MATERIALS AND METHODS

Describing and monitoring of basin, watershed and sub watersheds are one which have attracted the attention of foresters, geographers, ecologists and other scientists interested in the spatial distribution of natural resource. At present, usage of remote sensing technology for various resource monitoring has not only been tested and demonstrated but it is also being routinely applied in an operational way. Satellite remote sensing has demonstrated a large potential to obtain information especially for high-resolution sensors. The remote sensing devices are being constantly improved to acquire high-resolution remotely sensed data. However the spatial and spectral bands in which sensors collect the remotely sensed data are two important parameters in mapping and development of forest resource and watershed management system.

The scientific community has looked increasingly towards the remotely sensed data as a means of obtaining more accurate land cover information for wide range of applications because of its receptivity and internally consistent measurements. Geospatial technologies, such as remote sensing, Geographical Information System (GIS), and Global Positioning System (GPS) provide vital support to collect, analyze and store all types of geospatial information. Vegetation characteristics derived from remotely sensed data are particularly important for both qualitative and quantitative forest assessment. Traditionally, watershed boundaries are drawn manually onto a topographic map. But who draws the boundaries uses topographic features on the map to determine where a divide is located. Now computer programs are used to derive watersheds from DL:Ms. Using computer technology, we can generate preliminary watershed boundaries in a very accurate way. Delineation of watersheds can take place at different spatial scales. According to Garbrecht and Martz 2000, a large watershed may cover an entire stream system. In point based method, we derive a watershed for each select point. The select point may be an outlet, a gauge station or a dam. It helps to assess the structure of the vegetation cover and watershed model and functions involved within this.
SATELLITE DATA:
The different satellite images were used for Hasdeo river basin study:

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Satellite</th>
<th>Sensor</th>
<th>Path Row</th>
<th>Date of Pass</th>
<th>Spatial Resolution</th>
</tr>
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<td>01</td>
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<td>TM</td>
<td>142 44/45</td>
<td>11.11.1999</td>
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<tr>
<td>04</td>
<td>IRS-P6</td>
<td>LISS 3</td>
<td>102 55/56</td>
<td>29.10.2008</td>
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<td>TM</td>
<td>142 44/45</td>
<td>16.12.2009</td>
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</tbody>
</table>

IMAGE PROCESSING AND GIS SYSTEMS:

Following hardware and software were used for image processing and GIS analysis:

A. Hardware:

During present study the image processing was carried out in a system with Pentium Processor, 1GB RAM and 24 bits Graphics Windows acceleration Board with resolution of 1024 x 768.

B. Software:

a. ArcGIS for GIS analysis
b. ERDAS IMAGINE 9.0 software for image processing
c. MS Office XP: MS-Excel. Ms-Word for word processing
Fig. 1 Original satellite imagery of IRS-P6 LISS 3 (2008) covering the whole Hasdeo river basin area.
PRELIMINARY INTERPRETATION:

The study is primarily based on topographical sheets on scale 1:50,000 published by the Survey of India (SOI). Near twenty five sheets has been used for study on (Scale 1: 50000) number.
64-1/3, 1/4, 1/6, 1/7, 1/8, 1/10, 1/11 and 1/12
64-J/1, J/2, J/5, J/6, J/7, J/8, J/9, J/10 and J/11
64-K/9 and K/10

The three (Scale 1: 250000) toposheets numbers covers the study area are 64J, 64J and 64K. Pre field visual interpretation of imagery was carried out on False Colour Composites (FCC) using image elements such as tone, texture, pattern, location, association and shadow.

GEOMETRIC CORRECTION:

Subset of satellite images were rectified for their inherent geometric errors using digital topographic maps in Modified Universal Transverse Mercator coordinate system obtained as reference material. It is applied to raw data to correct errors of perspective due to earth curvature and sensor motion. Some of these errors are commonly removed at the sensors data processing centre. The common uniformly distributed Ground Control Points (GCPs) were marked and imagery was resampled by nearest neighbour resampling method. The resampling method used the nearest pixel without any interpolation to create the warped image (Richards, 1994; Jensen, 1996). Images through image-to-image registration technique with rectification error of 0.108 pixels were accepted during the process of geometric correction. A very high level of accuracy in georeferencing of the images were possible because of the use of digital source as the reference data that allowed zooming to the nearest possible point location. The area of study was extracted by overlaying the boundary. The local enhancement was carried out for taking the GCPs and also in the later stage of mapping. Digital data pertaining to hasdeo river basin and its watersheds were subjected to digital classification for stratifying various forest types. The images used were scanned, saved in *. tiff format and registered to
the digital topographic maps. This allowed direct comparison of features between the images during the selection of sample plots for use in image classification and accuracy assessment of classified images.

**SATELLITE IMAGE ANALYSIS:**

Image processing techniques employed so far have generally concentrated on aspects related to data manipulation namely image restoration, image enhancement and information extraction. Non-uniformity of detector characteristics and contamination of image data by diffuse reflection from the atmosphere, both of which are wavelength sensitive, are the primary causes of image restoration. Evaluation of spatial and temporal changes and their linkages with other contextual or collateral data sets require development of powerful analytical tools for collecting, storing, retrieving, transforming, integrating and displaying all the relevant parameters, either in isolation or in conjunction. Raw, remotely sensed image data gathered by a satellite are representations of the irregular surface of the watershed area. Even images of seemingly flat areas are distorted by both the curvature of the earth and the sensor being used. Principal Components Analysis (PCA) technique is used in study for the transformation of multispectral images of IRS P6 LISS3 (fig 1).

**DATA GENERATION:**

The development of the GIS, which brings together diverse information from a variety of sources, enabling information, is a significant development in success of the field of remote sensing data processing. The prerequisite to geographic analysis is that the data is in proper format for the software used to perform analysis. It is very important that the data is free of all type of errors and the data is well structured. It should be insured that a functional geographic database containing the number of associated coverage is available, where coverage contains clean topology, accuracy of all features and attributes are verified and a system of tics or ground control points exists. The digital format offers flexible input as well as output. Hence, this has been used to its maximum
capability. For the present study a number of geographically analyzed layers were prepared viz., drainage network, contours, forest type, forest cover type and settlement etc. The digital satellite data of IRS acquired from NRSC were evaluated on ArcGIS.

Digital Elevation Maps (DEM) was prepared by digital presentation of the continuous variation of relief over space. By means of digitized contour lines of 1:25000 scaled topographic maps in every 20m interval, DEM of the study area were performed by using interpolation procedure. The classification image dated 2008, superimposed with DEM in order to obtain better visualization. Reliability of data sources, frequency of the points selected on the land.

The zoomed imaged were studied wherever necessary. The interpretation key necessary for identifying different features were developed systematically on the basis of image characteristics and associated elements viz. shape, size, shadow, pattern, colour/tone, texture, association, location and available ground truth. Among these characteristics shape, size, shadow and pattern are basically dependent on the scale of the image whereas the colour / tone and texture depends upon the brightness, contrast and resolution of the image. The data were generated for landuse/landcover classification.

CLASSIFICATION OF SATELLITE IMAGES:

The supervised maximum likelihood classification technique for the classification of all the images was used. This rule requires that the operator must have the knowledge of the study area so that representative training sets can be chosen efficiently. These training sets represent a range of land-use/land-cover in the study area, eg. forest, agriculture field, scrubland, water bodies etc. For producing forest land use maps of 1999, 2006, 2007, 2008 and 2009 of the hasdeo basin and to investigate changes that occurred between these periods, the following five forest land use classes were considered in image classification: dense forest, non forest, open forest, scrubland and water bodies. Choice of these forest land use classes were guided by: (i) the parameters to be studied (ii)
expected certain degree of accuracy in image classification and (iii) the easiness of identifying classes on the images. In the other phase forest land use maps of 2008 of different sub watersheds in Hasdeo basin were produced and analysed.

Among the forest land use classes, dense forest and non forest are the most complex class for the sub watersheds. In fact, it includes other combinations of land use. For dense forest land class: sal forest, sal mixed forest, mixed miscellaneous forest, dry deciduous forest and teak forest land classes were considered whereas, non forest land class includes agriculture land with crop and agriculture land without crop were considered.

After selectively combining classes, classified images were sieved, clumped and filtered before producing final output. Classified images were then exported to ERDAS Imaging 10.0 and rest of the analysis was performed in Arc View GIS Version 9.2 environment. The images were first converted to grid and then to shape format. The polygon themes so generated were exported to Arc Info GIS Version 9.5.2 (ESRI, USA) and polygon of <0.5 ha in size were eliminated in Arc Info. This elimination was necessary to minimize the effects of classification errors arising from resolution.

**CHANGE DETECTION OF FOREST LAND USE/LAND COVER (LULCC):**

The most commonly used land change detection methods includes; image overlay, classification comparisons of forest land use/cover, change vector analysis, principal component analysis and image rotation. The method used in the study was classification comparison of forest land use/cover statistics. This method was adopted because the study sought to find out the quantitative changes in the areas of the various forest land use/cover categories. The forest land use/land cover polygon themes for 1999, 2006, 2007, 2008 and 2009 obtained from the digital classification of satellite data and subsequent GIS analysis using the method describing above. The area converted from each of the classes to any of the other classes was computed. The number of land use plots
under each forest land use class, their areas and perimeters in 1999, 2006, 2007, 2008 and 2009 were determined using information contained in the forest land use maps developed for respective periods.

FIELD SURVEY:

A reconnaissance survey was carried out to the whole Hasdeo basin area and then randomly selected areas of the hasdeo basin were examine to recognise the variation of watersheds and vegetation types found on the ground to their respective tonal variation on satellite image. For identifying the actual location we have used GPS (Global Positioning System) by feeding actual latitude and longitude which is calculated through topo sheets and Google earth. Various observations were noted on hasdeo river basin and its watersheds viz. vegetation types, soil type, forest land cover variation, forest fire condition, agriculture fields, settlements, water bodies etc. Major forest types in the basin watersheds are observed on existing maps images. All roads, major drainage, contours (for hilltops), agriculture fields, canals, dam were traversed for collecting ground truth. The literature survey and interaction with forest department, hasdeo river basin department and local institutions were also made for collecting the past/present status of forest, land use change etc.

Informations were acquired from the local forest officials, water resource department and from the local people through interaction/formal interviews, regarding previous/past status of Hasdeo river with its watersheds, forest and its distribution, soil types, forest fire activities and land use/cover dynamics.

The population variation in the different tehsils of the sub watersheds of the hasdeo basin have also been recorded for analysing the Rural and Urban population pressure on the sub watershed and how much they are dependent upon the forest resources as well water bodies.

For the fire study in the basin area MODIS data were interpreted of the year 2006-2008. It provides the fire prone areas identification in the different sub watersheds of the basin.