Clean and healthy environment is necessary for the survival and growth of all living beings. Our present environment and ecology is threatened by anthropogenic activities including mining, quarrying and other industrial activities. The growing concern about environmental degradation has prompted the world to think on a new dimension and address the environment-related issues in a more scientific manner. Sustainable development of any region mainly depends on three important aspects: social progress, economic growth and protection of environment. Increased pressure on land for satisfying the greed of human beings accelerated the interventions in the form of mining, quarrying and unscientific conversion of landuse etc which in turn led to significant land modifications, thereby influencing the biophysical system and adversely affecting the ecological security and environmental stability.

Environment is a composite term denoting the conditions in which organisms live. The environment for living organisms is never constant or static. It always undergoes changes, either slow or rapid. These changes in environment may benefit or harm human beings and other organisms living in it. Most of the anthropogenic activities cause degradation/pollution of the environment. Pollution of the environment is one of the most dangerous crises we are facing today. The major reasons for environmental pollution are urbanization, industrialization, technological revolution and exploitation of natural resources including mining and quarrying activities. The rapid industrialisation has left us with polluted rivers, contaminated soil and air and depleted natural resources. The unlimited rapacious exploitation of nature by man has disturbed the delicate ecological balance existing between the living and non-living components on the earth. The root cause of environmental pollution has been man’s misbehaviour with nature under the false notion that he is the master of nature. This undesirable situation created by man has threatened the very survival of mankind and also other living beings on the earth. The basic necessities for living organisms are air, land and water. Day by day, these basic necessities are getting polluted alarmingly due to rapid industrialisation and large-scale exploitation. In general, pollution is the unfavourable alteration of our environment, largely because of human activities.
There are compelling biological and ethical reasons for preserving certain parts of nature in its primeval state. True conservation is only a very small part of ecological philosophy because immense areas of earth have been continuously, profoundly and perhaps irreversibly transformed by human intervention.

1.1 Mining and quarrying - Indian scenario

Mining in India is an important economic activity which contributes significantly to the economy of India. The mining sector underwent modernization following the independence of India although minerals have been mined in the region since antiquity. The country exports a variety of minerals found in abundance in its geographically diverse regions—while it imports others not found in sufficient quantities within its geographical boundaries. Though in the national economic picture, mineral revenues constitute only a small part, India is currently one of the major mining nations of the world, this fact does not show up in the breakdown of its GDP because of low capital accumulation from many of these mines and the fact that the small quarries and traditional mineral processing activities are part of the ‘informal sector’ of Indian economy which, according to some experts, can be around ~88% (Harriss-White, 2003). However, this kind of mining becomes important because together, these mines employ a very large number of people. In many of these mines, often little or no machines except simple tools are used in the processes, every stage of processing being literally done by the human hand. Again, the importance also lies in the range of minerals mined under Artisanal and Small Mines (ASM) in India, beginning from gemstones and gold to low value bulky products such as gravels, sand and building stones. Whereas the stones are meant primarily for local or domestic consumption, some of these products can have high value and serve non-local markets. Even low value products such as stones may be exported although the exact amount of revenue earned by them is unrecorded. India has a very long history of artisanal mining extending back to the ancient times. Kautilya’s *Arthashastra* (see the English translation by Shamasatry, 1956, p. 82-89) gives detailed instructions on the examination of gems that are to be entered into the Treasury, and on conducting mining operations and manufacture. It describes not only the methods of testing gems, but also of methods of extracting minerals from hard and soft ore bodies, and of making gold and silver coins from the metals thus
obtained: ‘Mines which yield such minerals as are made use of in preparing vessels as well as those mines which require large outlay to work out may be leased out for a fixed number of the shares of the output or for a fixed rent (bhagena prakrayena va). Such mines as can be worked out without much outlay shall be directly exploited (by governmental agency).’ From the documentation, it can be assumed that mining was a well-organised activity around that time in India. So was illegal mining. Arthashastra also gives instructions on dealing with illegal mining. The capital city of Delhi, referred to as Indraprastha in the epic Mahabharata and flourishing since the Mughal times, stands in the middle of Gangetic plains on the edges of Delhi ridge, a part of the Aravalli ranges made of quartzite. The series of empires that used this location as a capital used local stones to build the forts, palaces and mosques. Besides building stones, the mining of which seems to be ubiquitous, there were precious metals such as gold and silver, and the mining of precious and semi-precious gemstones.

Quite a few industries grew up in the ancient times based on the quarries. However, with the advent of British rule and introduction of modern legal frameworks of resource governance, many of the old systems were destroyed and a new system of artisanal mining came into existence. The legal frameworks that were established during the colonial times aimed at controlling the mineral resources of India by the British state. Colonial mining also brought in European models of labour relations and management techniques, and altered the earlier systems. Consequently, the traditional artisanal system of mining gradually moved outside of the legalized sphere of resource governance, thus invisible and in many cases illegal. Thus, in India as in several other post-colonial countries, the ‘legal battle’ has become an established reality in the area of artisanal mining (Cramer, 1990). At present, the Indian mining industry exhibits almost the entire spectrum of extractive and mineral products, including iron ore, coal, lignite, base and precious metals, building materials and gemstones. Operations range from small mining and quarrying through to some of the largest mining operations. Mining practices ranging from major opencast and strip mines, through underground long wall and hard rock ore mines, through dredging operations, oil and gravel extraction, to panning and hand excavation of gemstones are found in the country. India is included among the top ten mineral producing nations in the world, and its economy
benefits from the revenues accrued from minerals output, raising the hope of a possible ‘small scale route of mineral-based development’ (Ghose, 1991; 1986).

Mineral distribution in the country is widespread; the prospective deposits occurring from the fragile foothills of the Himalayas, deserts, arid and semi-arid regions, along vast coastlines, plains and rich forests (Srivastava, 1987 and Kumar, 1997). Quite commonly, mineral deposits are worked in areas considered ecologically sensitive and/or rich in bio-diversity (Rai, 1994; Ghose and Sen, 2001).

1.2 Mining Laws

The Mines and Minerals (Development and Regulation) (MMD&R) Act of 1957 is the main legal framework governing the mines besides the Indian Mines Act of 1952 which is primarily meant for labour welfare and safety and health issues. The Central Government has empowered the respective State Governments to frame their own rules in the case of minor minerals under section 15 (1) of M.M. (D&R) Act, 1957. Accordingly, the State of Kerala has framed its own Minor Mineral Concession Rules, 1967. Subsequently, in pursuance of Granite Conservation and Development Rules (GCDR), 1999, the State Government has suitably amended the KMMC 1967 in tune with GCDR. 1999. These amendments will ensure greater revenue earnings, scientific exploitation, greater regulation and supervision over mining activity, removal of procedural delays and expeditious disposal of applications. In pursuance of the 73rd Amendment to the Constitution of India (Central Act 40 of 1996), a provision has been incorporated in the Minor Mineral Rules to obtain the recommendations of Gram Sabha or Panchayats for granting of leases in the scheduled areas. Thus, the local governments also have some form of control over permitting a mining operation.

1.3 Artisanal and Small scale Mining (ASM)

The artisanal mining practices in India represent an informal, illegal and unregulated system of small-scale mining by local communities, similar to those prevalent in some of the world’s poorest countries and as such do not figure in the official records. Because of inadequate facilities and illegal operations, artisanal miners do not make large profits out of their activities. The artisanal miners even risk their own lives in these unsafe mining operations for making a livelihood for
supporting their families. Some of the profits earned out of mining actually go into the hands of middlemen due to the poor organisation of the economy. Artisanal mining activities have also been noted for creating environmental problems; the most common example being that of mercury pollution in surface water by gold amalgamation, and land surface degradation by unregulated digging. Despite these problems, this mining provides sustenance to many people. It is for this reason that Ghose (2002) estimated that the small scale and the artisanal sector together comprise 95-98% of the entire mining activities in India. This view is supported by Chakravorty (2001), who opines that in reality, the large-scale mines contribute only about 2% of the mining activity in India. Nevertheless, available facts and figures indicate that current ASM practices will continue to be in operation for decades to come (Ghose, 2002; 1994) in spite of the many environmental problems associated with them. Small mines and quarries represent a growing and important component of the mineral sector in terms of output value, contribution to the economy and employment. The increasing importance of small mines and quarries to local and state economies has led to their increased importance as an employment-generating economic activity, in India (Ghose, 2003) and elsewhere in South Asia.

Because little is known of the extent of their production and their technical and environmental implications, there is a need to obtain better information so that the promotion of small-scale mines can proceed in sustainable manner and with effective environmental management practices. Small mining and quarrying is well-known for being inefficient, suffering from poor working conditions, safety and health problems, and causing environmental degradation (Hickie and Wade, 1998).

The states see this quarrying sector as an easy and relatively quick source of revenue generation and, as in most cases they are cash strapped, they prefer to side with the quarry-owners who often have their associations acting as pressure groups on the politicians and the governments. The term ‘unorganised’ is valid primarily in terms of the lack of unionization amongst the quarry workers and their invisibility to the development planners. In reality, the large number of small mines and quarries are part of the burgeoning informal economies of India. However, for mines, the term ‘informal’ comes with the stamp of illegality, and is often rejected by mine-owners and district administrators (Kuntala Lahiri-Dutt, 2006)
1.4 Mining/Quarrying and environment

Mineral commodities are produced either by open cast or underground mining methods. Though both of the methods of operation produce adverse environmental effects, the former method generally has a greater impact. Mining by open cast method in particular has been the cause of more severe environmental damages as compared to underground mining. In India, since opencast mining contributes to as much as 65% of the total production of minerals, environmental pollution due to surface mining activities are rather alarming (Thipathy et al., 1994). The magnitude and significance of the impact on environment and ecology due to open cast mining activity are related to the topography of the area, the nature of the mineral deposits, agricultural activity before the commencement of the operations, the forest resources existing in the area of operations etc. Modern industrial, economic and commercial activities depend a lot on the exploitation and consumption of minerals. The process of extraction of mineral resources and its use in various ways generate a wide range of environmental changes – positive as well as negative impacts. Resource extraction through mining and quarrying activities degrades the environment in various ways. The process of environmental deterioration begins with the resource extraction activity and results in land–water degradation. The various mining/quarrying activities include sand mining from the river channels and from bank areas, soil quarrying, hard rock mining, laterite mining, tile and brick clay mining etc.

1.5 Environmental sensitivity of Kerala state

The state of Kerala with a geographical area of 38,863 km² has a length of 560 km along the coast and width ranging from 11 km to 124 km. The altitude ranging from 5 m below sea level to the soaring heights of 2695 m within the short span of 120 km. Physiographically, the terrain has three natural regions namely, lowlands, midland and highlands. Geologically the state is occupied by four major rock formations namely, crystalline rocks of Pre-cambrian age, sedimentary rocks and recent and sub-recent sediments forming the low-lying areas and river valleys. The varied rock formations under different geological domains host mineral deposits and the transformed rock strata stockpile copious groundwater resource. The state comprises ten soil types derived from the laterite base and has twelve distinct agro-
climatic zones. The state is endowed with 44 rivers formed due to its undulating topography, vibrant climate and vivacious hydrology in the background of ever active tectonics (KSCSTE, 2007). A chain of kayals (back waters) lying roughly parallel to the coastline is another interesting feature of the state. There are 27 estuaries and 7 lagoons in the state. The kayals are mostly connected by natural and manmade canal system. Inland navigation is active along these canal and backwater system. Over 55% of total geographical area is under agriculture and residential use and 28% is under forest, making the state agro-environmentally very sensitive. Only less than 11% area is under non-agricultural use. The coastal plains and lagoons, falling in the lowland is important in terms of economic activity and demographic distribution. Beach dunes, ancient beach ridges, barrier flats, coastal alluvial plains, river terraces marshes and lagoons form part of this unit. The midland consists of dissected peneplains with numerous flood plains, terraces, valley fills and colluviums. The high ranges run parallel to the coast from the extreme north up to the south with a break at the Palghat gap region.

1.6 Mineral occurrence/deposits of Kerala State

The state is endowed with a number of occurrence/deposits of minerals such as heavy mineral sands, Gold, Iron Ore, Bauxite, Graphite, China clay, Ball clay, Fire clay, Tile and brick clay, Silica sand, Lignite, Limestone, Limeshell, Dimension stone, Magnasite, Quartz, Steatite etc. (Department of Mining and Geology, Govt. Of Kerala, 2005). However the mining activities on a large scale are confined mainly to heavy mineral sand, limestone, china clay, dimension stone and minor minerals such as construction grade sand, granite building stone, laterite building stone, tile and brick clay. Mineral occurrence/deposit of the state is shown in Fig.1 and minor mineral quarry distribution in the central region of the state is given in Fig.2.
Fig. 1 Mineral occurrence/deposits of Kerala.
Mining/Quarrying activities in Kerala

The environmental and socio-economic scenarios of the midland and lowland regions of Kerala face serious problems due to indiscriminate quarrying and mining activities. Quarrying operations in the State is mostly to win the minor minerals such as granite building stone, aggregates, laterite, construction grade sand and tile/brick clay. The quarrying activities for the above minerals have been carried out even before the formation of the state of Kerala. Initially quarry operations were on a small scale activity for individual’s sustenance, one’s own house construction etc. without having a quarry plan or proper structure for future development. The recent boom in construction of buildings, road development, sea wall construction etc. has led to a rise in the number of quarries being worked on a permanent basis and an expansion in the size and activity of these quarries. Thus the haphazard and unplanned mining/quarrying activity resulted in environmental degradation including the lowered productivity of the top soil. In general, quarrying/mining activities are accompanied by a variety of environmental impacts, which can
contribute towards degradation of the environment as a whole. The process of environmental degradation starts with the extraction of minerals, resulting in land degradation and addition of pollutants to air and water, continues as the minerals are beneficiated and further processed (Moitra et al., 1994). Man is both, a creator and moulder of his environment. The relationship between human health and environment is a two way process. In the quest for improving the quality of life, he has exploited various resources available i.e., human, ecological and natural. Improvement in the standard of living has resulted in either gradual or drastic change of environment, which is normal and sometimes disastrous to human health (Kumar, 1987). Economic activities like mining and manufacturing are often considered to be the main activities in the process of modern economic changes and development. The establishment of mining/quarrying in any country, irrespective of its economic return, will have bearing on certain criteria like pollution and contamination leading to health hazards of both man and animals. Mining/quarrying activity plays a vital role in changing the socio-economic environment of any given area. It directly involves in the socioeconomic environment by generating employment potential to the locals, uplifting the economic profile and also changes in the culture of the local population (Sunitha et al., 2010).

A high demand for construction necessitates more volume of aggregates to be extracted from quarry sites. Gravel and sand, the most common extractive resources, are two of the most important materials in the construction industry. Gravel and sand extraction widens the river banks, lowers its elevation, and weakens soil cohesion. (Norma et al., 2008). The major environmental issues of quarrying/mining are the fall in agricultural production, loss of fertile top soil, lowering of water table in domestic wells adjacent to mining sites especially during summer season, as well as creation of fallow lands / water logged areas.

The unorganized mining especially with respect to tile and brick clay, alluvial sand crystalline rock, soil etc, is posing serious threats to the natural resource system and societal well-being. The poor planning and implementation of environmental management systems, lack of periodic environmental monitoring system and corrective measures etc have aggravated the issue due to mining (KSCSTE, 2007) in Kerala, where land utility as well as density of population is
high and areas suitable for mining / quarrying are very limited. Moreover, most of the mineral-bearing areas are fragile and eco-sensitive. Due to increased demand for building materials as well as minerals, the number of quarries and mines have increased manifold. After the enactment of the Kerala Minor Mineral Concession Rules 1967 only the quarrying activities for minor minerals in the state were being regulated. Even though the quarrying operation is an age old practice in the state the estimated extend of land degradation due to quarrying and storage of wastes is not available. Under these circumstances, only indirect methods like remote sensing coupled with ground truthing can be used to arrive at a realistic estimate of the extend of land degradation in any particular region. Geo-environmental spatial data integration using Geographical information System (GIS) provides an effective methodology to analyse the environmental impact of mining/quarrying over an area.

1.8 Environmental Impact Assessment

Environmental Impact Assessment (EIA) particularly aims to optimise a trade-off between developmental activities and socio-ecological losses. It is a management tool to be linked closely to the project life cycle to ensure that appropriate environmental information is provided at the correct time (Wood, 1995). The overall objective of the EIA is to design developmental projects and activities taking into consideration the environmental perspective. In India, the first EIA was ordered, during early 1980s, on the Silent river valley hydroelectric project, which was a controversial project (Valappil et al., 1994; MoEF, 2003). This project, proposed by the Kerala State Electricity Board (KSEB) to build a 130 m high dam across the Kuntipuzha River and a reservoir, was considered a big threat to the biodiversity and forest ecosystem of the Silent valley. Later in 1985, the project was abandoned and Silent Valley was declared a national park. This case marked a new beginning in India and since then, EIA was extended to other activities. Projects like mining, industries, hydroelectric plants, thermal power plants, atomic power plants, ports and harbours, rail, roads, highways, bridges, airports and communication project, required EIA if:

- Project needed the approval of public investment board/planning commission/ central water commission/central electricity authority, etc.
• Project was referred to Ministry of Environment and Forest (MoEF) by other ministries.

• Project was to be located in environmentally fragile or sensitive areas.

• Project was under dispute.

However, EIA was introduced in 1994, when MoEF passed an EIA notification under Environmental Protection Act (EPA), 1986, which made EIA mandatory for 29 highly polluting activities and later on three more activities were added to this list (MoEF, 1994; MoEF, 2004). Over the years, the system has undergone several amendments to improve the environmental clearance process and to make it an integral component of decision-making (Paliwal, 2006).

1.9 Wetland and paddy lands of Kerala

Wetland and paddy land conversion is a very serious agro-environmental issue in Kerala. Wetlands are transitional areas between the coast and well-drained uplands that contribute a wide array of biological, social and economic benefits to the community. The Ramsar Convention (1997) defines wetlands as areas of marsh, fen, peat land or water whether natural or artificial, permanent or temporary with water that is static or flowing, fresh, brackish or salty including areas of marine water, the depth of which does not exceed six meters. It may also incorporate riparian and coastal zone adjacent to the wetlands and islands or bodies of marine water deeper than 6m at low tide lying within the wetlands (Barbier et al., 1997).

The state of Kerala has around 328402 ha of wetlands covering lakes, reservoirs, rivers, estuaries, prawn fields, Kole wetlands and ponds. The aggregate minimum ecosystem service value of these wetlands would be around Rs.157.97 billion (Vijayan et al., 2007). The Vembanad Kol wetland system is a complex aquatic system of coastal backwaters, lagoons, marshes, mangroves and reclaimed lands with intricate networks of natural and man-made channels. The seasonal rainfall followed by excessive flooding leaves extensive portion of these wetlands inundated for various periods of the year. When the flood water gradually recedes, nutrient-rich alluvial soils get deposited, resulting in highly fertile agricultural lands. Wetlands help in controlling floods, recharging groundwater and maintaining water quality. Considering the role of wetlands as source, sink and transformational media
these are called ‘Kidneys of nature’. The shrinkage of the Vembanad wetland to 37% of its original area has been the most devastating environmental consequence of the human intervention in the wetland system (James, 2009).

The Kole lands of Kerala are well known for its paddy cultivation and they are known as one of the rice granaries of the state. The term Kole refers to the peculiar type of agricultural practice carried out on these lands. Kole lands of Mukundapuram taluk is part of the Vembanad-Kole wetland ecosystem. The Kole lands remain submerged under flood water for about six months a year and this seasonal alteration gives it both terrestrial and water-related properties. Due to the coexistence of water-related as well as terrestrial properties, various types of economic activities are undertaken on the Kole lands, which support the livelihoods of the local population. Most of the paddy fields in Kerala are currently being reclaimed for settlements, industrial purposes and cultivation of plantations crops. Approximately 30% decrease in the area under paddy cultivation has been observed during the last one and a half decade.

Rice is the most important crop cultivated in this area. The crop seasons are Virippu, Mundakam, Kadumkrishi and Punja. Virippu is usually cultivated in the rice fields at higher elevation where the flood lasts only for few days. Mundakan is cultivated in medium-elevation fields where the flood water recedes by August. Kadumkrishi in Kole lands coincides with Mundakan in normal lands but usually it starts by September. In order to undertake Kadumkrishi, the Kole lands are to be protected by bunds. In Kadumkrishi water management is very important as it requires continuous pumping out of water, while towards the end of the crop irrigation water supply is needed as well. Punja is the crop raised over the entire Kole land area (Jeena T Srinivasan, 2010).

1.1 Scope of the study

Mineral resources are the foremost valuable treasure to the society to achieve economic development and growth. Unscientific and haphazard clay mining/quarrying from lowland paddy fields, wetlands and granite building stone and laterite form midland and high lands of the Kerala have serious environmental problems. In order to develop strategies for sustainable mining/quarrying, it is
essential to gather data and generate information based on field surveys and remote sensing and create real world models using Geographic Information System. GIS along with satellite imagery, can provide a user friendly and reliable platform for planning judicious and sustainable mining/quarry activities with proper environmental management and protection practices. Constant monitoring of the change in environment and ecology is essential in a densely populated and eco-environmentally fragile and sensitive state like Kerala.

The present study is aimed to evaluate the environmental impact of clay, sand and granite building stone mining/quarrying from the paddy field and wetland systems, midland and uplands of the Mukundapuram Taluk of Thrissur District using an integrated approach of Remote Sensing and GIS. Qualitative and quantitative aspects relating to mining area pollution considering it to be a non-point source of pollution is also included.

1.1 Objectives

The objectives of the study are

- To develop a multi-disciplinary database, both spatial and non-spatial, for the analysis of the environmental impacts of mining/quarrying.
- Study of sequential land use changes using multi-date satellite imagery and land degradation loss of soil fertility and productivity.
- Study of morphological changes of landforms due to the mining - damage to sites of topographic, cultural, historical and scenic importance.
- Study of hydrogeological changes due to the mining.
- Study of human-environmental problems
- Study of air and noise pollution due to mining and quarrying activities.
- Integration of various data layers in a Geographical Information System (GIS) platform to derive various environmental models and to suggest suitable environmental management practices to achieve sustainable development with minimal environmental degradation.

Primary focus would be given to those factors, which are found to be most evidently affected, such as the effect on the resource base including land, water
quality, public services other environmentally critical areas. The present study is also aimed to evaluate in brief about the bio-diversity of the Mukundapuram taluk and to verify the extent of changes in the biotic system due to the mining

1.12. Relevance of the study

Since many of the Minor Mineral quarries are illicit, there is no data available regarding area coverage of mining/quarrying activities and quantity of minerals and associated earth materials removed. A systematic and user friendly flexible geo-environmental spatial and non spatial data on a GIS platform is the urgent need of the hour to monitor and assess the environmental impact of the clandestine mining/quarrying activities taking place in agro-environmentally sensitive areas like wetlands, lowland paddy fields, midlands and even in high land forest areas of Kerala. The study area has three distinct physiographic divisions, closely corresponding to that of the state. This consists of sensitive wetland lands, extensive paddy lands which are being converted to other land utility including clay and sand mining. Many laterite and granite building stone quarries are under operation in the midland and the quarrying activity areas extending towards the dense forest areas of high lands represent a typical sample area for the analysis of environmental impact of mining/quarrying activities in the state. Though many studies have been carried out on the environmental impact assessment of tile brick clay mining in Thrissur District and Chalakkudy River basin not much work has been done for generating geo-environmental spatial and non-spatial data on GIS platform to evaluate the mining/quarrying for minor minerals from different physiographic units of an agro-environmentally sensitive taluk of Kerala. Most of the mining and quarrying operations in the state commenced without any Environmental Impact Assessment and Environmental Management Plan studies and there is no systematic database available on quarrying and mining operations in the state. Most of the mining and quarrying operation in the state is ASM. The primary and secondary data generated from the study could be used for chalking out strategies for the conservation and management of the environment, especially in midlands and lowlands affected by indiscriminate mining/quarrying activities. The study can also be used for framing suitable guidelines to streamline the mining/quarrying activities of the state on an environment-friendly basis.