CHAPTER IV

IMAGE ANALYSIS OF THE STUDY AREA
CHAPTER 4

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4.1 Introduction

In continuation of the previous chapter describing the methodology, the digital data of the remote sensing satellite image (RSI) of the upper Noyyil basin was studied to understand the intrinsic nature of the terrain. It is known that in the remote sensing satellite data, the intensity of reflection by the objects on the earth’s surface is recorded and converted as corresponding digital number (DN) values of that particular object. More practical portion of the visible part of electromagnetic spectrum (EMS) and near-infrared region is generally used by the sensors for recording the emanating energy from the objects so that human could appreciate the color differences among objects and interpret them. But in true situation, DN numbers though reflect the energy of an object may vary slightly depending upon the constituent elements of objects as well contamination by other objects. Based on this approach information extraction from remote sensing satellite image may be carried out both by visual interpretation and processing the digital data. The former represents hard copies or FCC (false color composite) image and latter using digital image processing (DIP). In context to the present study, analysis of digital data was carried out to understand the exactitude of the regional terrain setting. This requires a brief understanding on the data format and various image processing techniques, which is discussed in the following sections.
4.2 Data structure

Based on the mode of acquisition by the sensors, remote sensing data may be broadly termed as "active" and "passive". In the active remote sensing, it generates its own energy and it does not record the emitted energy by the earth's object as in the case of RADAR and LIDAR. On the other hand, the passive remote sensing records the energy emanated from the object after its interaction with the solar energy in some specified *electromagnetic* spectrum range. Satellite data type of passive remote sensing (passively recording energy emanated by objects on the earth's surface) is the most accessible source of RS data available at a regular and frequent interval. The sensors on-board of remote sensing satellite record energy emanating from various objects in analog signal, which is later converted to digital format by A-D converter. Such digital remotely sensed image is typically composed of picture elements (pixels) located at the intersection of each row "*i*" and column "*j*" in each *K* bands of imagery. Associated with each pixel is a number known as Digital Number (DN) or Brightness Value (BV) that depicts the average radiance of a relatively small area within a scene (Figure 4.1). Size of the pixels control the scene detail as the reduced pixel size presents more scene detail in digital representation.

These pixels are then stored in a specific format such as Bands Sequential Format (BSQ), Bands interleaved by Lines (BIL), and Bands interleaved by Pixels (BIP). Understanding such arrangement of pixels is important for carrying out image analysis especially in information extraction procedures. A smaller number indicates low average radiance from the area and the high number is an indicator of high radiant properties of the area. The size of
this area effects the reproduction of details within the scene. As pixel size the present study, the satellite data Landsat TM image has BIL data format where the pixels follow row by row arrangement of the first band followed by all the rows in second band and so on (Figure 4.2).

Figure 4.1 Spectral Bands of digital image of RSI

| BIL   | BIP                           | BSQ
|-------|-------------------------------|-----
| R R R R R | G G G G G                   | R R R R R |
| G G G G G | R G B R G B R G B R G B R G B | R R R R R |
| B B B B B | R G B R G B R G B R G B R G B | R R R R R |
| R R R R R | R G B R G B R G B R G B R G B | G G G G G |
| G G G G G | R G B R G B R G B R G B R G B | G G G G G |
| B B B B B | R G B R G B R G B R G B R G B | G G G G G |
| R R R R R | R G B R G B R G B R G B R G B | B B B B B |

Figure 4.2 Structure of digital image of RSI

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The selected image for the present study has to be rectified and pre-processed for any geometrical error before further analysis.

4.3 Pre-processing of the digital image of the study area

In the present study, the image was geometrically corrected so that it exactly depicts the terrain position before analyzing the digital image data for terrain understanding. It is mandatory for resource investigation to avoid any possible error of pixels wrongfully representing the terrain objects. In other words, geometric distortions manifest themselves as errors in the position of a pixel relative to other pixels in the scene and with respect to their absolute position within some defined map projection. In case of neglecting such error may render the image unsuitable for analysis. This holds true when the extracted information form basis for further analysis of the terrain for specific application studies. Such image correction or rectification is particularly necessary if the information is to be geo-referenced, especially for generating other thematic maps that are to be used as GIS data set as in the present study.

Geometrical correction or rectification is a process of geometrically correcting an image so that it can be represented on a planar surface, conform to other images or conform to a map. This is a process by which geometry of an image is made planimetric that could provide accurate area, distance and direction measurements from the imagery. In the present study, rectification is carried out by transforming the data from one grid system (toposheet) into another grid system (image) using a geometric transformation using some ground control points (GCP). GCPs are the specific pixels in the input image for which the output map coordinates are known. GCPs are selected carefully since their number, quality and distribution affect the result of the rectification. During rectification, resampling is employed
that matches the coordinates of image pixels to the corresponding real world coordinates and a rectified geometrically corrected image of the study area was obtained. The resultant satellite image was then processed to extract area of interest (AOI) facilitating further analysis of the study area.

4.4 Details of the Area of interest (AOI) of the satellite data

The boundary of the selected study area, upper Noyyil basin of Coimbatore district of Tamilnadu, geo-referenced and digitized in GIS environment, was superimposed on the rectified image and an exact area of interest (AOI) was clipped from the satellite image depicting the study area using ERDAS Imagine software (Figure 4.3).

Figure 4.3 Landsat ETM FCC image of the study area
The image is a color composite combining Bands 2, 3 and 4 to give a false color composite (FCC). In FCC, a color infrared composite ‘standard false color composite’ was displayed by placing the infrared in red layer, red in green and green in blue layer of the three primary colors red, green and blue (RGB). A simple reconnaissance statistical approach of studying the satellite image was carried out to understand the distribution of DN values in each band from which pattern of terrain objects may be inferred.

![Distribution of DN values in all the bands of the RS image](image)

**Figure 4.4** Distribution of DN values in all the bands of the RS image
Except the thermal band (sixth band) all the six bands of the selected Landsat ETM showing the study area was studied. Among them bands 5 and 7 are noteworthy because they throw light on the predominant features in the selected image. Also, the bands 5 and 7 are significant in terms of discriminating two major objects of terrain vegetation and lithological features respectively. The distribution pattern of DN values also suggested that large number of pixels were observed in band 7, a lithological discriminating spectral region, suggesting lithological predominance of the study area. Similarly a concentrated reflectance behavior (DN values) was observed in the first two bands depicting the spectral influence of terrain objects or features such as waterbodies and green (chlorophyll) vegetation content. Spectral behavior of objects in red and near-infrared (bands 3 and 4) showed a similar pattern of DN values of pixels, that is the number of pixels and their DN range were similar. High reflectance value (DN) was observed in band 5 which would throw light on the plant vigor status and moisture stress. Statistical parameters such as mean, mode and standard deviation of each band revealed certain significance of interaction between objects and energy in a given spectral region.

Enhancement techniques such as histogram equalization, edge enhancement and principal component analysis (PCA) were applied on the satellite image to bring out more information on the geological features of the terrain. Moreover, by applying histogram equalization on the satellite image and compared with the statistical details of the normal FCC have further reiterated the process of information extraction.
4.5 Enhancement Techniques for Terrain Analysis of the study area

Image enhancement techniques improve the quality of an image and most useful because many satellite images when examined on a color display give inadequate information for image interpretation. There exists a wide variety of techniques for improving image quality and histogram equalization, edge enhancement and spatial filtering are the more commonly used techniques. Some of these digital image processing techniques were applied on the image of the study area and attempted to understand the significance of such enhancement techniques in contributing lucid information about terrain features.

4.5.1 Histogram Equalization

Histogram equalization being the most simple and effective method for enhancing the contrast of an image was one of the fields where a non-trivial, but not always successful generalization from gray-scale images to color images has been observed. As expected, the literature on color histogram equalization is not as rich as that on gray-scale histogram equalization. The most simple and straightforward extension is the application of gray-scale histogram equalization to the different bands of the color image. Histogram equalization is mainly based on the brightness component of the original color image. Since the aforementioned techniques use only marginal color histograms and the resultant output of the satellite image is shown in Figure 4.5.
From figure 4.5, it could be observed that hilly area and forest were highlighted along with sand deposits at the foot hills in the western part of the image and river alluvium along the main drainage. Few isolated patches granitic complex lithological unit at the center of the Noyyil basin near Tiruppur was enhanced. Similarly, shallow pediments, alluvial plains along the drainage course and hilly terrain at the western part of the study area were well enhanced. Such enhancement helped to understand the geomorphic pattern of the study area. Besides these, man-made objects such as roads and settlements were clearly delineated avoiding confusion with structural (lineaments) and geological units of the study area.

To amplify the significance of such stretching of DN values, a comparison of statistical values of original FCC image and the equalized values were compared. The estimated mean values of the first band of the original FCC and the corresponding histogram
equalized were 38.91 and 127.43 respectively. Similarly, median values were given as 63.0 and 126.0 and estimated standard deviation as 35.756 and 70.448. Histogram equalized image showed same range of DN values stretched for all the bands of the image so that the importance of each objects were enhanced by enhancing their brightness values. A table showing range of DN values of each band of the study area and their corresponding stretched or enhanced DN values after applying histogram equalization procedure on the image (Table 4.1).

While observing the above table, it could be well understood that mean value of the seventh band of the ETM image of the study area showed a relatively higher value than that of first five bands, which reflected the lithological significance of the study area. The corresponding values of median and standard deviation reflected such inherent lithological pattern by mean of the spectral reflectance pattern of the study area. Whereas in the output values of the histogram equalization, as the name implied, the statistical values of the bands signified the stretching of the DN values equally thus increasing the brightness value of the pixels enhancing interpretability of the study area. Even the seventh band as seen from the above table showed similar values as that of other five bands. It showed 85.79 as mean value, 139 as median and 78.22 as standard deviation deviating enormously from the other five bands in the FCC. The corresponding values in the histogram equalized image showed an enhanced value similar to that of other five bands.
Table 4.1 Comparison of DN values of FCC and enhanced image of the study area

<table>
<thead>
<tr>
<th>Bands</th>
<th>Mean</th>
<th>Median</th>
<th>Mode</th>
<th>Std. Dev</th>
</tr>
</thead>
<tbody>
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<td>63</td>
<td>0</td>
<td>35.76</td>
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<tr>
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<td>31</td>
<td>0</td>
<td>19.34</td>
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<tr>
<td>3</td>
<td>23.35</td>
<td>28</td>
<td>0</td>
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<td>4</td>
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<td>67</td>
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<td>5</td>
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<td>73</td>
<td>0</td>
<td>53.32</td>
</tr>
<tr>
<td>7</td>
<td>85.79</td>
<td>139</td>
<td>0</td>
<td>78.22</td>
</tr>
</tbody>
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<table>
<thead>
<tr>
<th>Bands</th>
<th>Mean</th>
<th>Median</th>
<th>Mode</th>
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<tr>
<td>1</td>
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<td>126</td>
<td>57</td>
<td>70.448</td>
</tr>
<tr>
<td>2</td>
<td>127.411</td>
<td>128</td>
<td>57</td>
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</tr>
<tr>
<td>3</td>
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<td>127.482</td>
<td>128</td>
<td>57</td>
<td>70.526</td>
</tr>
</tbody>
</table>

Thus, the output image of the study area helped to identify the extent of lithological and landform units of the study area as well as the man-made objects (settlements and roads) alleviating confusion with structural features such as lineaments of the study area.

4.5.2 Linear Edge Enhancement

It is known that for geological investigation, both for groundwater or mineral investigation, structural aspect of a terrain is paramount. The most valuable information that could be derived from an image may be in the edges surrounding various objects of interest. The edge enhancement is a typical local operation in which the DN-values at a particular pixel in the new image depend also on the DN-values at neighboring pixels in the old image.
The high-frequency variations of DN-values correspond to local changes from pixel to pixel in an image and influenced by terrain properties, vegetation and solar elevation.

Applying certain filtering techniques such as convolution, low-pass and high-pass filters, statistical filters and filtering with fourier transform could delineate these edges and makes the shapes and details comprising the image more conspicuous. The advantage of using filtering techniques lies in bringing out features that were imperceptible to naked eye as well throwing light on the significance of such features with respect to groundwater investigation. These enhancement algorithms could be applied both in non-linear and linear direction.

Laplacian filtering operator, a common and simple method that was applied to extract edges in the satellite image showing the study area, helped to highlight points, linear features and edges in the image of the study area suppressing uniform and smoothly varying regions (Figure 4.6). The algorithm involved compute the first difference of the image input in the horizontal, vertical, and diagonal directions. The advantage of using Laplacian filter in the study was based on the simplicity of operation with meaningful information extraction of features. It helped to selectively enhance image features having specific direction components (gradients) and was used to detect the boundaries or lineaments in the study area. Lineaments are the mappable linear features of a surface, whose parts were aligned in a rectilinear or slightly curvilinear relationship and which differ from the pattern of adjacent features and presumably reflect some subsurface phenomenon (O’Leary et al. 1976).
Figure 4.6 Laplacian Edge enhancement of the study area

The above figure illustrates various natural as well as man-made linear features including hill ridges, drainage course and roads. Besides, linear arrangements of certain natural features implying subsurface weakness controlling stream courses and vegetation cover. These weaknesses were inferred as lineaments. Some of them were inferred at the western part of the study area near the foot hills striking in the NW - SE direction. Some of them were inferred at the eastern part of the study area striking along NE-SW direction. Many smaller lineaments were observed in the northern parts with most of them striking along NW-SE and NE-SW directions. Man-made linear features such as roads were pink in color and were easily discernable owing to their continuity and proximity to settlements, which were depicted as agglomerated pink color pixels from where many linear features radiate to other parts within the study area. Their pattern and association enabled to infer them as roads and thus only natural linear features could be easily inferred. To understand the
significance of other edge detecting filters on inferring structural feature and lineaments, other convolution filters such as low pass and high pass filters, edge detect and edge enhance filters were applied on the image to understand the structural features of the study area.

Figure 4.7 Convolution Low pass filter enhancement of the study area

In the low pass filter (Figure 4.7) almost all the man-made features were easily discernable facilitating to infer lineaments and thus avoiding man-made objects. Structural ridges in the western part of the study area were sharply highlighted against the paleo-sand dune deposits at their foot hills. Alignment of waterbodies in the southern part of the study area was used to infer the presence of lineament in NE-SW direction. Similarly, a prominent stream in the northeastern part of the study area revealed a possible presence of lineament,
structurally controlling the stream course. There were many lineaments identified at the southeastern part of the watershed which were inferred by the linear alignment of vegetation.

The high pass spatial filter (Figure 4.8) applied on the satellite image reiterated the findings of the low pass filter. Besides it showed certain significant lineament trends inferred in the northern part of the study area as well as segregated certain lithological boundary at the central part of the study area. It led to the inference that many of the stream courses in the northern part of the study area were structurally controlled.

Figure 4.8 Convolution High pass filter enhancement of the study area
The hills at the western part were prominent and many parts in the northern part and its periphery showed presence lineaments mostly striking in the NESW direction which could be inferred from alignment of vegetation and stream courses. Also few isolated patches in the northeastern part indicated presence of lithological and landform units mostly buried pediments of high thickness (BP-Deep) of charnokitic origin.

**Figure 4.9 Convolution Edge enhancement of the study area**

In similar fashion, edge enhance filter as well as edge detection filters were applied on the image to study their effect on bringing out structural significance of the study area, upper Noyyil basin. Edge enhancement of the study area as shown in Figure 4.9 revealed that many lineaments could be inferred in the entire study area mostly striking in the NE-SW direction as well as NW-SE direction as inferred at the eastern part of the study area.
Man-made objects like roads and settlements are clearly delineated enabling confusion with naturally occurring linear pattern of features revealing sub-surface weakness. Course of the main river Noyyill could also be clearly observed in the resultant image of the edge enhanced filter. Almost all the man-made objects were clearly delineated and could not be confused with linear features and thus encouraging detection of lineaments.

The edge detection filter, on the other hand, suppresses the uniform and smooth features and detects the anomaly in the DN values (Figure 4.10). The resultant output image of the edge detect filter revealed a similar linear pattern as observed in the edge enhance filter. There were not much difference except a more striking pattern of lineaments in the NE-SW and NW-SE directions were inferred. The man-made objects were clearly identified and avoided while observing the pattern of lineaments.
4.5.3 Non-Linear Edge Enhancement

Some of the non-linear edge enhancements techniques are Sobel and Prewitt enhancement techniques. Sobel operator consists of a pair of 3×3 convolution kernels complimenting each other by a simple rotation of 90 degrees. These kernels were designed to respond to edges running vertically and horizontally relative to the raster pixel grid of the satellite image. When the sobel non-linear filter was applied both the absolute magnitude of the gradient at each point and the orientation of that gradient could be estimated. This would form basis for identifying edges both in horizontal and vertical directions (Figure 4.11). Prewitt enhancement techniques also operate in the principle as that of the Sobel with only a marginal variation in the values of the masks or kernels. The resultant output derived from applying Prewitt operator was similar to that of Sobel’s with some small variations in terms of linear features and prominence of sharp ridges in the western part of the study area (Figure 4.12).

Both the enhancement techniques helped to identify not only the linear features but other lithological anomalies of the study area. The Sobel detector is incredibly sensitive to noise in pictures, it effectively highlight them as edges. In the study area, the ridges in the western part were shown very clearly and it also few lineaments were seen extending which were inferred from the alignment of features. Along the southeastern part there were some lineaments in NWSE direction and a major lineament striking along the river Noyyil at the central part of the study area.
Figure 4.11 Sobel Filtering enhancement of ETM data of the study area

Figure 4.12 Prewit Filtering enhancement of ETM data of the study area
Man-made features such as roads and settlements were clearly delineated as well as the presence of airport runway at the central part south of river Noyyil, which was identified by their typical linear shape and pattern. In the resultant image of the Prewitt operator, similar pattern were discernable except that they were bit subdued. Since the study area is hard rock complex terrain many lineaments were observed mostly striking in the of NW — SE and NE-SW directions.

4.5.4 Textural analysis of the study area

Textures provide important characteristics for the analysis of remote sensing data for terrain application studies especially in the arena of landuse and groundwater. In the context of remote sensing image (RSI), texture may be defined as a function of the spatial variation in pixel intensities (gray values). Textural characteristics of the RSI provided information about the structural arrangement of objects and their relationship with respect to their local neighborhoods (Caridade et. al., 2008).

Texture analysis may also be defined as the classification or segmentation of textural features with respect to the shape of a small element, density and direction of regularity. From figure 4.13, it could be observed that many objects were segregated or grouped as clusters based on the frequency of their intensity (DN values). The resultant output image also depicted the average tonal variation in the various bands of the image, thus stressing that textural features contain information about the spatial distribution of terrain features within a specific spectral band and also among a range of spectral bands. The textural measures derived from a grey level co-occurrence matrix (GLCM) and estimated relative spatial frequency with which two neighboring pixels occur on the image. Because of such comparison among pixels and their tonal variations (DN values), many of the similar and not
discernable through naked eye could be identified and their patterns could be studied. Texture analysis of study area also helped to understand the nature and extent of geomorphological features and delineating lithological characters. While examining the textural aspect of the image, the study area revealed existence of similar lithological units at the eastern and western parts that were seen as dark brown color in the resultant image, Figure 4.13.

Geomorphological such as buried pediments of varying thickness (shallow, medium and deep) could be identified from their association with existing drainage pattern and by their spatial extent and intensity. In this image, settlement was not as prominent as it was in other enhancement techniques but roads were seen in violet color. The dendritic drainage pattern at the northeast and southeast parts and lesser frequenting drainage channels in other parts suggested a lithological control in the study area. The spatial enhancement in the form of texture definitely provided an insight about the geological and landform settings of the study area, upper Noyyil basin.

The study area may further be analysed applying statistical filters to enhance the distribution of DN values of the digital RSI to provide geological, structural and landform information of the study area as discussed in the following section.

4.5.5 Statistical filtering of the study area

Statistical filtering as the name implies, is a simple linear filter, reducing the amount of intensity variation between one pixel and the next in the selected RSI of the study area. In the present enhancement technique, each DN value of pixel in the spectral band replaced with statistical values such as mean, median and standard deviation of the DN values of that
spectral region. The filter calculates the shape and size of the neighborhood to be sampled when calculating the statistical parameters and assigning the new brightness value.

The resultant image of the study area after such application revealed the linear features very clearly (Figure 4.14). From the image it could be seen that man-made features such as roads showed distinct linear pattern. This allowed the user to identify other linearly occurring natural features such as alignment of vegetation and waterbodies and thus helped to infer lineaments of the study area. This form of linear pattern was very vivid in the southeastern parts indicating sub-surface weakness of the study area mostly in the NE-SW direction. The main river Noyyil drains almost a NE-SW direction coinciding with other lineaments of the study area.
In the northern part of the study area many such lineaments were inferred mostly striking in the NE-SW direction. Similar color at the eastern part, a small patch in the northern and southeastern parts (pink color) led to the inference of similar lithological and landform units. This type of units was also seen in the central part of the study area too. While observing the enhanced image, three major lithological units - first one in the eastern part and the northern and southern peripheral parts, second southern and southwestern parts and third in the north western part - were observed in the study area.

Thus, statistical filtering in many ways enhanced the lithological, structural and geomorphological units of the study area.
4.6 Principal Component Analysis (PCA) of the study area

Principal component enhancement techniques are particularly appropriate in areas where little \textit{apriori} information concerning the region was available. This is a spectral enhancement where DN values of the spectral bands are rotated and compressed so that the resultant image could be easily interpreted for information about the terrain. PCA was generated by transforming the original uncorrelated DN values of the image to a new correlated single band image. This was accomplished by a linear transformation of variables that corresponds to a rotation and translation of the original coordinate system.

PCA operates on all spectral bands of the RSI and thus alleviates the difficulty of selecting appropriate bands for band ratioing or for specific application. It helped to compress the original data of different bands to a single band accounting for a maximum portion of the variance in the data set, often as high as 98% in the first rotation. Furthermore, PCA reduced the redundancy of DN values in other spectral bands of the image and successive PCA accounting for successively smaller portions of the remaining variance. PCA images thus generated were uncorrelated and ordered by decreasing variance. Because of this PCA was very useful in studying the terrain for spectral pattern recognition.

In the present study, initially first order PCA was applied on the image but the resultant PCA output was not lucid and hence, a second order PCA was applied on the image. That is the image was rotated again and the output was stored (Figure 4.15). PCA output of the image showing the study area revealed significant lithological, structural and geomorphological units of the study area. It clearly demarcated the hilly terrain in the western part of the study area. Paleo-sand dune landform at the foot hills of the hill range was
clearly identified and their spatial extent could be demarcated by their typical bright white color and spatial extent.

Figure 4.15 Principal Component Analysis (PCA) of the study area

Linear patterns along the streams at the central part, northwestern and southeastern parts of the study area were showing linear to curvilinear course leading to the inference of sub-surface control, and inferred as lineaments. Also, massive lithological unit of similar tone was identified in the eastern part of the study area and in conjunction with the available baseline data, interpreted as charnockite. Apart from these, valley fills along the stream channels in the northeastern part and buried pediments along north of a major settlement, Coimbatore, were identified. Besides, many lineaments were also inferred, as in the case of other resultant enhanced images of various enhancement techniques.
So far various enhancement techniques such as radiometric, spatial and spectral enhancements were applied on the RSI showing the study area to understand the geological, structural and geomorphic settings of the terrain. Each enhanced image after such processing revealed certain significantly relevant geological and structural features. Enhancement techniques were especially useful to infer lineaments a sub-surface weakness of the terrain by alignment of vegetation, stream channels and waterbodies. Lithological units could be also be separated by different tonal and color variations observed in the resultant enhanced images. Similarly, geomorphic units such as hills, valley fills, paleo-sand dune deposits, buried pediments were inferred and could be identified by their significant color and tonal variations observed in the enhanced images of various filtering techniques – linear, non-linear, spatial, spectral, textural and statistical filtering operators. To further the image analysis of the study area regarding feature recognition, a clustering technique based on color was applied on the ETM image of the study area and discussed in the following section.

4.7 Normalized Difference Vegetation Index (NDVI) analysis of the study area

The Normalized Difference Vegetation Index (NDVI) is a numerical indicator that uses the visible and near-infrared bands of the electromagnetic spectrum, and applied to analyze remote sensing measurements and assess whether the target being observed contains live green vegetation or not. The NDVI was calculated by calculating the ratio between added spectral value in Red and near-infrared and their difference.

\[ \text{NDVI} = \frac{(\text{near IR band} - \text{red band})}{(\text{near IR band} + \text{red band})} \]

In the present study, it was applied on the satellite image to understand the condition of vegetation cover of the study area. The NDVI resultant image showed a value ranging from -0.976 to 0.611. The range of values indicated presence of cloud and water whose
values were negative and zero respectively. Similarly vegetation based on their chlorophyll content showed a higher value in the positive side. The resultant image shown below clearly depicted the above observation. The vegetation was indicated by the Theoretically, NDVI values are represented as a ratio ranging in value to 1. The extreme negative values represent water, values around zero represent bare soil and values over 0.6 represent dense green vegetation.

The resultant image depicted green vegetation and its vigor and dense vegetation showed up strongly in the output image and areas with little or no vegetation were also clearly identified. Identification of such differences was based on the brightness since vegetation were shown white and as the density or vigor of vegetation decreased it showed correspondingly darker tone. Hence, NDVI was used to understand the crop condition of the area. From the figure, it was observed that eastern part showed dark grey tone and western parts showed white tone. This indicated limitation in terms of vegetation cover in the eastern part (sparse or devoid of vegetation) and healthy vegetation (forest area along the hills) in the western part of the study area. Waterbodies were shown as dark color.

To understand more about the distribution and pattern of geological features besides land use land cover, the satellite image may be applied for some reconnaissance classification of features in the study area. To cater such requirement, a color index clustering technique may be applied to assess the geological condition of the terrain, which is discussed in the following section.
4.8 Clustering analysis of the study area

One of the simplest and easiest methods of image processing of RSI is clustering techniques. This may otherwise be called as unsupervised classification where user has no priori knowledge of features and objects of the terrain. Instead, the distance among pixels, their origin and intensity were considered and similar pixels (of DN values) were clustered which were later identified as particular class unit based on the domain expertise.

![Figure 4.16 NDVI analysis of the study area](image-url)
One of the clustering techniques proposed for the present study was color index mapping where color intensity of each pixel in three layers (Red, Green and Blue) were estimated and similar color values instead of DN values were grouped or clustered. The advantage of using such technique lies in its simplicity and secondly the ability of human eye in appreciating differences among primary colors (RGB). In this, only the color intensity of the pixels are considered for the analysis to extract features and were compared. Though certain limitation exist in terms of class segregation of features individually, still it helped to understand the general trend and pattern of various features including lithology, structural and geomorphic features of the study area (Figure 4.17).

The resultant output image of the clustering technique using color indexing segregated features ad highlighted them in different colors. Red color spread throughout the
entire study area implied the presence of vegetation cover. Features in broader perspective could be interpreted using the present clustering technique, since it involved no training samples, an unsupervised feature extraction process. At the same time, once the type and nature of features were identified, it could be refined and pave way for local level interpretation to identify sub-categories of various features. Settlements and roads were clearly segregated and clustered as grey color pixels in the image. Pink color seen at the foot hills in the western part of the study area could be interpreted as sand deposit and erosional surface and this could be extended to the entire study area. Few negligible patches of cloud cover were seen at the westernmost periphery of the study area by their typical white color, texture and shape. The most intriguing part was observed at the central part of the study area, near Tiruppur, showing green color that may represent massive lithological unit, probably granitic complex, and it was observed at the northern periphery and as few isolated patches in the western part. This corroborated well with the existing baseline data and major part of the study area was covered by metamorphic rocks. A simple reconnaissance analysis using such clustering analysis of the image of the study area helped in further information extraction for hydrogeological studies in GIS environment.

4.9 Summary

To summarize, image analysis of the study area revealed many geological, structural, geomorphic and land use/land cover features of the study area. The study also helped to understand the spectral behavior of various objects and allowed to appreciate the inherent spectral nature of objects in the form of DN values and their intrinsic relationship with the study area. Various enhancement techniques in radiometric, spatial and spectral domain highlighted many structural features and infer the presence of lineaments and their direction.
This would give an insight regarding the structural alignment of objects and provide necessary knowledge while studying the groundwater condition of the study area. PCA analysis provided concise knowledge on the lithological and geomorphic settings and NDVI has clearly brought out the landuse and land cover condition that exist in the study area. The NDVI output showed vegetation condition as well as presence of waterbodies in the study area. Apart from all these enhancement techniques, clustering of pixels based on their primary colors and indexing similar colors as clusters or features has helped to identify and understand various terrain features. It was used as a simple reconnaissance analysis of the study area and provided significant information about the terrain that helped in understanding hydrogeological condition and groundwater level fluctuation of the study area in GIS environment, as discussed in the following chapter.