CHAPTER 4

MATERIALS AND METHODS

The impact of mining on groundwater quality and quantity is there in any mining activities. However, the impact scale is varying from mine to mine depending upon the magnitude of mining, geological and hydrogeological setting in the area. Singrauli coalfields having large mining activities. Both public and private sectors mining are going on this basin. A systematic methodology has been developed to conduct the study in order to achieve the stipulated objective. A brief of materials and methods are given in the subsequent paragraph.

4.1 Secondary data collection

Some secondary data, literature, map and site characteristics were also collected from the following different district offices of the governmental agencies.

a. Northern Coalfield Limited (NCL), Singrauli
b. CMPDIL Singrauli
c. Geological Survey of India (GSI), Kolkata
d. Indian Meteorological Department, Kolkata
e. Central Ground Water Board
f. Agriculture Management and Extension Training Institute

The literature related to the study area has been reviewed by consulting various research journals, articles and e-learning sources such as e-books, web surfing, etc.

4.2 Instrument and software used

Global Positioning System (GPS) was used to obtain the geographical coordinates of the observed field location during the ground truth study for monitoring the water table and collecting groundwater samples. ERDAS Imagine 2013, QGIS and ArcGIS 10.5 software used for prepared different thematic maps and water quality maps. Grapher 8, Surfer 9, AQUA version 1.1.1 and SPSS 20 were used for the evolution of the geogenic and anthropogenic sources of the elemental chemistry in the water resources of the study area.

4.3 Methodology adopted for assessment of groundwater level fluctuation

The groundwater level (mbgl) of the dug-wells were monitored to assess the trend of water-level fluctuation (WLF) in the study area. The research objective is accomplished by the preparation of thematic maps of various hydrogeological parameters by using remote sensing and GIS, which parameters have significant impact on groundwater level fluctuation. The detailed methodology adopted for carrying out the research is shown in the flow chart (Fig 4.1).

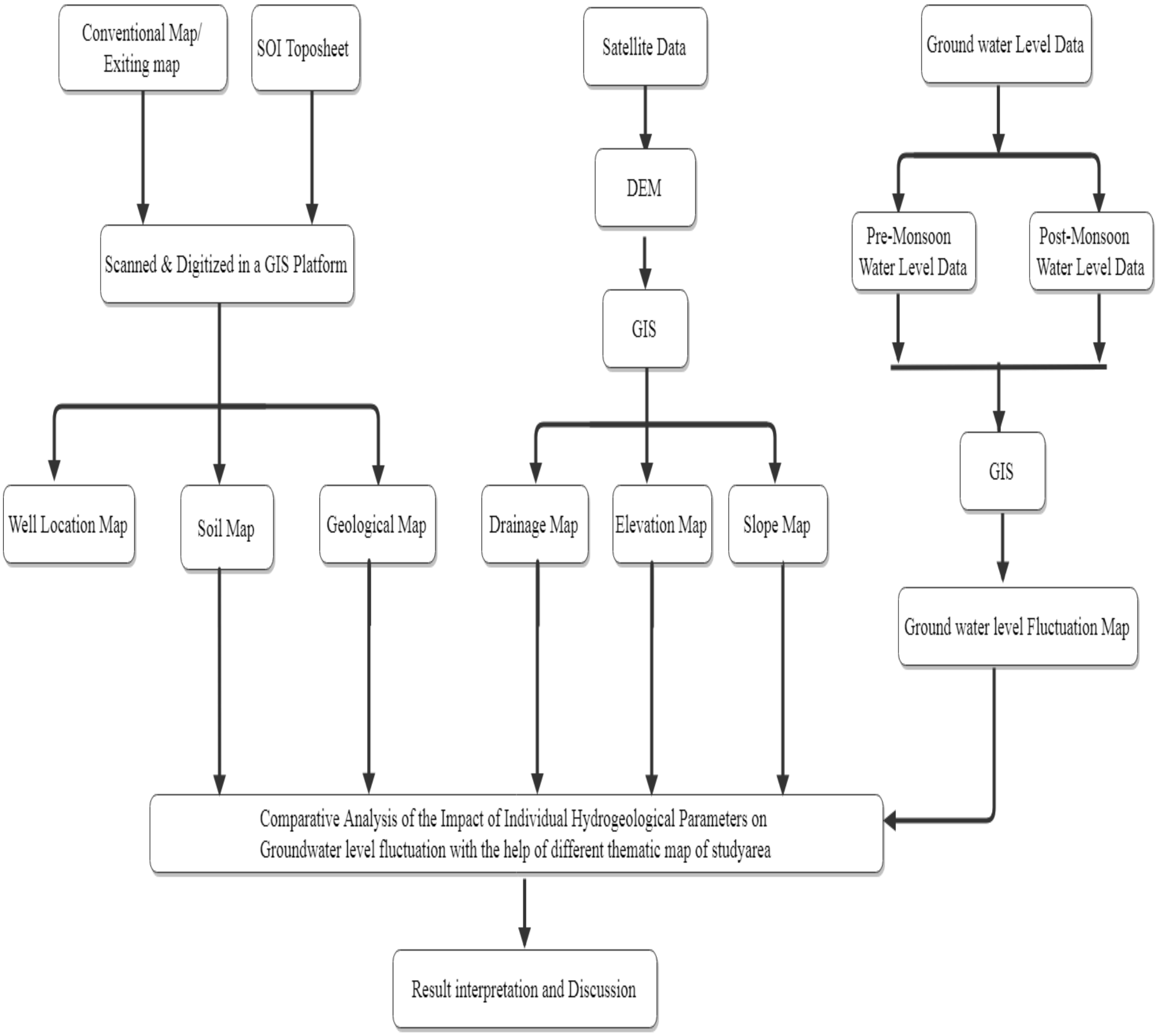

Figure 4.1 Methodology adopted for carrying out the objective

4.3.1 Preparation of various thematic maps

The Survey of India Toposheet were digitized in the ArcGIS platform to generate the base map of the study area. The geological map and soil map was collected from the central mine planning & design institute limited, Singrauli and the state agriculture management and extension training institute respectively were digitized in ArcGIS platform. The slope map, elevation map and drainage map of the study area were extracted from the digital elevation model (DEM) generated from ASTER data and exported to ArcGIS software.

4.3.2 Groundwater level monitoring

A total of eighty-six (86) dug-wells were selected for monitoring the groundwater level around eleven different mining projects of NCL Singrauli such as Kakri, Bina, Marak, Khadia, Dudhichua, Jayant, Nigahi, Amlohri, Moher, Gorbi and Jhingurdah.

Figure 4.2 Sensor-based water level indicator

The depth to the groundwater level of dug-wells of the study area has been recorded by using a sensor-based water level indicator is shown in Fig 4.2. Pre-monsoonal and post-monsoonal groundwater level (mbgl) data have been monitored in the month of April and November for the year 2016.

Figure 4.3 Photograph showing monitoring of groundwater level

4.4 Methods for computing groundwater potential zone

The present research was carried out to various groundwater potential zones for the assessment of groundwater availability in the study regions have been delineated using remote sensing, GIS and MIF techniques. The methodology adopted to determine the groundwater potential of the study area consists of three main steps.

In the first step, the identification of the thematic layers which are relevant to the groundwater potential. Six thematic layers such as lineament, land use/land cover, geology, drainage, slope, and soil has been prepared to delineate the groundwater potential zones.

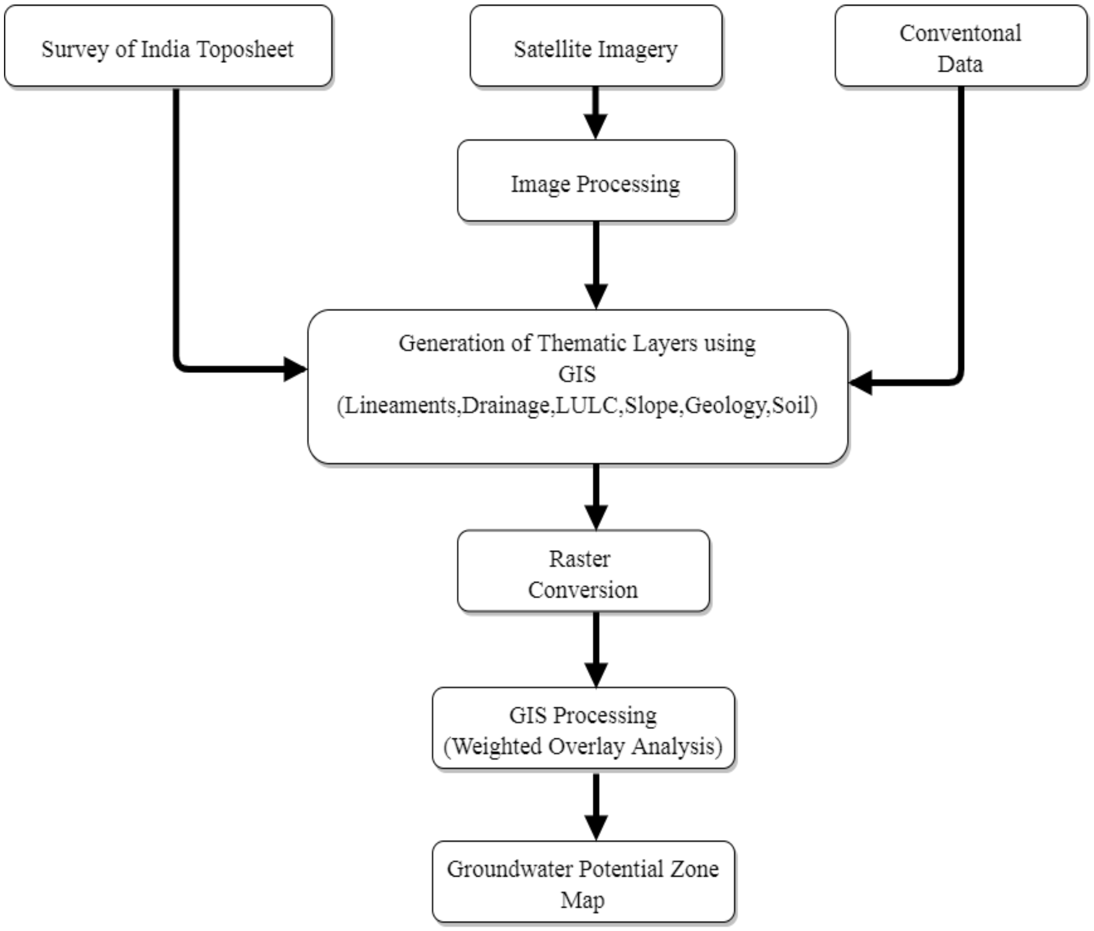

Figure 4.4 Flowchart for delineating the groundwater potential zone

In the second step, these thematic layers were transformed to raster format (30 m resolution) using the feature to raster converter tool in ArcGIS. The raster maps of these factors are allocated a fixed score and weight computed from the multi-influencing factor (MIF) technique.

In the third step, the groundwater potential zones of the study area were obtained by overlaying all the thematic maps in terms of weighted overlay methods using the spatial analysis tool in ArcGIS**.** During weighted overlay analysis, the ranking was given for each parameter of each thematic map and weights were assigned according to the multi influencing factor (MIF) of that particular feature on the hydro-geological environment of the study area (Shaban et al., 2006). The methodology adopted for the present study is shown in Fig. 4.4.

4.5 Sample collection, Preservation and Analysis

4.5.1 Groundwater sampling techniques

Before selecting the sampling sites a preliminary survey of the study area was conducted. To assess the groundwater quality or chemistry under natural conditions of the study region, a systematic sampling of groundwater was carried out during dry seasons in the month of May, 2018. For sample collection, preservation, and analysis, standard methods (APHA 2005) were followed. A total of forty-six (46) groundwater samples were collected from different locations that are covering all the mining block areas of the Singrauli coalfields. All the groundwater samples were collected from the hand pumps and tube wells. The groundwater samples were collected in 1000 ml narrow mouth pre-washed polyethylene bottles. Prior to each fieldwork, polyethylene bottles were washed in the laboratory with dilute hydrochloric acid and then rinsed twice with double distilled water.

At the sampling sites, before collecting the samples bottles were also washed with the water samples. Coordinates of the sampling points are collected using Garmin GPS and marked on the map. The collected water samples were immediately sealed and labeled to provide identification at later dates. Proper care was taken to avoid any changes in the quality of groundwater samples during the handling of water samples from the study area to the laboratory of IIT (BHU) Varanasi. The location map of the various sampling stations of groundwater samples is shown in Figure 5.19 (Chapter-5).

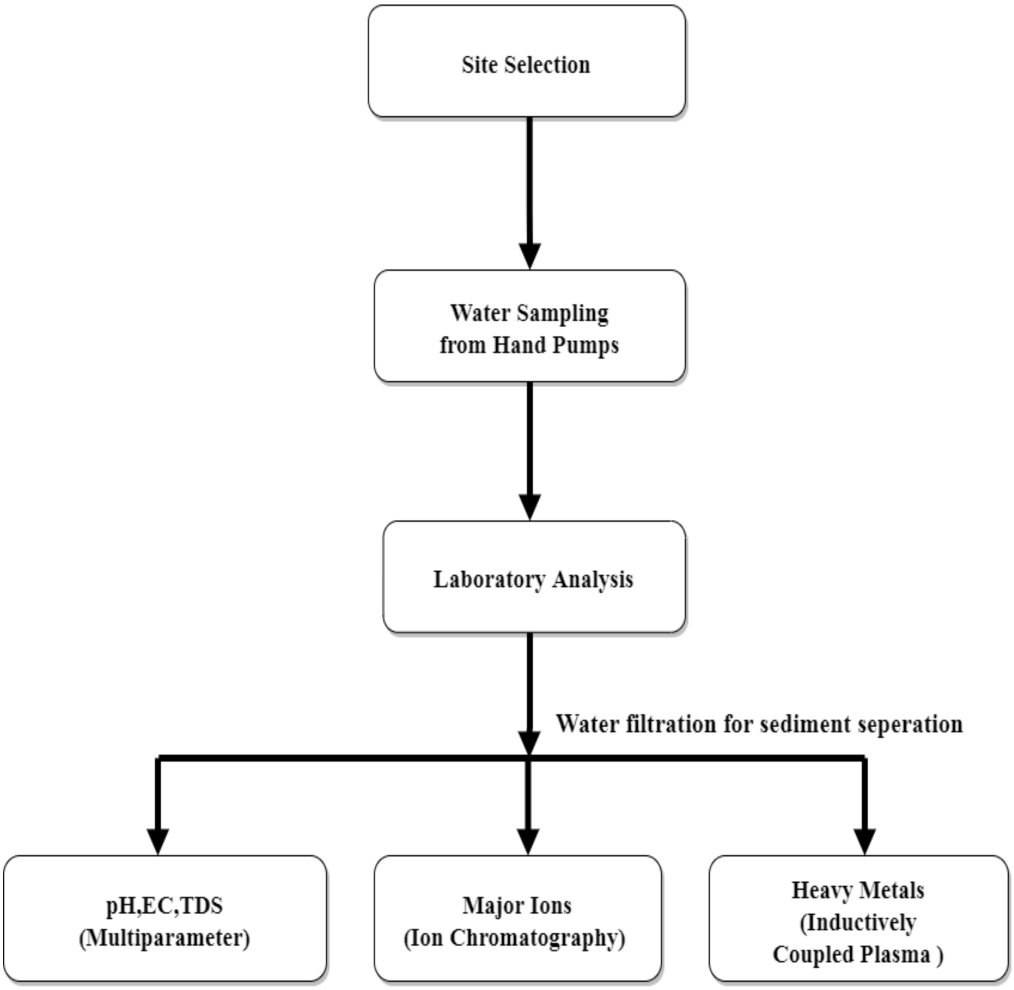

Figure 4.5 Flow chart of analytical methods

Figure 4.6 (a) Field photograph showing sampling of groundwater

Figure 4.6 (b) Field photograph showing sampling of groundwater

4.5.2 Preservation of groundwater samples

Proper preservation practices must be followed and can be found for each analysis. Immediate analysis of water samples is ideal, otherwise all water samples were brought to the lab and stored at 4°C to avoid any chemical alteration. The groundwater was collected in two sets from each location in polyethylene bottles, one after filtered through Nylon Syringe filter and acidified to $pH < 2$ with HNO_3 for metal analysis and the other set for different ions analysis as per APHA (2005) standard methods.

4.5.3 Labelling of groundwater samples

Label the sample container properly, preferably by attaching an appropriately inscribed label. Before the container was used, it should be labelled as follows:

- **a.** Sample code number (Identifying location)
- **b.** Name or place of sampling station
- **c.** Date and time of sampling
- **d.** Source and type of sample either raw or final
- **e.** Sampler's Name

Figure 4.7 Photograph showing collected groundwater samples

4.5.4 Separation of suspended sediments

Suspended sediments were eliminated from the groundwater samples in the laboratory by using Nylon Syringe filter of 0.22 µm size with the help of Syringe.

4.5.5 Methods of analysis

Analysis of groundwater samples was followed according to the American public health association (APHA 2005). Polyethylene bottles (100 ml) were used for the collection of groundwater samples for the analyses and delivered to the laboratory of the IIT (BHU). The concentration of major ions and heavy metals of groundwater samples were estimated by using the different analytical methods at the different departments of IIT (BHU). The details of analytical methods are summarized in Table 4.1 and Fig 4.5.

Table 4.1 Analytical methods used for water quality analysis

S.No	Parameters	Instruments/ Methods	Laboratory
1.	pH, EC, TDS,	Portable Multi-parameter Analyser	Deptt. of Mining Engg. IIT BHU Varanasi
2.	Major Cations	Ion Chromatography(IC)	Central Instrumental Facility Centre of IIT (BHU).
3.	Major Anions	Ion Chromatography(IC)	Central Instrumental Facility Centre of IIT (BHU).
Heavy Metals			
4.	Fe, Cu, Pb, Cd, Cr, Ni, and Zn	Inductively Coupled Plasma (ICP-MS)	Interdisciplinary School of Life Sciences (ISLS) BHU,

Hydrogen ionic concentration (pH), Electrical conductivity (EC) and Total Dissolved Solids (TDS) were measured by using multi-parameter analyser at the laboratory of department of mining engineering (Fig 4.8).

The concentration of major ions such as Sodium(Na^+), Potassium(K^+), Magnesium(Mg^{2+}) and Calcium (Ca^{2+}), Fluoride (F^-), Chloride (Cl^-), Nitrate (NO_3^-), Sulphate (SO_4^{2-}), ions in groundwater samples were estimated by using Ion Chromatography (IC) at Central Instrumental Facility Centre of IIT (BHU) Varanasi (Fig 4.9). Bicarbonate concentrations were determined respectively by acid titration methods (APHA 2005). The physicochemical analysis of the groundwater samples were evaluated against the drinking water guidelines outlined by the World Health Organisation (WHO, 2011) Standards.

For the analysis of heavy metals, the groundwater samples were filtered through Syringe filter (0.22 µm) to separate the suspended particles. The concentrations of heavy metals such as Fe, Cu, Pb, Cd, Cr, Ni, and Zn were determined in groundwater using Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) at Interdisciplinary School of Life Sciences (ISLS) BHU, Varanasi (Fig 4.10).

Figure 4.8 Photograph showing (A) Multi-parameter (B) Analysis of water samples using multi-parameter kit

Figure 4.9 Photograph showing analysis of water samples using Ion Chromatography

Figure 4.10 Photograph showing analysis of water samples using ICP-MS

4.6 GIS analysis for various water quality parameters

The spatial analysis of various physico-chemical parameters and heavy metals was carried out using the ArcGIS software. In order to interpolate the data spatially and to estimate values between measurements, an inverse distance weighed (IDW) algorithm was used. The IDW technique calculates a value for each grid node by examining surrounding data points that lie within a user-defined search radius (Burrough and McDonnell 1998). All of the data points are used in the interpolation process and the node value is calculated by averaging the weighted sum of all the points.

4.7 Calculation of CCME Water Quality Index

The Water Quality Index (WQI) is calculated using the Canadian Council of Ministers of the Environment Index method. The CCME WQI was developed with the intent of providing a tool for simplifying the reporting of water quality data (CCME 2001). The formulation of the CCME WQI is described in the Canadian Water Quality Index 1.0 – Technical Report (CCME 2001). Essentially, the model consists of three measures of variance from selected water quality objectives (Scope, Frequency and Amplitude). The "Scope (F1)" represents the extent of water quality guideline non-compliance over the time period of interest. The "Frequency (F2)" represents the percentage of individual tests that do not meet objectives. The "Amplitude (F3)" represents the amount by which failed tests do not meet their objectives. These three factors combine to produce a value between 0 and 100 that represents the overall water quality.

Factor 1: F_1 *(scope)*

Scope assesses the extent of water quality guideline non-compliance over the time period of interest, which means the number of parameters whose objective limits is not met. It has been adopted directly from the British Columbia Water Quality Index:

$$F_1 = \left(\frac{\text{Number of failed variables}}{\text{Total number of variables}}\right) \times 100 \tag{4.1}$$

Factor 2: F_2 *(frequency)*

The frequency (i.e., how many occasions the tested or observed value was off the acceptable limits) with which the objectives are not met, which represents the percentage of individual tests that do not meet the objectives ("failed tests"):

$$F_2 = \left(\frac{\text{Number of failed tests}}{\text{Total number of tests}}\right) \times 100 \tag{4.2}$$

Factor 3: F_3 (amplitude)

The amount by which the objectives are not met (amplitude) that represents the amount by which the failed test values do not meet their objectives, and is calculated in three steps.

The number of times by which an individual concentration is greater than (or less than, when the objective is a minimum) the objective is termed an "excursion" and is expressed as follows. When the test value must not exceed the objective:

$$\text{Excursion}_i = \left(\frac{\text{Failed test value}_i}{\text{Objective}_j}\right) - 1 \tag{4.3}$$

For the cases in which the test value must not fall below the objective:

$$\text{Excursion}_i = \left(\frac{\text{Objective}_j}{\text{Failed test value}_i}\right) - 1 \tag{4.4}$$

The collective amount, by which the individual tests are out of compliance, is calculated summing the excursions of individual tests from their objectives and then dividing the sum by the total number of tests. This variable, referred to as the normalized sum of excursions (nse) is calculated as:

$$\text{nse} = \frac{\sum_{i=1}^{n} \text{excursion}_i}{\text{Number of tests}} \tag{4.5}$$

F_3 is then calculated by an asymptotic function that scales the normalized sum of the excursions from objectives (nse) to yield a value between 0 and 100.

$$F_3 = \left(\frac{nse}{0.01nse+0.01}\right) \tag{4.6}$$

The CWQI is finally calculated as:

$$\text{CWQI} = 100 - \left(\frac{\sqrt{F_1^2+F_2^2+F_3^2}}{1.732}\right) \tag{4.7}$$

The CCME WQI values are then converted into rankings by using the index categorization schema presented in Table 5.7 (Chapter-5). The index produces a number between 0 (worst water quality) and 100 (best water quality). These numbers are divided into five descriptive categories to simplify presentation.

4.8 Statistical analysis

The correlation matrix was prepared in Microsoft excel 2016. Box-plot diagram to show the minimum, maximum and mean value and it was prepared by Origin 8 software. Hierarchical Cluster Analysis is used for grouping water samples by similar monitoring sites in their chemical composition and HCA was prepared by using SPSS software.

4.9 Methods adopted for analysis of land use/land cover changes

The mining activities result in change of topography, drainage pattern (Akiwumi and Butler, 2008; Khan and Javed, 2012; Manna and Maiti, 2014, 2016) and major environmental impact comes out as physical disturbance such as landscape change, soil erosion, degradation and general environmental changes (Dhar et al., 1991; Prakash and Gupta, 1998). In the present study, the unsupervised classification has been applied to the multi-date Landsat data sets collected over time (1990, 2000, 2009, and 2019), that provided recently and used to evaluate land use/land cover changes and coal mining expansion in the study regions.

4.9.1 Data Source

The satellite data used for of land use/land cover (LULC) classification are derived from Landsat-5 Thematic Mapper for the years 1990, 2000 and 2009, whereas Landsat-8, Operational Land Imager-OLI data sets are used for the year 2019. The source for land use/land cover dynamics was freely downloaded Landsat imagery from http://earthexplore.usgs.gov. The detail of the satellite data are presented in Table 4.2**.** These data were used for classification and overall accuracy assessment of the classified images. Employing multi-dated TM Landsat data sets of Singrauli coal mining area, various digital image processing techniques were adopted to prepare LULC maps of the study area for the years 1990, 2000, 2009 and 2019.

Table 4.2 Remote sensing data and their source used for the study

Data used	Dates of acquisition	Path/row	Resolution(m)	Source
Landsat-5	11/02/1990	142/43	30 × 30	earthexplorer.usgs.gov
Landsat-5	10/03/2000	142/43	30 × 30	earthexplorer.usgs.gov
Landsat-5	15/02/2009	142/43	30 × 30	earthexplorer.usgs.gov
Landsat-8	11/02/2019	142/43	30 × 30	earthexplorer.usgs.gov

4.9.2 Mapping

The Earth Explorer satellite data were subject to radiometric and geometric (ortho-rectified with UTM/WGS84projection) corrections and standard FCC were generated for land use mapping (Prakash and Gupta, 1998). The LULC information can be obtained from the multiband raster imageries through the process of image interpretation and classification (Li et al. 2014).Six main land use/land cover classes were implemented by unsupervised classification method (ISODATA technique) with the help of ERDAS Imagine software (Areendran et al., 2013). The classified images were cleaned using recode process. Post-classified images were cleaned for obtaining better accuracy results and for reduction of misclassification (Harris and Ventura, 1995).

4.9.3 Change analysis

To get changes of the LULC classes during the study period i.e., from 1990 to 2019. Land use/land cover area distribution results were used to compute the trend, net change, percent change and rate of change between the years 1990 -2000, 2000 – 2009 and 2009 – 2019.

4.9.3.1 Percent change estimation

To calculate the change in percentage (%), initial and final LULC areal coverage was compared using the following formula:

$$\Delta\text{A (\%)} = \frac{A_{t2} - A_{t1}}{A_{t1}} \times 100 \tag{4.8}$$

Where, ΔA (%) = Percentage change in the area of LULC class type between initial time A_{t1} and time period A_{t2},

A_{t1} = Area of land use and land cover type at initial time.

A_{t2} = Area of land use and land cover type at present time.

4.9.3.2 Rate of LULC change

The rate of change of land use and land cover type was calculated by using the following formula:

$$\text{R}\Delta\left(\frac{\text{km}}{\text{year}}^{2}\right) = \frac{\text{X} - \text{Y}}{\text{A}} \tag{4.9}$$

Where, RΔ = Rate of change X = Recent area of LULC type in km^2, Y = Previous area of LULC type in km^2, A = Time interval between X and Y in years.