CHAPTER — II

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2.1 Data Sources

The following sets of data were used for the present study.

(i) Survey of India (SOI) topographic map (54 F/5) on 1:50,000 scale, surveyed in 1968-1969 (Figure 2.1) was obtained from Survey of India, New Delhi. The relevant information on villages/town, elevation, contour lines, drainage network, watershed boundary, major road and rail network were extracted from the toposheet and a base map was prepared.

(ii) The present study utilized Geocoded Standard False Colour Composite (FCC) of Indian Remote Sensing Satellite (IRS-1D) LISS III (Path-Row: 96-52) of April, 2001 having a spatial resolution of 23.5 meter and band combination 2 3 and 4 (Figure 2.2). Digital data of Indian Remote Sensing Satellite (IRS-P6) LISS III (Path-Row: 96-52) of May, 2005 having a spatial resolution of 23.5 meter was procured from National Remote Sensing Centre, Hyderabad, and a standard FCC was prepared (Figure 2.3).

(iii) Meteorological data for Bharatpur district corresponding to annual average rainfall for the period 1971 - 2006 and annual average maximum and minimum temperatures for the period 1974-1985 and 1996-2006 were obtained from India Meteorological Department (IMD), Pune. However the temperature data for the period 1986-1995, was not available at IMD, and hence presents a data gap.

(iv) Shuttle Radar Topography Mission (SRTM) data of 90 meter resolution was downloaded from the website http://www.srtm.csi.cgiar.org/ for generating Digital Elevation Model (DEM) and was subsequently used for preparing slope map.
Figure 2.1: Kakund watershed clipped from topographic map
Figure 2.2: Kakund watershed clipped from IRS-1D LISS III FCC of 2001
Figure 2.3: Kakund watershed clipped from IRS-P6 LISS III FCC of 2005
(v) The secondary information/data were collected and utilized wherever required for subsisting the current study. Relevant information was extracted from the following secondary sources:


(c) Rajasthan Forest Statistics 2005, State Forest Department, Jaipur, Rajasthan.


(vi) The software utilized for the present study are Arc-View (3.2) for digitization, analysis, data input, editing and output generation. Various modules available in ERDAS Imagine 8.7 were used for data processing, image generation and other image processing functions. Other softwares utilized for the present study include Geotrans 2.3 version, (http://earth-info.nga.mil/gandg/geotrans/), Georeferencing software (http://www.mapwindows.org/download.html?show_details=17), 3DEM (http://www.visualizationsoftware.com/3dem.html), and SAGA 2.0.3 version (http://www.saga-gis.uni-goettingen.de/html.index.html) these softwares are open source softwares. The infrastructural facilities available at the Remote Sensing and GIS lab of the Department of Geology, Aligarh Muslim University, were availed during the course of study.

(vii) Data from the field in the form of ground truth verification and photographs of various features/land cover types are also used as supportive evidence in the analysis.

2.2 Methodology

A systematic approach comprising multiple steps was followed to carry out the present work (Figure 2.4). It includes preparation of base map, drainage map, demarcation of watershed and sub-watershed boundaries using contour values, relief, slope and elevation values. Drainage map was initially derived from SOI toposheets and later updated from satellite data. Other thematic maps such as, land use/land cover, hydrogeomorphological, geological and lineament were generated using IRS LISS III FCC based on visual interpretation using photographic and geotechnical elements such as tone, texture, size, shape, association, pattern, drainage, erosion etc. Subsequently field checks were conducted during April /May 2006 and 2007 in key areas to check the veracity of remote sensing data and to incorporate field observations onto the map.
Figure 2.4: Methodology followed for the present study
Arcview GIS has been used for digitization, computational purpose and for output generation. Thematic maps generated from visual interpretation of satellite data were geo-referenced with the help of ground control points (GCP) obtained from Survey of India (SOI) topographic maps. The drainage map was created as line coverage, assigning unique ids for various stream orders (1\textsuperscript{st} order, 2\textsuperscript{nd} order, 3\textsuperscript{rd} order and so on), lineament map was also digitized as line coverage assigning unique ids for different lineaments. The geological map, land use/land cover map and geomorphological map were digitized using modules available in Arcview GIS. Polygon topology was built for geologic, land use/land cover and hydro-geomorphic units after assigning a unique id for every polygon feature. Thematic maps were edited, cleaned and polygon topology was built in Arc View GIS and the coverages were saved as shape files. Step wise methodology followed during the course of the study is briefly described in the next section.

2.2.1 Preparation of base map and watershed boundary:

Base map was prepared on a tracing sheet (Mylar) using Survey of India (SOI) topographic maps on 1:50,000 scale. The basic information such as latitudes, longitudes, major roads, railway lines, important towns/cities, major rivers and streams were plotted on the base map. The base map was then superimposed on the IRS geocoded FCC so that major features on the base map overlay with features on the FCC. Base map was used as a key map for subsequent thematic mapping using remote sensing data. Watershed boundary was demarcated based on the drainage lines, considering slope, contour, spot heights, elevation etc. Subsequently sub-watershed boundaries were also demarcated following the same approach.

2.2.2 Drainage delineation and morphometric analysis:

The drainage parameters are important as they play a vital role in watershed management and planning irrigation development of an area (Javed, 1995). Drainage is controlled by climate, rainfall, lithology, slope, topography etc. (Melton, 1957). The drainage network was initially derived from SOI topographic maps on a tracing sheet (Mylar) and subsequently updated using IRS-1D LISS III FCC data. The whole Kakund watershed has been demarcated into seven sub-watersheds namely, Narauli, Rudawal, Bankukara, Tarsuman, Nahro, Seupura and Thanadung sub-watersheds.
based on drainage flow directions, elevation, relief, contour values etc. The
demarcation of sub-watershed boundaries involved deriving information on first order
stream onwards (Dwivedi et al., 2006). This was achieved by picking up, initially,
some details on both natural as well as cultural features from topographical maps
followed by updating information using IRS- FCC data. The largest sub-watershed
(Narauli) covers an area of 83.44 km² whereas the smallest sub-watershed (Tarsuman)
covers 16.87 km² area. The drainage map was scanned, geo-referenced and
subsequently imported in Arc-View software for digitization and creation of drainage
layer as line coverage. Distinct ids were assigned for various stream orders during
digitization and the errors in digitization were removed using edit module in the
Arcview.

Morphometric parameters such as stream number (Nu), stream order (u),
cumulative stream length (Luc), mean stream length (Lsm), stream length (Lb), basin
area (A), bifurcation ratio (Rb), drainage density (D), stream frequency (Fs), drainage
texture (Rt), relief ratio (Rh), basin shape (Bs), compactness coefficient (Cc), form
factor (Rf), circularity ratio (Rc), elongation ratio (Re), infiltration number (If), length
of overland flow (Lg) and constant of channel maintenance (C) were computed using
standard methods and formulae (Horton, 1932, 1945; Miller, 1953; Schumn, 1956;
Strahler, 1957, 1964; Chopra et al, 2005; Nooka Ratnam et. al., 2005; Solanke et al.
2005). The input values such as area of the watershed, perimeter, maximum basin
length, difference in relief etc. were computed in GIS using digitized map.

2.2.3 Land use/land cover analysis:

Standard visual image interpretation method based on photographic
recognition elements such as tone, texture, size, shape, pattern, association and field
knowledge was followed to identify and delineate land use/land cover categories on
IRS LISS III data. First the details from the base map were transferred onto the
tracing film, which was superimposed on FCC to delineate land use/land cover
categories. Interpretation of satellite data led to the identification and delineation of
 Cultivated land (CL), Uncultivated land (UCL), Dense forest (DF), Open forest (OF),
Open scrub (OS), Wasteland (WL) (Culturable), Water body (WB), Barren/Rocky
area (RA) (Unculturable), Rock quarry (RQ) and Built up land (BL), in the study area.
Ground truth verification was carried out in April/May 2006 and 2007 to check the veracity of remote sensing data and spectral signatures of land cover feature. Field inputs wherever required were incorporated in the final mapping.

The watershed and sub-watershed boundaries were transferred on the land use/land cover map to facilitate analysis at sub-watershed level. Land use/land cover details at sub-watershed level were imported to Arc View GIS software for digitization editing and spatial analysis. Each land use/land cover category was assigned a unique id in the polygon coverage and area under each land use/land cover category was computed in square kilometers as well as in percentage. Change in area under each land use/land cover category from 2001 to 2005 was analysed and recorded in order to find out changes in land cover at sub-watershed level.

2.2.3.1 Geo-referencing:

The thematic maps generated from visual interpretation of satellite data were geo-referenced with the help of ground control points (GCPs) obtained from Survey of India (SOI) topographic maps using 3dem software. The maps were projected in Universal Transverse Mercator (UTM) projection, taking World Geodetic System (WGS84) as the datum. The study area lies in UTM zone 43 North. For geo-referencing, the latitudes and longitudes of a reference map were converted into X, Y co-ordinates, and the corresponding X-Y co-ordinates were transferred on the map.

2.2.4 Digital Image Processing:

Digital image processing involves manipulation and interpretation of digital images with the aid of a computer (Lillisand et al., 2004). The basic purpose of image processing is to rectify the data of its errors due to technical or systematic errors or external errors and improve the visual quality of imagery. The following methods are incorporated to improve the data and extract information from the data (Figure 2.5).

While the pre-processing is generally done by NRSC the sole distributor of the satellite data before sending the data to the users. Image enhancement and information extraction are normally done by the user depending upon his/her requirement. For the present study a limited analysis to support the results obtained by visual interpretation of the data has been attempted using ERDAS imagine 8.7.
Several image processing techniques were applied to IRS-P6 digital data in ERDAS IMAGINE 8.7 which include filtering, band rationing, unsupervised and supervised classification.

![Diagram of Digital Image Processing]

**Figure 2.5: Major steps in Digital Image Processing**

2.2.4.1 Band Rationing:

Band rationing was carried out using the module interpreter, utilities and operators for generating different combination of bands. First combination was made of i.e. green and red, second red and near infra red and the third between green and near infra red bands.
2.2.4.2 Spatial Filtering:

Spatial Filtering was applied to the IRS-P6 data using the module raster, filtering, convolution filtering. Two filters, i.e. Right diagonal filter and Left diagonal filter (3 X 3) were applied for enhancing the lineaments present in the southern part of the study area.

2.2.4.3 Unsupervised Classification:

Unsupervised classification uses an automatic clustering algorithm that analyzes the "unknown" pixels in the database and divides them into a number of spectrally distinct classes based upon their natural grouping (clusters) in n-spectral dimensions. Unsupervised classification was generated using the module classifier, unsupervised classification. A command of 10 classes was applied to the IRS-P6 image.

2.2.4.4 Supervised Classification:

The initial step involves defining image properties as pixel DN values that represent a group of information of training classes. The module classifier, signature editor and supervised classification were used to generate the supervised classified map. In case of supervised classification 51 known signatures, which fall under 10 land use/land cover categories in the image were specified to the computer as training areas, which were saved as .sig format. Statistical measures were generated for the training areas and input to the classifier, which then determines other areas in the image that have similar spectral characteristics. Finally in supervised classification both image and signature editor (.sig format) was taken as an input for generation of land use/land cover map.

2.2.5 Lineament Mapping:

A lineament is identified as a large scale linear feature, which expresses itself in terms of topography of the underlying structural features (Qureshy and Hinze, 1989). Lineament map was prepared through visual interpretation of FCC data. The factors used for the delineation of lineaments are of changes in topographic slopes, relief patterns, crest type, drainage type and image characteristics. The single most dominant factor for picking up lineaments on the satellite data is the linearity of...
tone/texture. The maximum number of lineaments interpreted on the satellite data fall in two major azimuthal groups i.e. NE-SW and NW-SE, however majority of the lineaments fall in first azimuthal group. Length of the lineament was computed and total length was then worked out by adding up all the lineaments. Directional filters were also used to enhance the lineaments.

2.2.6 Hydrogeomorphic mapping:

Visual interpretation of FCC led to the identification and delineation of various hydrogeomorphological units, such as valley fills, plateau, buried pediments, pediments, intermontane valleys, residual hills and linear ridges. The hydrogeomorphic map was digitized using modules available in Arcview GIS. Polygon topology was built for hydro-geomorphic units, after assigning a unique id for every polygon feature. Information relating to geology, hydrogeology, groundwater and field was incorporated into hydrogeomorphic map to prepare groundwater potential map. Based on the image characteristics, field data, lithology and morphology, which were integrated in GIS domain, the Kakund watershed was demarcated into four groundwater potential zones, namely good to very good, moderate to good, poor to moderate and very poor to poor ground water potential zones. Sub-watershed boundaries were transferred onto the groundwater prospects maps to find out the sub-watersheds where groundwater prospects are poor to moderate.

2.2.7 Geology and Soil mapping:

Information on geology and soil of the study area was obtained from secondary sources and the same was used for the present study. The factors used for the preparation of soil and geology map are lithology, morphology, vegetative cover, topography, slope drainage and field data. Two types of soils such as sandy soil, and sandy loamy soils were identified. Similarly two geological units i.e. Vindhyan sandstone and Quarternary alluvium, which show distinct image characters, are easily demarcated on the FCC data. The geology and soil maps were digitized using modules available in Arcview GIS. Polygon topology was built for geologic and soil units, after assigning a unique id for every polygon feature.
2.2.8 Digital Elevation Model and Slope:

Shuttle Radar Topography Mission (SRTM) is a unique mission dedicated for generating an accurate Digital Elevation Model (DEM) which was successfully launched on February 11, 2001 by National Aeronautics and Space Administration (NASA). The digital elevation data for the study area was downloaded from the NASA-NGA SRTM processed dataset freely available from CGIAR CGNET server in California (http://srtm.cgiar.org/SRT-ZIP/SRTM_Data_GeoTiff) via the Google Earth KML interface. The data is available as 5 x 5 degree tiles in zipped ArcASCII and zipped GeoTIFF formats and as 1 x 1 degree tiles in zipped ArcASCII format. The coordinate system of the digital elevation data is geodetic (i.e. latitude and longitude), horizontally referenced to WGS84 datum and vertically referenced to WGS84 EGM 96 Geoid. The horizontal resolution of the data is 30 meters that has been downscaled to 90 meters (at the equator) for free distribution to the global scientific community. The horizontal and vertical accuracy has been reported to be less than 20 and 16 meters respectively. The 5 X 5 degree tile in GeoTIFF format was imported in 3DEM software and cropped to the limits of the study area. Since the tiles are available in geodetic coordinate system, the cropped tile was transformed into UTM projection (zone 43N). The desired area was subsequently imported into SAGA software, taking the whole study area boundary in the .shp format as input for extent of limits of the study area. The watershed boundary was superimposed on the imported SRTM file and a color coded Digital Elevation Model (DEM) was generated.

Taking the Digital Elevation Model (DEM) as input for creation of slope map of the area, a command was given in SAGA software through module, terrain analysis and standard terrain analysis, an automatic slope map was created which shows slope ranges from 0° to 15°. The slope map was then imported into the Arc-GIS software and classified into five categories of equal intervals viz; very gentle (0° to 3°), gentle (3° to 6°) moderate (6° to 9°), steep (9° to 12°) and very steep (12° to 15°).
2.2.9 Parameters for watershed Management:

Morphometric, land use/land cover and hydrogeomorphic analysis at sub-watershed level was taken into consideration for suggesting measures and strategies for watershed management. The parameters considered for watershed management include:

- Morphometric parameters
  - Drainage density
  - Elongation ratio
  - Relief ratio

- Major land use/land cover category
- Sub-watershed area (changed)
- Lineament density
- Geology
- Elevation/relief
- Slope
- Groundwater prospects

Individual sub-watersheds were examined in respect of these parameters and strategies for watershed management were suggested which vary from one sub-watershed to the other sub-watershed. These parameters were correlated so as to arrive the inter-relationships amongst them and to suggest possible measures for watershed management.