6.1 General statement:

Digital images are available from many sources like commercial and governmental earth resource satellite systems, meteorological satellites, airborne scanner data, airborne digital camera data, image data generated by photogrammetric scanners and other high resolution digitizing systems (Sabins, 2000; Lillesand et al., 2004).

Remote sensing images are mostly recorded in digital forms, as a two dimensional function, \( f(x, y) \) where \( x \) and \( y \) are spatial (plane) coordinates, and the amplitude of \( f \) at any pair of coordinates \( (x, y) \) is called the intensity or grey level of the image at that point. Digital images are array of many individual values (digital values) known as pixel that together form an image. Digital images have many advantages over analog images such as digital values can be added, subtracted, multiplied and may be subjected to statistical manipulation. Digital image are also easy to store in compact formats and easily transmitted thus digital format increases our ability to display, examine and analyze remotely sensed data (Campbell and Wynne, 2011). Digital image processing is a technique to enhance raw image received from sensor/camera placed on satellite, space probe and air crafts whereas it also involves the manipulation and interpretation of digital images (Sabins, 1996). The advance technology used in digital image processing of remote sensing data for rectifying the remotely sensed data to a map projection, enhancing the data, classifying the data into land use and land cover, and the changes between different periods of imageries are identified routinely with reasonable accuracy. Basic elements of image interpretation have been involved in image processing using suitable software. Most of the digital image analysis depends primarily on the tone and color of the individual pixel in the scene using fundamental statistical pattern recognition technique (Hardin and Thompson, 1992).
The digital data of IRS P6 LISS III of 4th May 2010, with band combination 234 was subjected to digital image processing using ERDAS imagine 8.6. Various modules in ERDAS Imagine were used for Image classification, edge enhancement, band ratioing and Normalized difference vegetation index (NDVI).

6.2 Image Classification:

It is a technique by which the pixels in an image are automatically categorized into land cover classes or themes. Multispectral data are used to perform the classification using spectral pattern present within the data for each pixel on numerical basis. Different features show different DN’s based on their inherent spectral reflectance properties. Image classification uses the pixel by pixel spectral information as the basis for land cover classification (Sabins, 1996). Spatial pattern recognition involves the categorization of pixel on the basis of their spatial relationship with surrounding pixels therefore there will be points clustered around a mean value. Pixel that does not fall within any class is called unclassified based on the spectral signature (Joseph and Dhawan, 2003). Multispectral classification can be described under two broad categories as.

- Supervised classification.
- Unsupervised classification.

6.2.1 Supervised classification:

It is a technique used for extraction of digital information in which training sites are used by the computer to assign category for different pixels. In supervised classification the analyst supervises the pixel categorization process by specifying to the computer algorithm numerical description of various land cover types present in a scene. Since location of training sites plays an important role hence they should be selected intelligently and with utmost care. The training site data is used to calculate various statistical parameters like mean, standard deviation, variance, covariance matrix etc for carrying out classification (Joseph and Dhawan, 2003). Selection of
training sites in the image from the known land cover types which represents each land use category is the first step. In the study area, fourteen land use/land cover training sites whose spectral characteristics are known to the analyst on the basis of ground surveys are used to train the classification algorithm for land cover classification of the image using ERDAS IMAGINE 8.6 software. The training sites were drawn with polygon boundaries on the image display which was relatively homogenous and large enough to reliably estimate the statistical properties of the class. Some categories were represented by more than one training site in order to cover the full range of reflectance characteristic. Training sites are used to compare a numerical interpretation key that also describes the spectral attribute of each land use type. Using these signature files, supervised classification was done by maximum likelihood classification algorithm processing.

The resulting supervised classification image shows fourteen land use/land cover classes, few land use/land cover categories represent similar spectral characteristics like open forest and plantation, water body, coal dumps and mining pits. The waste land associated with mining area is overburden dumps but it shows similar spectral reflectance as that of wasteland. Stony banks of ash pond and the fresh rocks in the overburden dumps represent the similar reflectance as that of settlement area with same tone. Figure 6.1 show the supervised classification of IRS P6 LISS III data.
Figure 6.1: Supervised classification generated from IRS LISS III
6.2.2 *Unsupervised classification:*

Unsupervised classification is a technique which can be selected to extract digital information in which the computer categorizes the pixel without any instruction or training site from the operator. Unsupervised classification do not utilize training sites for classification whereas this classifier involves algorithm that examine the unknown pixels in an image and aggregate them into a number of classes based on natural grouping or cluster present in the image values (Sabins, 1996). Numerical operations are performed for grouping of the spectral properties of the pixels. The user allows the computer to select the class mean and covariance matrices to be used in the classification and then computer assign these natural or spectral class to the class of interest (Jensen, 1996). Unsupervised classification is simpler than the supervised classification signatures are automatically generated by an algorithm named ISODAT. Unsupervised classification has less discerning ability due to lack of training data supplied to the clustering algorithm, moreover it is crude and approximate.

Unsupervised classification was performed in ERADAS IMAGINE 8.6 by selecting the classifier, by assigning maximum iterations, threshold and number of classes. In the output image classes like dense forest, open forest, plantation, and open scrubs are merged and were assigned new class forest. Moreover thermal power plant area merges with settlement and forest due to the presence of open forest within the boundary, whereas wasteland merges with dry river. The land use/land cover classes were merged because these classes have similar spectral reflectance characteristics. The resultant unsupervised image has 9 land use/land cover classes like forest, cultivated land, uncultivated land, mining pits, overburden dumps, wasteland, settlement, ash pond and water body (Figure 6.2).
Figure 6.2: Unsupervised classification generated from IRS LISS III.
6.3 Image Enhancement:

Enhancement is the modification of an image to alter its impact on the viewer by changing its original digital value (Sabins, 1996). Image enhancement algorithm is applied to remote sensing data to improve the appearance of an image for human visual analysis or for subsequent machine analysis (Jensen, 1996). Since human eye is poor in discriminating the slight radiometric or spectral difference hence computer enhancement aims to visually amplify these slight differences to make them easily observable. Enhancement can be performed on single band images or on the individual components of multi-image composite. The resulting image may also be displayed in black and white or in color. The digital image enhancement techniques used in the present study are discussed below:

6.3.1 Edge enhancement filter:

An edge can be a boundary that separates two different features or can be a line that differs from the feature on both its sides and characterized by high frequencies (Sahu, 2008). Edge enhancement is an effort to emphasize the visual transition between regions of contrast brightness. Human interpreter prefers sharp edges between adjacent parcels or feature whereas the presence of noise, coarse resolution, and other factors are responsible to weaken or blur the distinctiveness of these transitions. Edge enhancement magnifies local contrast, which increases the contrast within a local region between different land cover features. A typical edge enhancement algorithm consists of a usually square window that is systematically moved through the image, centered successively in each pixel. A new digital value is calculated using original value and the local average five adjacent pixels. The output value is the difference between twice the input value and the local average thus increasing the brightness of those pixels that are already brighter than the local average and decreasing the brightness of pixel that are already darker than the local average. Thus the effect is to accentuate difference in the brightness especially at edges which is given value difference greatly from the local average (Campbell and Wynne, 2011).
The edge enhancement technique enhances edges only, high frequencies signify the large degree of tonal variation within a small spatial distance. Pixels that occur at the transition between two categories are exaggerated by edge enhancement filtering to make the digital image sharper than its original (Pratt, 1978; Sabins 1986). The blur edges of the original image shows rapid change in the DN values and sharp edges or boundaries between different land use features has been observed which helps analyst to classify image. The edge enhanced image clearly distinguishes the two features due to sharp edges which when compared with the original image. Figure 6.3 (a-c) represents edge enhanced image, a small area is subjected to edge enhancement filter and results are presented in Figure 6.3 b and 6.3 c. The edge enhanced image shows sharp edges of open forest, open scrub, plantation, overburden dumps and mining pits from each other which on original image are not so prominently seen.
Figure 6.3: (a) Edge enhancement filtered IRS LISS III image
(b) Original image (c) Edge enhancement image
6.3.2 Band ratioing:

Band ratioing is an enhancement technique mainly used in the field of remote sensing (Muniz et al., 2008). Band ratioing images are prepared by dividing the DN value in one band by the corresponding DN value in another band value for each pixel (Sabins, 1996). A major advantage of ratio images is that they convey the spectral or colour characteristics of the image features, regardless of variation in scene illumination condition. Ratioed images are also used for discriminating the subtle spectral variations in a scene that are masked by the brightness variation in the image from individual spectral bands or in standard color composite (Lillesand, 1994). This enhanced discrimination is due to the fact that ratioed images clearly portray the variation in the slope of the spectral reflectance curves between the two bands involved, regardless of the absolute reflectance value observed in the bands.

In the present study band ratioing was done in order to find out variation in spectral reflectance in different bands. The four ratio images are green/red (band 2/3), red/green (band 3/2), red /NIR (band 3/4) and green /NIR (Band 2/4). Figure 6.4 (a – d) shows ratio image which enhance different features as

a In green/red (band 2/3) ratio image, mining area and water body represents light tone because water and mining reflects more light in green band than in red band (Figure 6.4 a).

b In red/green (band 3/2) ratio image, open forest along the periphery of the G.B. pant reservoir, plantation and settlement has been enhanced and prominently displayed with light tones (Figure 6.4 b).

c In red /NIR (band 3/4) ratio image, ridges, exposed rocks, settlement and water body are prominent features and represents light tones (Figure 6.4 c).

d In green /NIR (Band 2/4) ratio image water body and linear features like roads and rivers are prominent with light tone whereas forest appears with dark tones (Figure 6.4 d).

Ratio images can also be used to generate false colour composite by combining three monochromatic ratio data sets. Those composite have two fold advantages of combining data from more than two bands and presenting the data in colour, which further increase the spectral reflectance differences.
Figure 6.4: Band ratioing images (a) green/red (b) red/green.
The ratio images were combined on the basis of the total variance present in each ratio and the degree of correlation between the ratios, combination containing the most variance and least correlation is assumed to convey the greatest amount of information throughout a scene. The ratio composite image has been produced by combining 3/4 (red/ NIR), 2/3 (green/red) and 3/2 (red/green) ratio images as RGB. The colour in this image represents many land use/land cover features such as pink represents mostly dense forest, open forest, open scrub and plantation, yellow to light yellow represents water bodies, rocky area, mining pits, settlement and ash ponds, whereas cultivated land give dark greenish tint and uncultivated land, wasteland give reddish purple tint (Figure 6.5).
Figure 6.5: Colour ratio composite of bands 3/4, 2/3 and 3/2 as RBG.
6.4 Normalized difference vegetation index (NDVI):

The normalized difference vegetation index (NDVI) is a numerical indicator that uses the visible and near infrared bands of the electromagnetic spectrum, and is adopted to analyze remote sensing measurements and assess whether the target being observed contain live green vegetation or not (Holm et al., 1987). NDVI has a wide range of application in vegetation studies using remote sensing.

\[
\text{NDVI} = \frac{(\text{NIR} - \text{RED})}{(\text{NIR} + \text{RED})}
\]

The NDVI algorithm subtracts the red reflective values from the near infrared and divides it by the sum of near infrared and red bands. It has been used as an indicator of the vigour of vegetative activity as reported by indirectly observable chlorophyll activity (Hastings and Emery, 1992).

NDVI is the direct indicator of the plants photosynthesis activity and can be used as an indicator of relative biomass and greenness index, values can range from –1.0 to 1.0 but the vegetation value typically ranges between 0.1 and 0.7, higher index values are associated with higher levels of healthy vegetation cover, whereas clouds and snow will cause index value near zero showing the vegetation is less green (Boone et al., 2000).

NDVI generated from IRS P6 LISS III ranges from 0.08 to -0.16, representing higher values for land use/land cover categories such as cultivated land, dense forest, open forest, open scrub and plantation. Lower NDVI values – 0.40 indicate absence of green vegetation and represent uncultivated land, waster land, settlement, mining area, overburden dumps, ash pond and water body (Figure 6.6).
Figure 6.6: Normalized difference vegetation index generated from IRS LISS III data