

5.12 Slope
Slope is very vital for planning water and sewage supply and drainage schemes, alignment of transport network, checking for soil erosion and conservation, land irrigability, land capability, ground water prospecting, forest fire spread assessment etc. Slope is expressed in degrees or in terms of gradient percentage or ratio between horizontal distance and vertical fall. The regional as well as local characteristics of slopes are important for both assessment and scientific management of land.

5.12.1 Methodology
Survey of India (SOI) toposheets on 1:50,000 scale with 20m contour interval was used for delineating different slope categories (Figure 5.17). The
vertical drop has been measured from the contour intervals and the horizontal distance has been estimated by multiplying the map distance with the scale factor. Close spaced contours on the map have higher percentage slope as compared to sparse contours in the same space. Hence density of contours on the map has been used for preparing the slope map which gave six groups / categories of slopes. The categories of slopes and corresponding contour spacing on 1:50,000 scale are given in Table 5.11.

<table>
<thead>
<tr>
<th>Slope Category</th>
<th>Lower and Upper Limit of Slope Percentage</th>
<th>Lower and Upper Limit of Contour Spacing</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Very gently sloping (0-3%)</td>
<td>More than 1.33 cm</td>
</tr>
<tr>
<td>2.</td>
<td>Gently sloping (3-5%)</td>
<td>More than 0.8 cm and upto 1.33 cm</td>
</tr>
<tr>
<td>3.</td>
<td>Moderately sloping (5-10)</td>
<td>More than 0.4 cm and upto 0.8 cm</td>
</tr>
<tr>
<td>4.</td>
<td>Strongly sloping (10-15%)</td>
<td>More than 0.26 cm and upto 0.4 cm</td>
</tr>
<tr>
<td>5.</td>
<td>Moderately steep to steep (15-35%)</td>
<td>More than 0.11 cm and upto 0.26 cm</td>
</tr>
<tr>
<td>6.</td>
<td>Very steep (&gt; 35%)</td>
<td>0.11 cm and less</td>
</tr>
</tbody>
</table>

To illustrate the slope category 2 which is “more than 3% and upto 5% slope”, the lower limit of contour spacing 0.8 cm means, over a horizontal distance of 0.8 cm x 50,000 = 40000 cm = 400 meters, there is vertical drop of 20 meters. Thus the slope percentage is \{(20 \times 100/400) = 5\%\} approx.}. The upper limit of 1.33 cm contour spacing means, over a horizontal distance of 1.33 cm x 50,000 = 66500 cm = 665 meters, there is a vertical drop of 665 meters. Thus the slope percentage is \{(20 \times 100/665) = 3\%\} approx.}. Thus all areas on the map having contour spacing between 0.8 cm and 1.33 cm belong to slope category 2 i.e. 3% to 5%. Based on the Table 5.11, slope map for both the subwatersheds has been prepared (Figure 5.18).
Fig. 5.17: CONTOUR DETAILS OF THE STUDY WATERSHED

Contour Intervals: 20 m
Figure 5.18 Slope map of study subwatersheds

LEGEND
- Very gently sloping (0 - 3 %)
- Gently sloping (3 - 5 %)
- Moderately sloping (5 - 10 %)
- Strongly sloping (10 - 15 %)
- Moderately steep to steep (15 - 35 %)
- Very steep (> 35 %)

GORNA SUBWATERSHED

BAGHARI SUBWATERSHED

1 0 1 2 Kilometers

N
5.12.2 Different slope classes in the study area

1. Slope class I (0-3%) - A very large part of the study area (60% of Gorna Subwatershed and 81% Baghari subwatershed) comes under this category. It covers shallow and moderately buried pediment plains, valley fills which, is suitable for cultivation. This slope class form potential area for ground water exploration. The soil erosion is moderate in this area.

2. Slope class II (3-5%) - This slope gradient class falls at mainly the part of denudational hills. The large portion of it comes under forest covered with thick vegetation in the study area. The soil erosion is moderate here. It constitutes approximately 15.5% and 13% of the Gorna and Baghari Subwatershed.

3. Slope class III (5-10%) - This slope gradient class include shallow buried pediments and denudational hills. The soil erosion is severe in these areas. This constitutes mainly the lower portion of the hills dominated by Shorea robusta and dry mix species. It forms 11.2% and 1.2% of the Gorna and Baghari Subwatershed.

4. Slope class IV (10-15%) - This slope gradient class constitutes mainly hill top of the denudational hills which are severely eroded. This is relatively drier area and support for Bamboo forest. It constitutes approximately 5.6% and 2.6% of the Gorna and Baghari Subwatershed.

5. Slope class IV (15-35%) - This slope gradient class constitutes mainly the slope side of denudational hills and dykes having poor moisture. Soil erosion is severe here and it supports for Bamboo along with other dry species. It constitutes approximately 11.7% and 2.0% of the Gorna and Baghari Subwatershed.
6. Slope class VI (15-35%) - This slope class forms the escarpments of the Dhanda Pahar in Gorna Subwatershed. Soil erosion is severe here and supports only the forest of drier species.

5.13 Drainages Network and Surface water bodies

A watershed is the surface area drained by a part or the totality of one or several given watercourses. It is the locus of those points from which runoff reaches the outlet of the stream. It is considered as the most scientific way to make development plan taking watershed as a natural unit. The evolution of any drainage basin like any other landscape on our planet is the result of interactions between the flow of matter and energy entering and moving within its limits, and the resistance of the topographical surface. Under normal conditions, precipitation is the major source of matter and solar radiation is the major source of energy (Zavoinu, 1985). The resistance of the topographical surface is determined by its altitude, resistance to erosion of the constituent rocks, percentage of the vegetation covers, presence of a layer of soil, etc. The interrelationship between these factors and their distributions in time and space govern to a great extent the evolution and present state of drainage basins topography (Verstappen, 1983; Chorley, 1969). The Gorna Subwatershed exhibits dendritic drainage pattern with closely spaced drainage network unlike the Baghari Subwatershed where it is sparsely distributed (Figure 5.19). Very few surface water bodies are observed in the subwatersheds and they are shown in (Figure 5.20) Quantitative morphometric parameters of the drainage basin play a major role in evaluating the hydrologic parameters, which in turn helps to understand the ground water situation. Keeping the same in view and to utilise these informations while preparation of ground water prospective zones of the
Figure 5.19 Drainage Network map of study subwatersheds

LEGEND

1st ORDER
2nd ORDER
3rd ORDER
4th ORDER
5th ORDER

GORNA SUBWATERSHED

BAGHARI SUBWATERSHED

1 0 1 2 Kilometers
Figure 5.20 Surface water bodies of the study subwatersheds
subwatersheds, attempt has been made to evaluate the quantitative morphometric parameters.

5.13.1 Methodology
The quantitative morphometric analysis for linear, areal and basin parameter has been carried out from drainage networks extracted from the Survey of India topographical maps on 1:50,000 scale for both the drainage basins. All the stream courses in the basin were traced and stream ordering was carried out using the system of Strahler (1964). The total numbers of streams of different orders were counted and their lengths were measured. Large-scale remote sensing data (LISS III & PAN) were also consulted during the analysis of the morphometric parameters. A comparative study of the details obtained through this technique has been carried out for both the basins.

5.13.2 Quantitative morphometry
The quantitative analysis of drainage basins and channel networks came into existence from a purely qualitative and deductive study subsequent to the valuable contribution made by R.E.Horton. Valuable contributions for further development came from Strahler (1952, 1957), Morisawa (1959), Melton (1957) and Leopold & Miller (1956). The quantitative morphometric analysis of the drainage basin is considered to be a most satisfactory method because it enables (i) to understand the relationship between different aspects of the drainage pattern of the same basin, (ii) for comparative evaluation of different drainage basins developed in various geologic and climatic regimes and (iii) to define certain useful parameters of drainage basins in numerical terms. One of the most important added advantages of the quantitative analysis is that many of the basin parameters derived are in the form of ratios or dimensionless numbers, thus providing an effective comparison irrespective of scale. The morphometric analysis of a drainage
basin and its stream channel system can be better achieved through the measurement of linear aspects of the drainage networks, areal aspects of the drainage basin and relief aspects of channel network and contributing ground slopes. In the present study, morphometric parameters have been derived for two different drainage basins. The drainage networks for each of the drainage basins has been prepared from the Survey of India topographical sheets on 1:50,000 scale.

5.13.3 Linear aspects of the drainage basin
The designation of stream orders is based on a ranking hierarchy of streams. Measurement and statistical analysis of stream lengths and the length of overland flow are some of the most commonly used attributes, in the study of linear aspects of a drainage basin.

(i) Stream Order
The designation of stream orders is the first step in morphometric analysis of a drainage basin. There are different methods of ranked hierarchy of streams indicating stream orders for a stream network. Horton R.E. (1945) proposed the allocation of order numbers to streams and the same was slightly modified by Strahler (1952). There are some other methods of stream ranking like the one proposed by Shreve (1967), European schools method, etc., which differ from the Hortons and Strahlers method of stream ordering. It is observed that by adopting either the Horton or Strahler systems certain general tendencies on 'laws' may be derived (Sparks, 1972). In the present study, the Strahler system of stream ranking has been carried out for both the subwatersheds.

Each one of the stream segments in the drainage basin is numbered as per the ranking suggested by Strahler and then the total number of segments
(Nu) in each order (u) have been computed. It can be seen from the tables, that the total number of stream segments of a particular order are smaller in number than for the immediate lower order but larger in number of segments than for the next higher order. This relation lead to the recognition of bifurcation ratio (Rb) which can be simply defined as the ratio of number of segments of a given order Nu to the number of segments of the higher order Nu + 1. The bifurcation ratios are calculated and the average bifurcation ratio obtained for Gorna Subwatershed and Baghari Subwatershed drainage basins is 4.34 and 3.90 respectively. According to the Horton's law of stream numbers, the numbers of stream segments of each order forms an inverse geometric sequence with order number. This law can be proved by plotting the logarithm number of stream against order, which reveal a linear relationship line. The plots made for both the drainage basins are in concurrence with the law of stream numbers (Figure 5.21).

(ii) Stream Lengths
The stream length of each individual stream segment for all the stream orders has been measured independently using a digital curvimeter. The total stream length of each stream order has been calculated by adding stream length of all the stream segments in a given order. The total number of stream segments (Nu) in a stream order (u), total stream length (Lu) in a stream order (u), cumulative stream length of all the stream segments of all the stream order, mean stream length (Lu) and cumulative mean stream length for both the drainage basins have been calculated and listed in Table 5.12 & 5.13.

The Mean stream length (Lu) of a stream-channel segment of order (u) is a dimensional property, which reveals the characteristic size of components of a drainage network and its contributing basin surfaces. In the present, study
Table 5.12: Linear characteristics of Gorna drainage basin

<table>
<thead>
<tr>
<th>Stream Order</th>
<th>Total No. of segments of order u (Nu)</th>
<th>Bifurcation Ratio (Rb)</th>
<th>Total Stream length of Stream Order u (Lu) (Km)</th>
<th>Cumulative total stream length (Km)</th>
<th>Mean Stream length (Lu) (Km)</th>
<th>Cumulative mean stream length (Km)</th>
<th>Length Ratio (RL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>355</td>
<td>4.32</td>
<td>164.4</td>
<td>164.4</td>
<td>0.46</td>
<td>0.46</td>
<td>1.62</td>
</tr>
<tr>
<td>2</td>
<td>82</td>
<td>4.56</td>
<td>61.55</td>
<td>225.95</td>
<td>0.75</td>
<td>1.21</td>
<td>2.71</td>
</tr>
<tr>
<td>3</td>
<td>18</td>
<td>4.5</td>
<td>36.7</td>
<td>262.65</td>
<td>2.03</td>
<td>3.25</td>
<td>3.04</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>4.0</td>
<td>24.80</td>
<td>287.45</td>
<td>6.2</td>
<td>9.45</td>
<td>2.65</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td></td>
<td>16.45</td>
<td>303.9</td>
<td>16.45</td>
<td>25.90</td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>431</td>
<td></td>
<td>303.90</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 5.13: Linear characteristics of Baghari drainage basin

<table>
<thead>
<tr>
<th>Stream Order</th>
<th>Total No. of segments of order u (Nu)</th>
<th>Bifurcation Ratio (Rb)</th>
<th>Total Stream length of Stream Order u (L_u) (Km)</th>
<th>Cumulative total stream length (Km)</th>
<th>Mean Stream length (L_u) (Km)</th>
<th>Cumulative mean stream length (Km)</th>
<th>Length Ratio (RL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>156</td>
<td>3.80</td>
<td>73.90</td>
<td>73.90</td>
<td>0.47</td>
<td>0.47</td>
<td>1.52</td>
</tr>
<tr>
<td>2</td>
<td>41</td>
<td>6.83</td>
<td>29.55</td>
<td>103.45</td>
<td>0.72</td>
<td>1.19</td>
<td>2.84</td>
</tr>
<tr>
<td>3</td>
<td>6</td>
<td>2.00</td>
<td>12.3</td>
<td>115.75</td>
<td>2.05</td>
<td>3.24</td>
<td>3.30</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>3.00</td>
<td>20.35</td>
<td>136.10</td>
<td>6.78</td>
<td>10.02</td>
<td>1.09</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td></td>
<td>7.4</td>
<td>143.50</td>
<td>7.4</td>
<td>17.43</td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>207</td>
<td></td>
<td>143.50</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
mean length of stream-channel has been calculated by dividing the total stream length by the number of segments of that order. It can be seen from the tables that the mean length of channel segments of a given order is greater than that of the next lower order but less than the next higher order. Horton's law of stream lengths states that the mean lengths of stream segments of each of the successive orders of a basin tend to approximate a direct geometric sequence in which the first term is the average length of segments of the first order. This law can be verified by plotting the logarithm of mean stream length versus stream order, in which all the points essentially tend to form a straight line. This statement has been found to be valid in the study basins, as it can be seen from the Figure 5.22 that regression of log of mean stream segments length on stream order shows the linear relation for the drainage basins with few deviations. Superimposition of lineament map showed that the drainage lines form straight lines at various places. This departure from the normal shape of the streams defined in a homogeneous terrain may result in a non-linear length-order relationship. The deviation of points pertaining to the 4th and 5th stream orders for Baghari Subwatershed may be caused due to the reason stated above.

(iii) Length of overland flow
The length of overland flow is a measure of erodability, which can be described as the length of flow of water over the surface, before it becomes concentrated in definite stream channels. It is observed that the speed of the unconcentrated flow overland is much lower than when concentrated into a channel. Horton (1945) noted that the "length of overload flow is one of the most important variables affecting both the hydrologic and physiographic development of drainage basins".
Figure 5.21 Regression of logarithmic of number of stream segments vs stream order obtained based on Strahler's system of stream ranking for two drainage basins.

- Baghari
- Gorna
Figure 5.22 Regression of logarithmic of mean stream lengths vs stream order obtained based on Strahler's system of stream ranking for two drainage basins.
Horton (1945) defined length of overland flow as the length of flow path projected to the horizontal, of nonchannel flow from a point on the drainage divide to a point on the adjacent stream channel. For first order basins the length of overland flow is approximately one half of the reciprocal of drainage density, in other words, one half of the constant of channel maintenance. It is observed that smaller the value of length of overland flow, the quicker surface runoff will enter the streams. In the study basins, the length of overland flow of 0.25 km/sq.km. and 0.30 km/sq.km has been obtained for Gorna Subwatershed and Baghari Subwatershed respectively. It can be noted from the values, that surface runoff on Gorna Subwatershed drainage basin will reach the streams quicker than Baghari Subwatershed drainage basins.

5.13.4 Areal aspects of drainage basins

Study of stream areas and their relation to length, as well as discharge, basin shape, drainage density, constant of channel maintenance, stream frequency has been carried out. In the present study some of these parameters have been worked out and compared for the two basins.

(i) Drainage Density

Drainage Density D, which is one of the important indicator of the linear scale of land form elements in stream eroded topography is defined by Horton as the ratio of total channel segment lengths cumulated for all orders within a basin to the basin area. The drainage density, which is expressed in terms of km/sq.km, indicates an expression of the closeness of spacing of channels, thus providing quantitative measure of average length of stream channel area of the whole basin. Drainage density measurements have been made for both the subwatersheds and also for microwatersheds. It has been observed that the low drainage density is favored in regions of highly
resistant or highly permeable subsoil material under dense vegetative cover, and where relief is low. On contrary, the high drainage density is favored in regions of weak or impermeable subsurface materials, sparse vegetation and mountainous relief.

The drainage density measurement made for the drainage basins of Gorna Subwatershed and Baghari Subwatershed shows the drainage density of 2.05 km/sq.km and 1.69 km/sq.km. respectively. As it can be seen that the drainage basin of Baghari Subwatershed shows relatively low drainage density than that of Gorna Subwatershed. The detailed landform study made using Indian Remote Sensing Satellite LISS-III images and topographical maps suggests that Baghari Subwatershed drainage basin is characterised by highly permeable subsoil material which is evident from broad buried pediment plains, dense vegetative cover especially agricultural crops and low relief. But on the other hand the drainage basin of Gorna Subwatershed exhibits impermeable subsurface material which is evident from fracture controlled narrow drainage / stream course, sparse vegetation and mountainous relief with presence of residual hillocks, dykes etc. Thus, the study of various factors which control the drainage density such as lithology, compactness of subsurface, vegetative cover, relief, etc., for the drainage basins of Gorna and Baghari Subwatersheds shows that the drainage density obtained for these basins are in concurrence with the drainage density measurements made in similar terrain, by many other researchers.

Based on the drainage density, drainage basin can be graded into anyone of the five different textures as (i) Very Coarse (<2), (ii) Coarse (2-4), (iii) Moderate (4-6), (iv) Fine (6-8) (v) Very Fine (>8) (Singh, 1967). Accordingly, Gorna Subwatershed drainage basins may be regarded as
coarse textured basin and Baghari Subwatershed drainage basin as very coarse textured basin.

(ii) Constant of Channel Maintenance
Schumm (1956) used the inverse of drainage density as a property termed constant of channel maintenance C, which may be simply defined as the area of basin surface needed to sustain a unit length of stream channel. The constant C is expressed as sq.km/km., which depends upon the rock type and permeability, climatic regime, vegetation cover and relief but also duration of erosion and climatic history. It has been observed that constant will be extremely low in an area of close dissection. The constant of channel maintenance obtained for drainage basins of Gorna Subwatershed and Baghari Subwatershed is 0.49 sq.km/km, and 0.59 sq.km/km respectively. As it can be seen that the Gorna Subwatershed basin has lower constant value than the Baghari Subwatershed drainage basins. The same result is expected since most of the stream channels within the Gorna Subwatershed drainage basin are controlled by lineaments/fractures / joints, etc.

(iii) Basin shape measures
The shape or outline form of the drainage network has the influence on the surface run off and stream discharge. It has been observed that a long narrow drainage basin with high bifurcation ratios would be expected to have attenuated flood discharge period but on the other hand the round basin with low bifurcation ratio would be expected to have sharply peaked flood discharge.

Various indices can be used to define the basin shape measures which include (i) the ratio between basin area and the square of basin length (ii) the ratio between basin area and the area of a circle of a circumference equal to
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the perimeter length of the basin, (iii) the ratio between the diameter of a circle with the same area as the basin and the length of the basin, etc.

Horton (1932) used a form factor \(R_f\) to express the drainage basin outline form in quantitative way. Form factor can be defined as the ratio of basin area to the square of basin length. The \(R_f\) value of 0.29 and 0.49 has been obtained for Gorna Subwatershed and Baghari Subwatershed respectively.

Miller (1953) used a circularity ratio \(R_c\), defined as the ratio between the basin area and the area of a circle having the same perimeter as the basin. He has observed from the \(R_c\) values obtained for first and second order drainage basins that small drainage basins representing homogeneous geologic material preserves geometrical similarity. A value of 0.6 to 0.7 and 0.4 to 0.5 has been obtained by him for drainage basins composed of shale / dolomite and dipping quartzite respectively. In the present study \(R_c\) has been worked out for the entire basin. Accordingly a value of 0.35 and 0.62 has been obtained for Gorna Subwatershed and Baghari Subwatershed respectively.

Schumm (1956) used an elongation ratio \(R_e\), which is defined as the ratio of diameter of a circle with the same area as the basin and the length of the basin. It has been observed that the \(R_e\) value ranges between 0.6 to 1.0 over a wide variety of climatic and geologic types. The \(R_e\) values obtained for Gorna Subwatershed and Baghari Subwatershed basins are 0.61 and 0.79 respectively.

Since the drainage basin shape is not exactly circular as it has been used for calculating all the above referred basin shape measures, Chorley, et al (1969) used a lemniscate function coefficient \(p\) which expresses roundity of the
basin. 'p' can be obtained by dividing the square of the maximum length of the drainage basin with the area of the basin. By substituting the measurement 'p' value of 3.41 and 2.05 has been obtained for Gorna Subwatershed and Baghari Subwatershed drainage basins respectively.

5.13.5 Details of analysis
The quantitative morphometric analysis was carried out for both the drainage basins each one representing a different environment. The study of the drainage network leads to understanding the dissection of the area, which in turn helps in deciphering the ground water condition in that basin. Based on the quantitative morphometric analysis, a comparative evaluation has also been carried out to understand the relationship between drainage development and other parameters such as, lithology, landform, lineaments, slope, etc (Table 5.14).

Both the subwatersheds have developed fifth order streams indicating similar level of dissection of the area and maturity attained. The stream number and bifurcation ratio is significant in deciphering the erosional activity of the basin. The cumulative stream length of Baghari Subwatershed is lesser than Gorna Subwatershed.

While the Gorna Subwatershed drainage basin is represented topographically by highly undulating mountainous terrain dominated by hillocks, dykes and narrow valleys suggesting high relief, the Baghari Subwatershed is represented by moderate relief. Since the bifurcation ratio of the streams indicates how the bifurcation of the streams is proceeding within the basin, an attempt has been made to study the same. The bifurcation ratio of first to second order stream is more in the case of Gorna Subwatershed suggesting that the headward erosion is stronger in Gorna Subwatershed than that of
Baghari Subwatershed. The average bifurcation ratio also supports this inference. Similarly the mean stream length of Gorna Subwatershed (0.66) is less than Baghari Subwatershed (0.69) suggesting that the headward erosion is more and this sub basin is less stabilized when compared to Baghari Subwatershed. This is corroborated by the presence of landforms in both the drainage basins. The length of overland flow measure suggests that surface run-off on Gorna Subwatershed drainage basin will reach the streams quicker than Baghari Subwatershed drainage basins.

Both the drainage basins are on concurrence with the Horton’s law of stream numbers. The frequency distribution of first and second order streams in terms of arithmetic and logarithmic distribution behaved as suggested by Schumm and Miller for both the basins.

The drainage density measures worked out for both the drainage basins indicates that the Baghari Subwatershed drainage basin is characterised by highly permeable sub soil material unlike Gorna Subwatershed drainage basin which exhibits impermeable subsurface material. These observations are confirmed by the presence of landforms and vegetative cover in the drainage basins. The lower value of constant of channel maintenance obtained for the Gorna Subwatershed drainage basin confirms the presence of structurally controlled stream segments within the basin. The basin shape measures have also been worked out for both the basins.

It can be noted here that the various drainage measures obtained for both the basins are in concurrence with the values obtained elsewhere in the similar terrain conditions.
Table 5.14: Characteristics of two drainage basins representing different environs

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Basin</th>
<th>Gorna Subwatershed</th>
<th>Baghari Subwatershed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Area (Sq. Km)</td>
<td>135.0</td>
<td>75.0</td>
</tr>
<tr>
<td>2.</td>
<td>Maximum Length (Km)</td>
<td>22.5</td>
<td>13.2</td>
</tr>
<tr>
<td>3.</td>
<td>Maximum Width (Km)</td>
<td>11.0</td>
<td>10.0</td>
</tr>
<tr>
<td>4.</td>
<td>Perimeter (Km)</td>
<td>72.75</td>
<td>41.65</td>
</tr>
<tr>
<td>5.</td>
<td>Stream Orders</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>6.</td>
<td>Cumulative Stream Length (Km)</td>
<td>303.9</td>
<td>143.5</td>
</tr>
<tr>
<td>7.</td>
<td>Cumulative Stream Segments</td>
<td>460</td>
<td>207</td>
</tr>
<tr>
<td>8.</td>
<td>Bifurcation Ratio</td>
<td>4.34</td>
<td>3.90</td>
</tr>
<tr>
<td>9.</td>
<td>Length Ratio</td>
<td>2.50</td>
<td>2.19</td>
</tr>
<tr>
<td>10.</td>
<td>Stream Frequency (per Sq. Km)</td>
<td>3.09</td>
<td>2.44</td>
</tr>
<tr>
<td>11.</td>
<td>Drainage Density (Km/Sq. Km)</td>
<td>2.05</td>
<td>1.69</td>
</tr>
<tr>
<td>12.</td>
<td>Constant of Channel Maintenance (Sq Km/Km)</td>
<td>0.49</td>
<td>0.59</td>
</tr>
<tr>
<td>13.</td>
<td>Length of Overland Flow (Km/Sq. Km)</td>
<td>0.25</td>
<td>0.30</td>
</tr>
<tr>
<td>14.</td>
<td>Form factor</td>
<td>0.29</td>
<td>0.49</td>
</tr>
<tr>
<td>15.</td>
<td>Circularity ratio</td>
<td>0.35</td>
<td>0.62</td>
</tr>
<tr>
<td>16.</td>
<td>Elongation ratio</td>
<td>0.61</td>
<td>0.79</td>
</tr>
</tbody>
</table>
5.14 Summary
As the remote sensing data along with conventional data is the efficient tool in understanding the disposition of the natural resources of an area, various thematic maps has been prepared on 1:50000 scale. Using the various thematic maps prepared, the natural resources availability and spatial distribution have been assessed for two priority watersheds. These informations generated have been utilised in the subsequent chapters.