1.1 Introduction

Accurate and reliable information on distribution of Earth resources as well as their level of degradation, depletion and contamination is very relevant for environmentally balanced economic development. The remotely sensed data, by virtue of its repetivity and synoptic coverage along with its computer compatibility, makes significant contribution towards this goal. The application of Remote Sensing and Geographic Information System (GIS) can facilitate better outcome in the environmental impact assessment of clay mining. The developmental needs of the state and the need of neighbouring states have necessitated vast lands to be quarried, so as to cater to the corresponding escalation in demand for brick and tiles. In order to meet this demand, the surface occurrence of clay is mined extensively and often unscientifically. The paddy fields of the state, which have got a vital role in the eco-balance of the area, are virtually destroyed leading to an irreversible ecological imbalance. When land becomes degraded its production declines, unless steps are taken to restore productivity and further losses. Tile/brick clay mining is present in 12 districts of Kerala except in Idukki and Pathanamthitta. Thrissur district has one of the leading clay mining sectors in Kerala.

Thrissur district formed on the 1st July 1949 and it is situated in the central part of Kerala and is also known as the ‘Cultural Capital’. The name “Thrissur” is the abbreviated form of “Thrissivaperur” and is related to the famous Siva (Vadakkunatha) Temple, the abode of Lord Siva. The total area of the Thrissur district comes to 3,032 sq.km which accounts 7.8% of the geographical area of the Kerala State. It ranks the 5th in area among the districts, with a population of 31,10,327 persons (as per 2011 Census), the district accommodates 9.32% of the total population of the state and stands 4th place. The literacy rate of the district is 95.32%. The district consists of five taluks viz. Talappilly, Chavakkad,
Thrissur, Kodungallur and Mukundapuram. Thrissur taluk, which includes Thrissur Municipal Corporation area is the most populous taluk of the district both as per 1991 and 2001 census. Thrissur city alone accounts 38% of the urban population in the district. The district is well connected by road and rail transportation. The nearest airport at Nedumbassery, near Kochi, is located at the distance of 55 Km and Kochi port lies at a distance of 80 Km from Thrissur town.

Thrissur district is bounded on the North by Malappuram and Palakkad district, on the East by Palakkad district and Coimbatore district of Tamil Nadu, on the South by Ernakulam and Idukki districts and on the West by the Arabian Sea (Fig. 1.1). The district is leading in its production of clay bricks and tiles for construction. This has led to extensive mining of clays which in turn has adversely affected the hydrological system, landform and land use system of the district. The clay mining affected taluks of the district are Talappilly, Thrissur, Mukundapuram and Chavakkad.

Fig. 1.1: Location map of Thrissur district
1.2 Conceptual Background

The term environment is broadly interpreted into whole complex of physical, social, cultural, economic and aesthetic factors which affect individuals and communities and determine their form, character, relationship and survival. Environmental impact is any alteration of environmental conditions or creation of a new set of environmental conditions, adverse or beneficial, caused or induced by the action(s) under consideration. Environmental Impact Assessment (EIA) is a new concept emerging to achieve judicious balance between economics and ecology through internalization of environmental quality considerations in decision making process. EIA essentially includes establishing quantitative values for selected parameters which indicate the quality of natural system and environment before, during and after the proposed interdisciplinary and objective decision making tool with respect to alternate routes for development, process technology and project sites. It also possesses tremendous potential as a policy instrument for ensuring ecological modernization for sustainable development.

The history of urbanization in India reveals that every year about 3 million rural people migrate to the cities and this flow is also showing a steady increase. In Kerala, 12 districts possess the tile/brick industry. Thrissur district is leading in Tile/brick production since the paddy land possess good quality clay. According to Kerala State Land Use Board (1981), among the 294 tile/brick manufacturing factories in the state, 135 were in Thrissur district. The brick manufacturing units of the area were causing serious threat to the ecosystem of the area are mostly seasonal and there is no available data for any period. While preparing a report on the conversion of paddy land in the state (1989), Kerala Statistics Institute made a systematic documentation of the area affected by tile and brick clay mining in various districts of Kerala. Thrissur district was the worst affected due to clay mining. The study conducted by Centre for Earth Science Studies (2004) in tile and brick clay mining and environmental problems of Chalakudy basin, reveals that around 2.92 sq.km was found to be abandoned.
clay mining area. Active clay mining was reported from 0.96 sq.km area. So the total clay mining affected area was 3.88 sq.km. As per the Kerala State Remote Sensing and Environment Centre report (2007), the active clay mining area, water logged clay mining area and fallow land generated were mapped using LISS-IV data (2005) and found increased than the previous records. The total clay mining affected area was 13.16 sq. km. Tile/brick clay is included in minor minerals in Kerala and its excavation is found to increase from 1,73,670.60 Tonne to 3,62,907.40 Tonne during 2003-2008 in Kerala. The KSCSTE report (2011) shows that near Chalakudy bridge area, Thrissur district, clay mining, transportation of mined clay and its processing, improper solid waste disposal cause notable changes in surface water quality. So it is essential and high time to conduct a study which can bring out the existing environmental situations due to tile/brick clay mining and can suggest scientific measures for the sustainable land use.

1.3 Review of Literature

The earliest studies related to open cast mining, tile/brick clay mining and the related environment problems stress that mining activities, as it has got direct and indirect imbalance on the ecobalance should be carried out only with scientific approach. Estimates suggested that the clay brick industry is degrading the fertile top soil to the extent of 20,000 ha. every year in India, thereby causing severe land degradation. In Kerala, particularly in the study area very limited studies are carried out in clay mining aspect.

1.3.1 Opencast Mining

Venkataraman et al. (1992) have studied environmental impact of open cast Iron ore mining using IRS-1A FCC on 1:50,000 scale. It covers over 2500 sq.km enclosing about 40 working and non-working pits in Goa. The environmental problems studied under this programme include land degradation and water pollution. In order to assess the water quality, optimum
band ratio image pertaining to the water bodies alone was generated by determining the actual maximum and minimum band ratio values and using these to code maximum and minimum grey values of the ratio image. Three zones were identified in waterbodies using level slicing techniques and correlated with shallow, deep and turbid water. Kirk (2001) studied the issues of compatibility and sustainability of mining, land use, and water quality in developed countries. It reveals that mineral resource production is vital to modern and industrialized societies. Air, water and soil resources are disturbed and degraded during mineral extraction and processing.

Kandrika et al. (2003) assessed the impact of iron ore mining on agricultural land using erosion-deposition model and space borne multispectral data in part of Goa state, South-Western India. The mining reserves are prominently seen in the Bicholim and Satari taluks. The data sets used are IRS-1C LISS-III and PAN data and SOI toposheet on 1:25000 scale. Both the images were resampled to 6 m spatial resolution. Entire image was classified using Gaussian Maximum Likelihood per-pixel classification. The Digital Elevation Model was also derived from the contour and other themes viz., land use, drainage and soil erodability were used for the analysis. Open cast iron ore mines, piles of over burden material and iron ore, scrubs, grasslands, mixed forests and agriculture lands are the major land use/land cover changes encountered in the study area. The study concludes that the sediment concentration from the mining area is very high as compared to undisturbed areas, which are protected well with the natural vegetation cover.

Babu et al. (2007) studied the quality of surface and groundwater around tile and brick clay mines in the Chalakudy river basin, Southwestern India. The study reveals that the concentration of certain chemical components like pH, DO, BOD, EC, TDS, Chloride, Hardness and Nutrients (N, P and Si) in groundwater from clay mine areas is high compared to that from non-clay mine areas. High incidence of bacterial contamination is observed in well waters, which stresses the need for proper treatment prior to human consumption.
Hegde et al. (2008) studied sand extraction from agricultural field around Bangalore. The field investigation and physico-chemical factor analysis reveals that sand supply from the river beds and sand taken by washing the surface soil have adversely affected the rural livelihood and agriculture sector. Brick industry was also found as major source of land degradation. Major problems noticed were loss of surface soil, nutrient losses, crop yield losses, siltation of tanks, groundwater depletion and soil erosion. The study suggested for a comprehensive policy to make the enterprise ecologically tolerable and safe.

Suraj et al. (2009) studied GIS approaches for sustainable mining of tile and brick clay, Parappukkara Panchayath, Thrissur district, Kerala by using LISS-IV data of 2005, SOI toposheet and secondary data. The study reveals that places such as Mulangu and Thottipal were found as suitable sites for tile and brick clay mining (3-4 m), derived through overlay analysis of relevant themes viz. land use, geomorphology, hydrology, depth of clay availability, status of mining, colour of clay and transportation facility. Mining of clay below such critical depth may affect hydrology, land use, geomorphology and soil fertility. Backfilling of abandoned mining pits with top soil, pisciculture in waterlogged mining pits and cultivation of vegetables and seasonal crops in degraded land were suggested as management plans.

Gupta and Narayan (2010) have studied the long-term impacts of brick kiln industry to biomass and diversity structure of plant communities in Bulandshahr, Uttar Pradesh. Floristic survey of the study site was done at monthly intervals from June 2003 to December 2004. Above ground (AGB), below ground (BGB) and total biomass (TB) of each plant species were calculated (gm⁻²). Dominance-diversity curves were prepared by plotting relative dominance of a species against species sequence. The brick kiln generation over the years not only covers the neighbouring area of vegetation with layers of brick dust, but also consistently dissipates heat all around. The study reveals that long-term brick kiln industrial activity affected the soil characteristics and concomitantly the structure of the plant biomass (particularly
the below ground) and species diversity. This structural alteration is suggestive of adaptational implications for plant communities in anthropo-ecosystems.

**Suraj et al.** (2011) studied clay mining impacts and management priorities for Nenmanikkara panchayath, Kerala using Cartosat-1 data of 2011. The study reveals that clay mining activity is changing the surface expressions of the landform, land use, soil fertility and hydrologic system when mined beyond the critical depth. Konnikarapadam, Cheruval, Madavakkara-1, Madavakkara-2, Nenmanikkara, Pazhai, Manali, Thalore-1 and Thalore-2 are the clay mining affected places in the panchayath. Proper management measures were suggested to curtail further degradation of the agricultural land.

**Dasgupta et al.** (2012) conducted a case study of the impact of mining on rural environment and economy in Kota district, Rajasthan. Kota district is well-known for its Kota-stone. Normalized Difference Vegetation Index (NDVI) has been taken as an indicator of land degradation. NDVI values were derived from both the images of 1991 and 2001, separately for agricultural and non-agricultural land, with proper masking. The study states that space technology and Geoinformatics along with ancillary data play an important role to assess the overall impact of mining on land degradation status, process, severity, and also on changes in economic structure and condition. It is due to deforestation and improper mining practices which is leading towards not only to a substantial deterioration in environmental quality but also a significant change in economic condition. Finally appropriate conservation measures like filling of work out pits, plantation in areas where mining is ended, use of waterlogged mining pits for recreational purpose and use of waste materials in cement industry were suggested to sustain the good quality of life in mining area.

### 1.3.2 Land use / Land cover

**Raghavswamy et al.** (2001) studied the assessment of land use and land resource pattern of Wadi limestone mining area and environment, Gulbarga district, Karnataka using IRS-1D LISS-III and PAN merged data of December
2000 and handheld GPS. Different land use classes were delineated and GPS has enabled the identification of geographic locations and positions of smaller units of built-up features on satellite imagery.

**Sikdar et al.** (2004) studied land use/land cover mapping from 1972 to 1998 and groundwater potential zoning for future groundwater development using remote sensing & GIS techniques in Raniganj area, West Bengal. The study indicates that the land covered by vegetation and settlement has decreased at the expense of mining activity, which is reflected in the increase in area of overburden dump, barren land, waste land and abandoned quarry filled with water. The overlay analysis using multi-criteria indicates that the groundwater potentiality is medium with high potential in the stretch along the Damodar river and in small pockets in the Northern part of the study area. The area affected by mining have medium groundwater potential. Therefore, the pumped out water from active mining areas should be utilized for domestic and other purposes to tide over the water crisis in the pre-monsoon period. The groundwater abstraction structures feasible in each of the various potential zones have also been suggested.

**Singh and Mohan** (2006) studied the brick kiln industry as drivers of land use change and related land degradation in rural-urban fringes of Delhi. The study reveals that the fringe which was meant to be an area of mixed land use outside the city, is slowly loosing its rural character, while catering to the urban requirement. The brick industry has played a significant role in altering the land use pattern of the fringe area, from agriculture and related activities to quarrying and consequent renouncing of the land as barren and uncultivable.

**Suraj et al.** (2006) studied clay mining and its impact in the land use and hydrologic system of Nenmanikkara Panchayath, Thrissur district, Kerala. The study states that the extent of paddy field was reduced at the expense of clay mining activity which is reflected in the increase in the area of fallow land and waterlogged area and also the clay mining activity is changing the surface
expression of the landform and land use. Total of 8 active clay mining area of the panchayaths were identified using the geospatial techniques.

Pangelova et al. (2006) studied land cover and land use change detection and analysis in Plovdiv, Bulgaria, between 1986 and 2000. Slope and elevation data were used as ancillary data. A 90 m digital elevation model (DEM) was resampled to 28.5 m and was used to produce second environmental variable slope. An unsupervised classification was performed on the data using the ISODATA clustering algorithm. A supervised classification was performed using cluster-sampling approach. The study shows that the urban areas increased by 9.1%, agriculture decreased by 3.8%, forest decreased by 2.6%, barren decreased by 4.3% and water increased by 1.6%.

Rashid et al. (2011) assessed land degradation in Budgam district, Kashmir, Himalaya, using Landsat-enhanced thematic mapper plus (ETM+) data of 2008 and advanced space-borne thermal emission and reflection radiometer (ASTER), digital elevation model (DTM) with spatial resolution of 30 m were used for the study. Drainage and slope map of the study area were derived from ASTER (30 m) DEM using ArcGIS hydrology module and ERDAS Imagine respectively. Normalized differential vegetation index (NDVI) was generated from the ETM+ imagine in ERDAS. Different thematic maps generated using satellite data are geology, drainage, land use/land cover, NDVI and slope. All maps were converted to raster data using 30 x 30 m grid cell size and georeferenced to UTM projection, Zone 43. The study recommended that slightly degraded areas can be recovered with the proper land use planning and detailed monitoring.

Roy et al. (2012) developed geospatial model for the identification of potential hot spots of land-use and land-cover changes for biodiversity conservation in Goa, India. The study indicates that the deciduous forest in Ponda taluk is most prone to the degradation and land cover change. This is logical due to the mining activities and development of infrastructure. The area
in the state which fall under level 4 and 5 hot spots have high to very high biological richness that needs to be conserved on a priority basis.

1.3.3 Clay Minerals

Deepthi and Balakrishnana (2005) have explored the climatic control on clay mineral formation evidence, from weathering profiles developed on either side of the Western Ghats. They made an attempt to understand how the nature of clay minerals formed due to weathering differs, in tropical regions receiving high and low rainfall using X-ray diffraction technique. The study states that the weathering of rocks to the west and east of Western Ghats leads to the development of distinctly different clay mineral suites in the weathering profiles. The extent of chemical weathering is more in the western part as evidenced by clay mineral assemblages dominant in iron aluminium oxyhydroxides and kaolinite irrespective of the parent rock type. Weathering profiles in the eastern part have more complex clay mineralogy and indicate less intense chemical weathering.

Diju and Thamban (2006) has explained the dominance of Kaolinite and Gibbsite in the sediments of Chandragiri river-estuary system, Kasaragod, Kerala. Spatial distribution of the texture and detrital clay minerals in the estuarine system and the shallow marine domain of the river provide insight on the sediment provenance as well as the intensity of weathering in the drainage area. The dominance of Kiolinite and Gibbsite in the sediments points to the intense chemical weathering that has taken place in the drainage basin under the prevailing warm and humid conditions. The major source rocks contributing towards the clay mineral distribution in the study area are the Precambrian crystalline rocks, laterites and the tertiary sedimentary formations exposed along the coastal belt.

Kotaky et al. (2006) examined characterization of clay minerals in the Brahmaputhra river sediment, Assam, India. XRD, FTIR and DTA studies on clay fraction of the Brahmaputhra river sediment revealed that Kaolinite is the
dominant mineral species with minor amount of Chlorite and Illite. This assemblage of clay minerals indicates a fluctuating nature of physico-chemical conditions operating within the studied stretch of the braided Brahmaputra river basin. Identification and characterization of clay minerals help in understanding probable nature and mechanism of active erosion processes, and may find use in flood mitigation and management approaches for the perennial flood affected part of North East India.

Shekhawat and Sharma (2009) have studied the mineralogical characteristics and mineral economics of Kaolinite deposit of Sawa area, Chittaurgarh, Rajasthan. The clay deposit of the area occurs as a prominent band near to the ground surface having a thin soil cover (1 to 4 m) and characterized by presence of lithological zoning. XRD, DTA, petrographic and SEM studies shows that Kaolinite is the only clay mineral and quartz, feldspar, biotite, muscovite, calcite and hematite are non-clay minerals in Kiolinite deposit of the area. Also suggested to upgrade the Kaolinite by suitable method of beneficiation for its appropriate and extensive utilization.

Schmatzm et al. (2010) analysed clay smear processes in mechanically layered sequences-results of water-saturated model experiments with free top surface. Displacement field was quantified using PIV (Particle Image Velocimetry). The study using analogue sand box model of fault gouge evolution in a layered sand-clay sequence states that in sufficiently thick layers, the stiffness of the clay has the strongest effect on fault gouge evolution. The evolution of fault gouge in sand-clay sequences is a complex interplay of kinematics and mechanics, with several feedback mechanisms. Weak, undercompacted clay is more prone to be enriched in the fault zone and forms a continuous smear, while strong, over consolidated clay first deforms in a brittle fashion but may be reworked to a soft gouge with ongoing fault movement.

Srivastava et al. (2011) studied characterization of clay minerals in the sediments of Schirmacher Oasis, East Antarctica: their origin and climatological
implications. The work encompasses the identification of various clay minerals through X-Ray Diffraction (XRD), Differential Thermal Analysis (DTA) and Thermo Gravimetric Analysis (TGA). Clay minerals, such as Chlorite, Illite, Kaolinite, Smectite and Vermiculite have been identified in the loose sediments of ice sheets, main land, including lakes, and shelf area. Illite is noticed to be a dominant mineral followed by smectite and vermiculite, whereas chlorite is found occasionally. Most of the clay minerals are formed due to weathering and alteration of highly metamorphosed terrain of Schirmacher in the cold climate.

1.3.4 Groundwater

Jain et al. (2003) highlighted the hydrochemistry of the Hindon river, India: Seasonal variations and quality-quantity relationships. The study states that the river Hindon is subjected to domestic and industrial pollution because of absence or poor enforcement, of water pollution control laws and regulations. The seasonal variations in the intensity of rainfall cause both the quality and quantity of flow of the rivers to vary widely. During the wet season, storm runoff conveys both suspended and dissolved matters into the rivers. It is recommended that the waste water generated by the municipal areas of Saharanpur, Muzaffarnagar and Ghaziabad be treated and utilized for irrigation through an organized network and the industrial units discharging their effluents directly into the river without any treatment should install effluent treatment plants.

Mondal and Singh (2004) developed a new approach to delineate the groundwater recharge zone in hard rock terrain of Dindigal district, Tamil Nadu. Cross-correlation of rise in groundwater level and precipitation is used to classify entire study area into various zones depending on variability on coefficient of correlation. Thus most favourable zones for artificial recharge were delineated.

Rai et al. (2005) identified groundwater prospective zones using Remote Sensing and Geoelectrical method in Jharia and Raniganj coal field of Dhanbad
district of Jharkand state. The study reveals that the area is very complex and in
general does not hold high potential for groundwater development through
deep tube/bore wells. But they could bring out the close relationship among the
geomorphic, hydrogeologic and geophysical parameters of groundwater. Three
groundwater potential zones (high in category first, moderate in category second
and low in category third) have been identified in the study area.

Panigrahy and Raymahashay (2005) studied the river water quality in
weathered limestone of upper Mahanadi basin, India. X-Ray Diffractogram
(XRD) of limestone rocks showed presence of a significant amount of Calcite,
Dolomite and Ankerite. The study reveals that congruent/incongruent
weathering is the characteristics of the basin. The river water was
undersaturated with respect to Calcite and Dolomite resulting in aggressive
chemical weathering of limestone. Carbonate weathering in the basin is a
primary factor influencing the quality of Mahanadi water.

Jasrotia and Singh (2005) studied the groundwater vulnerability using
DRASTIC Model in Devak-Rui Watershed, Jammu region, India. The study
reveals that pollutants from land fills, over use of fertilizers and pesticides,
septic system which enter the aquifer, can become a serious problem and can
result in groundwater contamination. Based on the DRASTIC method study it
was suggested that proper management approaches for areas which are
vulnerable to groundwater pollution should be adopted to provide a long term
pollution free groundwater supply. Mukerjee and Kumar (2005) assessed
groundwater quality in the south 24-parganas, West coast, India. Groundwater
quality of 46 groundwater samples were collected randomly from tube
wells/bore wells to monitor water chemistry of various ions. More groundwater
samples were suggested for analysis to establish physico-chemical variations
and trends in the study area. A GPS based groundwater sampling strategy was
proposed for accurate correlation of chemical signatures with subsurface
hydrogeology.
Ravishankar and Mohan (2005) studied a GIS based hydrogeomorphic approach for identification of site-specific artificial-recharge techniques in the Deccan volcanic province. The study demonstrates application of Remote Sensing and GIS techniques in the identification of site-specific watershed management techniques to enhance the groundwater potential in the area. The role of GIS and Remote Sensing for groundwater-potential zonation and conservation is being fully realized only since the last decade. The current multiparametric approach using GIS and remote sensing is holistic in nature and will minimize the time and cost especially of identifying suitable site-specific recharge structures on a regional as well as local scale, thus enabling quick decision-making for water management rather than adopting conventional practices.

Rao et al. (2007) studied the temporal change in the groundwater quality in the industrial area of Visakapattanam, Andhra Pradesh and found that \( \text{SO}_4^{2-} \) concentration was higher than the permissible limit due to prolonged industrial activity. The concentration of \( \text{Ca}^{2+} \), \( \text{Mg}^{2+} \), \( \text{Na}^+ \) and \( \text{Cl}^- \) were also higher. The study emphasizes the need for regular groundwater quality monitoring to assess pollution activity from time to time for taking appropriate management measures in time to mitigate the pollution activity.

Kumar and Riyazuddin (2008) studied the application of Chemometric techniques in the assessment of groundwater pollution in a sub-urban area of Chennai city and reveals that Factor Analysis (FA) is more effective in identifying the compositional differences of water quality data and Discriminant Analysis (DA) is more effective in grouping the sampling stations based on the extent of pollution and its spatial and temporal variations. The study indicates the need for proper industrial planning and the safe disposal of industrial and urban waste which would otherwise lead to severe environmental degradation.

Srinivasamoorthy et al. (2008) studied the major sources controlling groundwater chemistry from a hard rock terrain in Mettur taluk, Salem district,
an important industrial town. The study indicates that weathering of silicate minerals control the major ion chemistry of calcium, magnesium, sodium and potassium. Chlorine was dominant due to anthropogenic impact (human sources). The ion exchange and reverse ion exchange control the water chemistry of the study area.

**Mondal et al.** (2009) studied the aquifer characteristics and its modeling around the industrial complex, Tuticorin, Tamil Nadu. Integrated hydrogeological, geophysical and tracer studies were carried out in the coastal region encompassing an industrial complex. The combination of factors such as the industrial plant area having thick cover of clay soil and calcretic clay and low velocity of groundwater flow indicates that there is remote chance for contamination of groundwater sources in the down stream through movement of groundwater with pollutants originated inside the complex.

**Manjusree et al.** (2009) studied the hydrochemistry and groundwater quality in the coastal sandy clay aquifers of Alappuzha district. Groundwater qualities of Chennam-Pallippuram panchayath have been extensively monitored in summer from January to May, 2007 to assess its suitability in relation to domestic and agricultural uses. Overall evaluation during the study period showed that the groundwater in the area is soft to hard, oligohaline to brackish and slightly acidic in nature. The dominance of the cations and anions showed the following order: \( \text{Ca}^{2+} > \text{Mg}^{2+} > \text{Na}^+ > \text{K}^+ \) and \( \text{HCO}_3^- > \text{Cl}^- > \text{SO}_4^{2-} \). The Piper trilinear diagram revealed that the alkaline earth metals exceed alkalies and strong acids exceed weak acids for March and May periods (except January).

**Mohammed-Aslam et al.** (2010) evaluated groundwater potential of hard rock aquifer in Kasaragod, Kerala using remote sensing techniques in conjunction with geophysical investigation and yield analysis. The study reveals that the hydrogeological assessment and evaluation of groundwater resources can be improved by integrating the analysis of land cover classification of satellite data and resistivity surveys in areas having varied groundwater
resources. Yield performance of the tube wells in different land cover confirmed the existing correlation among the respective land covers, resistivity values and groundwater potential. Crop land and sparsely vegetated land cover showed good and bare lands showed low groundwater potentials respectively.

Kannan et al. (2010) examined the quality of groundwater in shallow aquifers of a paddy dominated agricultural river basin, Kerala. The study on physico-chemical parameters of 120 water sample locations in monsoon, post-monsoon and pre-monsoon seasons indicated that spatial and temporal variation of attributes do exist in the study area. The stress zones in the study area were delineated using ArcGIS spatial analyst and various management options were recommended to restore the ecosystem.

Prasanna et al. (2011) conducted hydrochemical analysis and evaluation of groundwater quality in the Gadilam river basin, the main objective of the study has to assess the utility of geochemical data including trace metals and geophysical data for delineating the areas suitable for groundwater development in the entire basin. Trace element concentrations were also noted in the areas of more contaminated zones. In non-contaminated zones, the apparent resistivity values were higher indicating the non-polluted nature of groundwater.

Neelakantan and Yuvaraj (2012) evaluated the groundwater status of Salem taluk, using geospatial data. The themes like geology, lineament density, geomorphology, drainage density, slope and land use/land cover were prepared from LANDSAT and SRTM satellite data. Then, ranks and weightages were assigned to all the thematic data, based on the groundwater prospects. The groundwater potential zones were identified by using Boolean logic method. The study reveals that the high groundwater potential zones are falling in major portions of Veerapandi block and others are priority-wise Pamamarthupatti and Ayothiapattanam.
1.3.5 Soil

Karale (1992) have studied developments, status and prospects in soil studies using IRS-IA satellite data. According to him, two major elements of field soil survey are (i) soil profile studies, and (ii) traversing for plotting soil boundaries. Aside from its penetrability through clouds, SAR data has a capability to highlight erosional and micro-relief features and enable estimation of soil moisture. Advancement in knowledge based expert system foretells exciting possibilities in resources management. The future scenario dominated by on-line access to IRS-data, advanced GIS and augmented artificial intelligence would create an information environment to cope up with new challenges and a plethora of new application fields.

Panigrahy et al. (1997) studied the system of growing rice under flooded conditions gives a distinct temporal signature to radar beam in Howrah and Hughly districts of West Bengal. This study indicates that multi-temporal ERS-1 SAR data used in an operational or semi-operational manner for acreage estimation of rice crop grown under rain-fed as well as irrigated condition. The SOI toposheet on 1:50,000 scale was used to image to map transformation through well distributed ground control points (GCPs). All other images were registered to this image through image to image transformation. Data acquired during the early vegetative stages of flooded fields was found essential for accurate map to image registration and to obtain high classification accuracy. This was also found useful to be used as a base map for collecting field level information for subsequent passes. Two date data: one acquired around 30 days of transplantation and another after 30 days was found optimum for early estimation of rice acreage.

Asadi et al. (2008) analyzed and mapped the soil quality in Khandaleru catchment area, using remote sensing and GIS. The study states that the rapid increase in human population had increased the stress on natural resources, including the soil. Soil degradation impacts agricultural production and
adversely affects other interrelated natural resources. Soil sample were collected from four different seasons (March, June, September and December) and computed Soil Quality Index (SQI). The spatial and attribute database generated were integrated for the preparation of spatial distribution maps of selected soil quality parameters like pH, Electrical Conductivity (EC), Ca, C, Mg, \( \text{SO}_4 \), Nitrate, Phosphorus, Potassium, bulk density, moisture content, Organic Matter (OM) and SQI. The study reveals that OM, Potassium, Phosphorus are within permissible limit in the Khandaleru reservoir. Fifty-eight percentage of the samples collected around the reservoir were of poor/average quality, while the remaining 42% are of good quality. The area of poor soil quality were observed to be located downstream of reservoir, and good water quality was observed upstream of the reservoir.

**Velmurugam et al.** (2009) assessed soil resources mapping using remotely sensed data and GIS in Solani river using IRS-P6, LISS-III, Landsat TM, SRTM and SOI toposheet. The study of soil from different physiographic units revealed that nature of parent material, topography and time are the factors responsible for the pedogenic differences in the soils developed on different physiographic units.

**Hedge et al.** (2011) states in soil degradation that extent and severity of various forms of land degradation is alarming at present. In India, the latest estimates indicates that soil erosion, salinity and alkalinity, waterlogging and declining soil fertility has affected about 57% (187.8 m ha) of the land resources in the country, threatening the sustainability of the resource base. Two major processes that lead to soil’s capacity to perform its functions are intrinsic and extrinsic process. Soil degradation due to mining is an intrinsic process because it changes their physical, chemical and biological properties. At the same time those prevent their use by other causes is extrinsic process. Soil degradation due to brick making and sand extraction are intrinsic process. The situation needs immediate attention of all the stakeholders, from policy makers to farmers, involved in the management of the limited land resources of the Earth.
1.4 Remote Sensing, GIS and GPS

1.4.1 Remote Sensing

It has emerged as a very useful tool for mapping and monitoring of various natural resources. Remote Sensing is the science and art of obtaining information about an object, area, or phenomenon through the analysis of data acquired by a device that is not in contact with the object, area, or phenomenon under investigation (Lillesand and Kiefer, 1979). The integration of remote sensing with the conventional system of mapping and monitoring provided accurate and reliable information in a timely and cost-effective manner. Through this technology, the extent of mining and mining affected zones can be mapped and changes can be studied by comparing the temporal satellite data. After evaluating the status, recommendations can be suggested for reclamation of the degraded zones.

1.4.2 Geographic Information System (GIS)

This is “an organized collection of computer hardware, software and geographic data, and personnel designed to efficiently capture, store, update, manipulate and analyze and display all forms of geographically referenced information”. GIS technology integrates powerful database capabilities with the unique visual perspective of a map (Burrogh, 1998). This makes GIS unique among information systems. Its analyses can be used in a wide range of public and private enterprises, helping in planning, cost reduction and better informed decision-making.

1.4.3 Global Positioning System (GPS)

It is a space-based satellite navigation system that provides location and time information in all weather, anywhere on or near the Earth, where there is an unobstructed line of sight to four or more GPS satellites. It is maintained by the United States government and is freely accessible to anyone with a GPS receiver. It can be used to spot the mining locations in the Earth surface.
1.5 Application of Remote Sensing and GIS in Mining

Mining in general, and open cast mining in particular may lead to severe environmental degradation. Remote sensing by virtue of synoptic coverage at regular intervals, is quite useful in monitoring land disruption due to mining, detection of mine fires, mining revegetation, and monitoring of reclaimed lands, water pollution assessment, monitoring and detection of land subsidence. With the advent of GIS, many mining activities (from exploration to development, and production to mine rehabilitation) evolved from pure luck to science. GIS replaced old map-analysis processes, traditional drawing tools, and drafting and database technologies. The major applications in mining sector are as follows:

- Targeted mineral exploration, evaluate mining conditions, model mine construction and display data such as geochemical or hydrological.
- For applying mining permits, assessing environmental impact, formulation of management plan and designing closure and reclamation plans.

1.6 Objectives

The study on environmental impact of tile/brick clay mining has been undertaken with the following precise objectives:

- To study land use/land cover pattern, geomorphology, soil characters and hydrology of the study area using remotely sensed data, GIS and GPS.
- To identify the mining affected areas and assess the impact over landforms and hydrological systems.
- Integrated all the parameters using GIS techniques and suggest remedial measures for curtailing further degradation and reclaiming the degraded zones.

1.7 Study Area

Thrissur district in the state of Kerala, in India is the study area and it covers an area of 3,032 sq.km and district has 5 Taluks, 17 Blocks, 1 Corporation,
6 Municipalities and 92 Panchayaths. It is located in the central region of Kerala state lying between 10°13’00” and 10°44’00” North latitudes and 75°39’00” and 76°52’00” East longitudes. It is falling in the Survey of India Toposheet No. 58B/1 to B/8, B/11 and 49N/14. The district is well connected by road and rail. Canoli canal is the major canal present in western part of the district for water transportation (Fig. 1.2).

![Study Area Map](image)

**Fig. 1.2: Study area**

### 1.8 Methodological Framework

The study identified the extent of clay mining and the effect of mining on the environmental aspect like landform, hydrology, land use and soil by using high resolution satellite data coupled with field visit and secondary data. After the finalization of parameters, the impact of clay mining was assessed by integrated analysis. The suggestions for sustainable management of the affected area are also recommended. The methodology adopted for the study is given in Fig. 1.3.
Chapter I

Introduction

Fig. 1.3: Methodological framework
1.8.1 Inventory

Mining site inventory was carried out with the help of high resolution satellite data of Cartosat-1 (2010) and LISS-IV (2005) data, Survey of India toposheet (1966), field visit and secondary data. As brick making is only seasonal work, and has limitations to be identified in the satellite imagery. GPS locations are taken to locate the clay mining sites which also helped to separate waterlogged mining sites, from the natural waterbody.

The high resolution Cartosat-1 PAN data having 2.5 m spatial resolution is used for the study. The projection is UTM, Zone 43 and datum WGS 84. The mono georeferenced data in GeoTIFF format were imported to IMG format in ERDAS 9.2 and those data having mismatch with adjacent scene were subjected to edge matching. Total of 16 scenes (Path: 539, 540, 541, 542, 543, 544, 545 and Row: 345, 346, 347, 348) were used for the delineation of clay mining area in the district.

1.8.2 Geomorphology

The geomorphic units were delineated using the satellite data sources and field visit. The impacts of clay mining to alluvial plains and valley fills were analyzed as these units are the locations for clay mining.

1.8.3 Land use Pattern

Land use classes such as paddy fields, valley fills cultivation and fallow lands were studied. The changes in land use/land cover pattern were analyzed in ERDAS (9) with the help of temporal satellite data, toposheet and field survey.

1.8.4 Hydrologic Aspect

The surface water and groundwater aspects were dealt with separately. In the surface water component, waterlogged area and drainage choking was identified by using satellite data, toposheet and field survey. In the groundwater component, water level changes and water quality (both physical and bacteriological) was assessed.
1.8.5 Soil

The available soil maps of the district were assessed, the soil profile study (type, texture and depth) was conducted in representative locations of paddy fields and soil quality map was derived.

1.8.6 Analysis

In analysis part, cropping pattern, land use/land cover changes, the clay mining impacts in hydrology, status of clay mining and virgin area, site suitability and recommended depth are discussed.

1.8.7 Recommendations

Optimal utilization of degraded lands for agriculture calls for their reclamation and proper management. Information about these lands on their nature, extent, spatial distribution and magnitude of the problem is a prerequisite for their reclamation. Remote Sensing data, both from areal and space platforms have been found very useful for providing information on various aspects of degraded lands since sixties (Dwivedi and Venkataratnam, 1992). Proper recommendations were suggested to curtail further degradation of the paddy field and already degraded zones due to tile/brick clay mining.

1.9 Hypotheses

Following hypotheses related to objectives for the study on clay mining in Thrissur district have been cited. An attempt has been taken to establish the hypotheses regarding ecological imbalance due to clay mining from paddy fields and its impacts to natural resources. The hypotheses are as follows:

- **Ecological imbalance**

  When extensive clay mining happens in the paddy field which has got a vital role in the ecobalance of the area and are destroyed, it will create an irreversible ecological imbalance.
• **Impact on hydrology, landform, land use and soil**
  The unscientific mining in paddy fields for the production of clay bricks and tiles for building purpose of construction will adversely affect landform, land use, hydrologic system and soil.

1.10 Expected Contribution of the Thesis

The thesis is expected to contribute in understanding the overall environmental condition of the study area by assessing important aspects such as clay mining site inventory, landform, land use, hydrology and soil. The integrated analysis of the data generated for a temporal range of 44 years will provide the following points which will contribute solid platform for generating proper management plans.

- Spatial distribution of clay mining locations in the study area.
- Evaluation of clay mining impacts in landform using the data source.
- Land use changes due to clay mining during 1966, 2005 and 2010.
- The mining impact over the hydrologic system can be evaluated by conducting groundwater fluctuations and groundwater quality study.
- In analysis part, cropping pattern, land use/land cover change, hydrological changes in surface water system, status of clay mining and virgin area can be evaluated. Then land use/cover change analysis can be studied by using toposheet (1966), Landsat MSS (1973), Landsat TM (1990) and LISS-III data (2010). Finally, suitable area for clay mining and recommended depth can be suggested.
- Based on the analysis, recommendations can be suggested for the management of clay mining affected area in the study area.