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Impact Assessment of Quarrying Activities Using Remote Sensing and GIS

Udhaya S[1], John Alexander J[2].
Assistant Professor, Department of Civil Engineering KCG College of Technology, Karapakkam, Tamilnadu, India
Associate Professor, Department of Civil Engineering KCG College of Technology, Karapakkam, Tamilnadu, India

Abstract: *The Construction projects require a wide range of raw materials, such as sand and gravel for concrete, crushed stone for road surface, clay for bricks, metals for plumbing and wiring, etc… Many of these materials are produced all around the world. But the location of their occurrence and impacts caused due to their extraction on the local and national environment is the major concern in the construction industries. The sources of these basic materials are quarries. A high demand for construction necessitates more volume of materials to be extracted from quarry sites. Such extractions alter the normal occurrences of nature. The main objective of this project is to develop the spatial information for determining the impacts of quarries on the urban environment using Geospatial Technology. Remote sensing, Geographic Information System and Global Positioning System constitutes the geo-spatial technology. In this work, the areal expansion of construction resource quarries and the affected land use/land cover over a period of 23 years in some parts of Madurai District, Tamil Nadu have been examined using Geographic Information System and Remote Sensing Techniques. Images captured by Landsat TM sensor of the year 1990 and ETM+ sensor of 2001and 2013 were used to determine the size and direction of quarry area expansion and the diminished hill ranges by performing GIS overlay analysis.*

Keywords: *Quarries, Spatial Information, Impacts, Geospatial Technology, Remote Sensing, Geographic Information System, Overlay analysis.*

I. Introduction

With nature as the foremost provider of resources, it has already been an accepted observation that the economic growth of any place lies on its resource extraction industries. The construction Industry is one type of resource extractive industry. In construction, sustainability is of great importance because: 50% of material resources taken from nature are construction related, Over 50% of national waste production comes from the construction sector and 40% of the energy consumption in developing countries is construction related[1]. A high demand for construction necessitates more volume of materials to be extracted from quarry sites.

Quarries vary greatly in size, with varying environmental impacts. The recent growth in the economy 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[2]. The economic contribution of materials in construction is counter-balanced by the environmental impacts of such use. Pits and quarries remain open long after extraction of construction materials has ceased. In some cases, groundwater levels were lowered by pumping to enhance mining operations[3]. Secondary effects, such as surface settlement and underground collapse occur as a consequence. Both environmental and economic complications may develop due to the extraction of construction materials[4]. Despite this, the local impacts of quarrying create significant public concern. Impacts include traffic along access roads, noise, vibration and dust caused by quarry machinery[5]. Determination of the mining activities impacts on environment is a major issue in sustainable development and resources management. The conflict between mining activities and environmental protection has intensified over recent years, emphasizing the need for improved information on the dynamics of impacts at regional and local scales[6].

Remote sensing (RS), Geographic Information System (GIS) and Global Positioning System (GPS) constituting the emerging field of geospatial technology offer great promise for generating spatial information on natural resources at national and subsequent disaggregated levels[7]. Further, the system is also highly useful for updating and monitoring the dynamics of land use changes through the monitoring capabilities of the multi-temporal remote sensing data[8]. This study aims at giving an overall view on the use of satellite data, particularly that provided by Landsat satellites, for analyzing the environmental impacts of quarries. Monitoring and mapping the distribution of quarrying activities in the region is necessary for developing a better understanding of the consequences of land-cover and land-use change.

II. Study Area

The Study area comprises of Melur, Madurai North and Madurai South Taluks of Madurai District, Tamil Nadu. The total area of this study is 1376.9Km^2 and is located between 9°45'N to 10°15'N latitude and 78°0' to 78°30' longitude. The study area is situated geographically at the eastern part of the District. The prominent geomorphic units in the district are structural and denudated land forms such as structural and denudational hills, residual wells, linear ridges, uplands and barred pediments. The total number of mines and quarry based industry in Madurai district is found to be reported as 356. Out of these 222 quarries are located in the Study area. The map showing the location of the study area is given in Fig 1.

Fig. 1 Study Area Map

III. Materials

This study was carried out using ArcMap 9.3, a vector based geographic information system, ENVI 4.7, a geospatial image analysis software and ERDAS Imagine 9.2, a remote sensing application with raster graphics editor.

IV. Data Used

A. Satellite Image

Two Landsat ETM+ images (path: 143, row: 53) and one Landsat TM image (path: 143, row: 53) were employed to map quarry exploration over a period of 23 years in the study area. Selection of these images was made based on the fulfilment of specific criteria, namely clear atmospheric conditions, high sun conditions, low water vapour and low image noise. The datasets used in this study were obtained at no cost from the United States Geological Survey (USGS) archive (http:// earthexplorer.usgs.gov/) at Level-1T processing, meaning that they were orthorectified. The details of the datasets used in this study is listed in Table No. 1

TABLE I SATELLITE IMAGE DETAILS

S.No	Landsat Satellite Data		
	Sensor	**Date**	**Spatial Resolution**
1	ETM+	25-02-2013	30m
2	ETM+	15-05-2001	30m
3	TM	23-04-1990	30m

B. Topographical Map

Open Series Maps (OSMs) are used for this study. OSMs will be brought out exclusively by SOI, primarily for supporting development activities in the country. OSMs shall bear different map sheet numbers and will be in UTM Projection on WGS-84 datum. The topographical map numbers collected from Survey of India, Chennai for the Study area are 58J04, 58J07, 58J08, 58K01, 58K05 and 58G13. The toposheet scale is 1:50,000.

V. Methodology

A. Base Map Creation

Madurai North, South and Melur Taluk's base map is created using the topographical maps in ArcGIS 9.3 software, which was georeferenced to UTM zone 44 N on WGS-84 Datum. The created base map is shown in Fig 2.

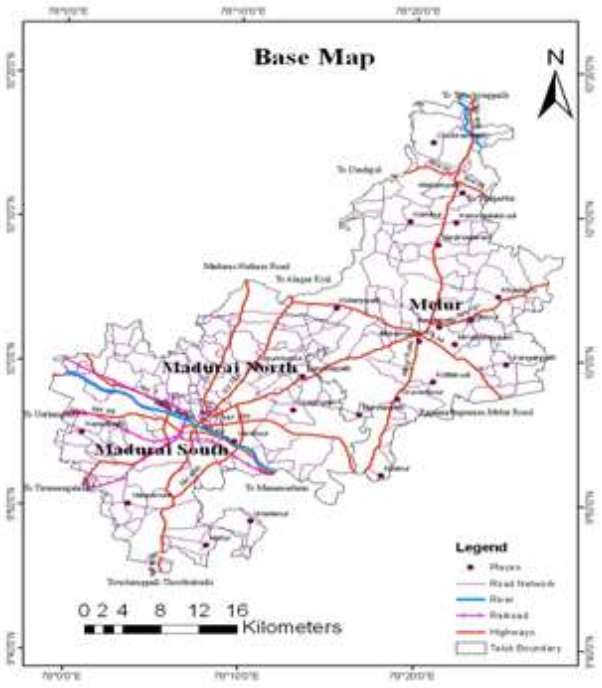

Fig. 2 Base Map

B. Pre-processing, Stack Layer and Subset Creation

Collected Landsat TM and ETM+ data was available as individual bands, which was combined together to form multi-band image using stack layer option in ERDAS IMAGINE 9.2 (Fig 3). Then the stacked images were processed to remove the SLC lines and cut to the base map boundary using subset creation option of ERDAS IMAGINE 9.2. (Fig 5a, 5b and 5c).

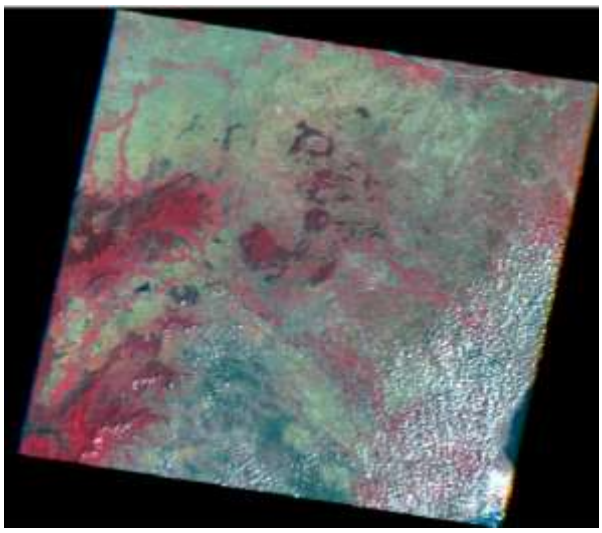

Fig. 3 Stack Layer created for 2013 image

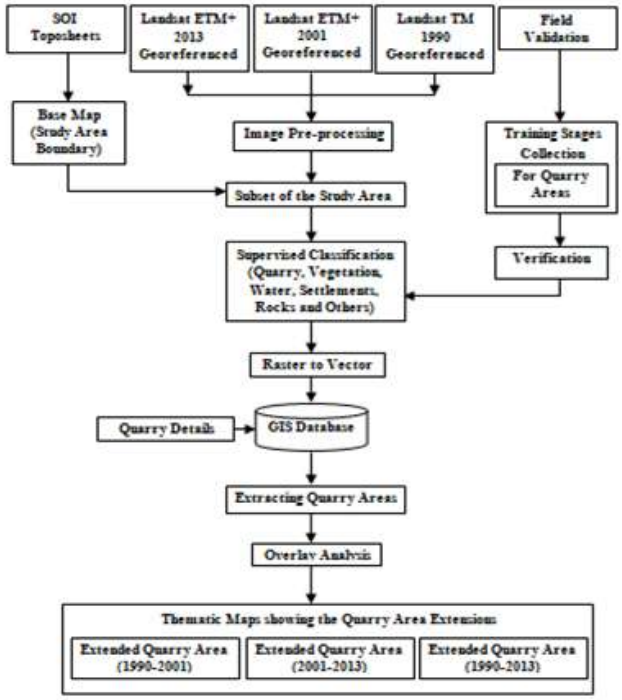

Fig. 4 Methodology

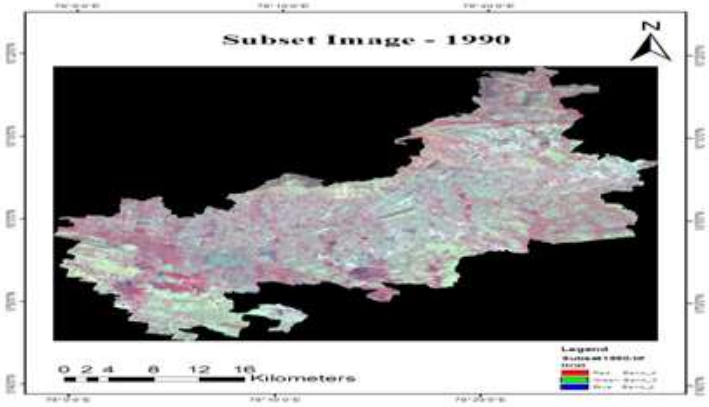

Fig. 5(a) Subset image of the year 1990

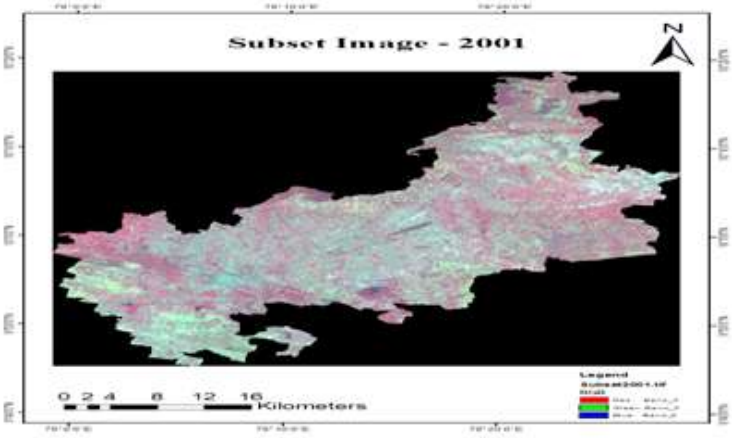

Fig. 5(b) Subset image of the year 2001

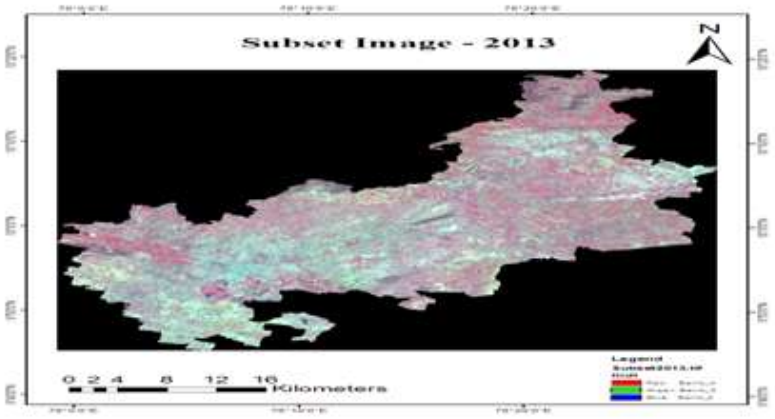

Fig 5(c) Subset image of the year 2013

C. Image Analysis

Image analysis is the extraction of meaningful information from images; mainly from digital images by means of digital image processing techniques. Image processing is any form of signal processing for which the input is an image, such as a photograph or video frame; the output of image processing may be either an image or a set of characteristics or parameters related to the image.

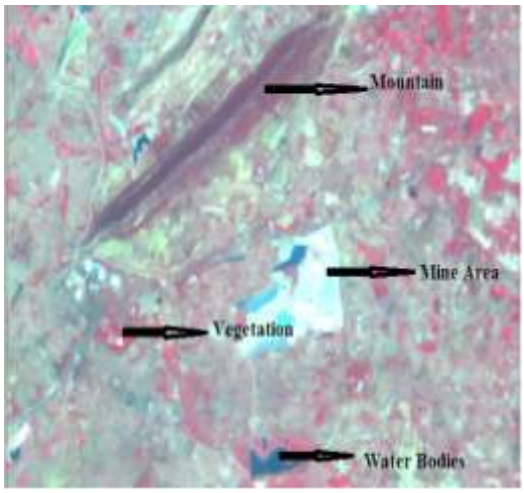

Fig 6 Identification of classes in FCC

D. Supervised Classification

Supervised classification uses the spectral signatures obtained from training samples to classify an image. Different objects have different spectral reflectance. Identification of that reflectance helps to classify different features from the image. Here, Maximum Likelihood Classifier is adopted to classify the images using Envi 4.7 software. This classifier accounts for the means and co-variance of each class and then comparing each candidates pixel with the likelihood to each class.

E. Distribution of Quarries

Classification using maximum likelihood algorithm with null class seemed to have yielded satisfactory results as far as separation of known land features was concerned. It is to remember that the statistics of area under quarry sites at this stage of the project work can indicate only the quarry areas which normally be attained by about twenty three years of age.

In the present project, a theme of quarry area distribution in a given geographical area is to be brought into GIS for analysis. Hence, an attempt was made to bring the classified raster image into vector format that can fit into GIS by vectorization. It was seen that the vectorization was done along the boundary of the quarry class. This was done to bring the quarry area distribution map of Melur, Madurai North and South Taluks into GIS environment. The spatial distribution of quarry areas in the Melur, Madurai North and South Taluks as derived from Landsat ETM+ and TM sensors is depicted in the figures below. The figures indicate that

quarrying activities was more popular in the Melur Taluk. The total quarry area estimated through geo-spatial technology in the study area is 2056.78 hectares.

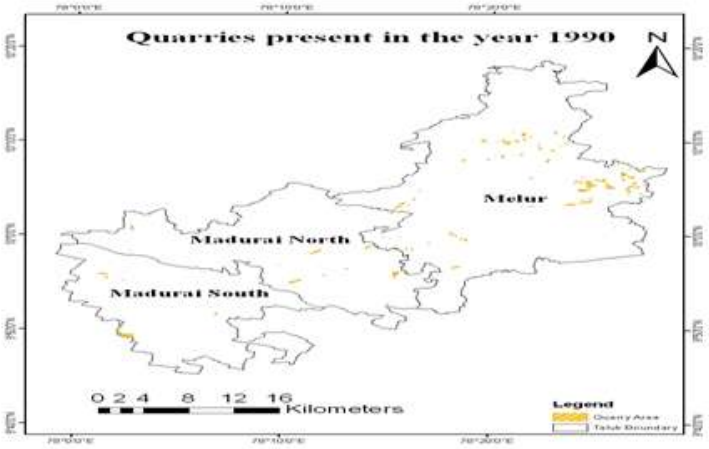

Fig. 7(a) Quarries present in the year 1990

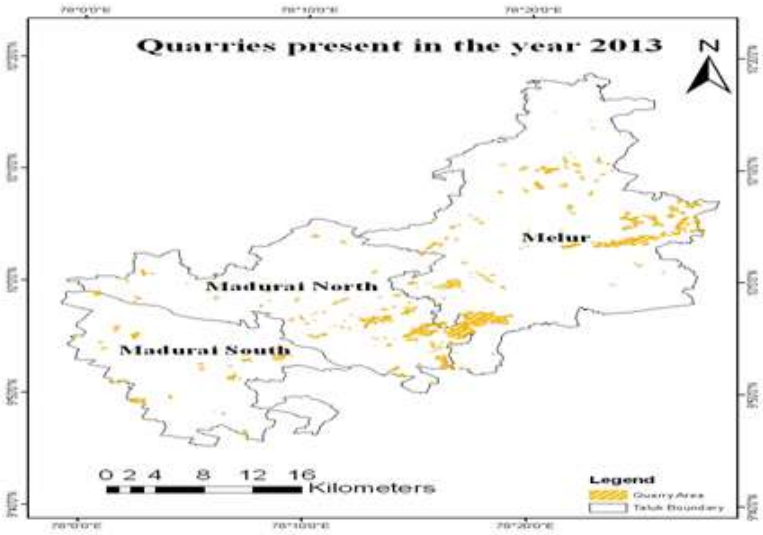

Fig. 7(b) Quarries present in the year 2001

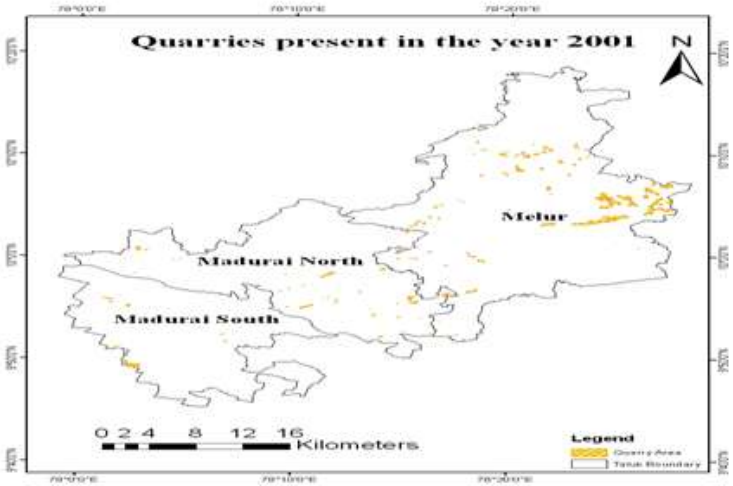

Fig. 7(c) Quarries present in the year 2013

F. Overlay Analysis

Overlay analysis is one of the spatial GIS operations. Overlay analysis integrates spatial data with attribute data. (Attributes are information about each map feature.) Overlay analysis does this by combining information from one GIS layer with another GIS layer to derive or infer an attribute for one of the layers. At its simplest, overlay analysis can be a visual operation, but analytical operations require one or more data layers to be joined physically. This overlay, or spatial join, can integrate data of different types, such as soils, vegetation, land ownership, jurisdictions, etc. with assessor's parcels. Results of overlay analysis rely on the spatial accuracy of the GIS layers.

In this study, overlay analysis was executed on the classified layers for detecting the changes of the quarry areas. Visualization of the analysis results was considered as another important issue in this study.

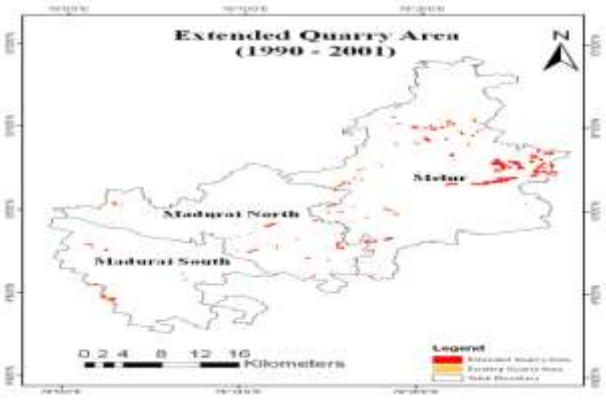

Fig. 8(a) Extended quarry area (1990-2001)

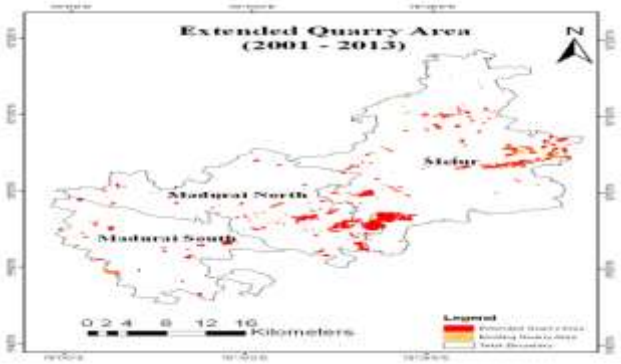

Fig. 8(b) Extended quarry area (2001-2013)

TABLE III AREA OF QUARRIES IN HECTARES

S.No	Year	Area of Quarries (Hectares)
1	1990	463.505
2	2001	932.927
3	2013	2056.785

G. Change Detection

Change detection process analyzes the multitemporal remote sensing images acquired on the same geographical area for identifying the changes occurred between the considered acquisition dates. Detection of changes was associated with modifications of the behavior of temporal signature of a land cover between two time series.

VI. Results and Discussion

Considerable reserves of limestone, blue metal jelly, gravel and quality granite is reported to be available in Madurai district. These resources were extracted by performing quarrying activities, which leaves a considerable effect on land, air and water resources.Between 2001 and 2013, the number of quarries in the study area increased by 65%. During the same time, the quarried land area increased by 54%. Based on the remote sensing data, many of these quarries were located on dense and sparse grassland, bare rocky lands, etc... which

significantly affected the sustainable management of rangeland in the country. Also quarry wastes dumped in arable lands pose severe problems for air quality and possible deterioration of soil and water quality. The thematic map showing the location of quarries in the study area is given in Fig.8.

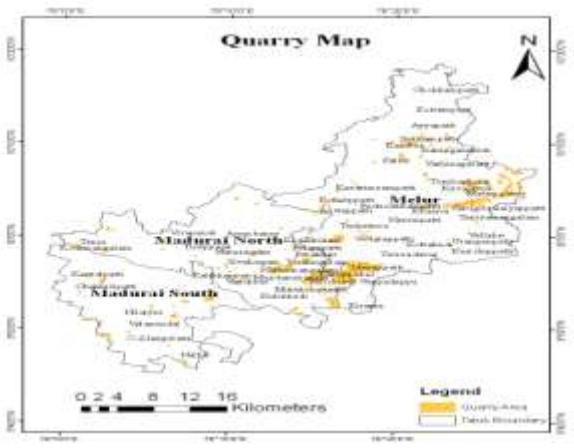

Fig. 9 Quarry location Map

VII. Conclusion

The study shows that that if the present quarrying rate remain continue, within few years many hill range will be completely diminished. Furthermore due to continuous quarrying, environmental problem will become more serious issue as already there is a lot of dust and people are suffering many diseases. Also, there will be a possibility for land degradation in and around quarry sites due to dumping of the quarry wastes. Proper solid waste management practices have to be installed in the quarry sites to prevent arable land from degradation.

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