Application of Remote Sensing and GIS techniques for exploring Construction Material from inaccessible terrains; case study in Eastern Province of Sri Lanka

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Abstract: *Demand for construction materials in the North and Eastern provinces of Sri Lanka has risen significantly due to accelerated construction work in progress to restore the destroyed infrastructures during the civil war. Ground surveying methods to locate quarries within this area are not applicable due to security reasons and the larger area to be covered. Thus a Remote Sensing method is suitable for this task. This study introduces a methodology to locate suitable quarries and sand mines for constructions in the Eastern province. LANDSAT ETM+ images were used for classification. Feasible rocks and sand deposits for quarry operations were located using Multicriteria Analysis (AHP).The highly suitable rock quarries and sand deposits were considered in closest facility analysis. The results showed that the integration of Remote Sensing (RS) and Geographic Information System (GIS) can serve as an effective tool in demarcating suitable sites for construction material and this methodology can also be applied for projects of similar nature.*

Keywords: *Closest facility analysis, MCDA, Sand deposits, rock quarries.*

1. INTRODUCTION

The twenty years long civil war has resulted in impoverishment and under-development, especially in the areas of Northern and Eastern provinces of Sri Lanka. Most of the infrastructures were severely disrupted by bombs, barbed wire, blockades and land mines. It is estimated that the 290,615 houses were destroyed during the civil war in Northern and Eastern provinces of Sri Lanka. About 58% of the total housing stock in the North and East and around 90% of the houses belonging to the displaced population were destroyed as the result of the war (World Bank 2008).

Presently, it has become a challenge to rebuild those areas. The demand for construction materials have also gone higher as a result of the major development and construction projects.There are plenty of resources in those areas to cater to the demands, but most of them are unknown. Hence exploration programs needed to be carried out to find suitable places to obtain construction materials. There are several methods available for this task. Many of them are related to direct field surveys and observations. Since the field access and observations are obstructed by land-mines lying beneath those areas and the removal process will be extended over many years, Remote Sensing (RS) and Geographic Information System (GIS) techniques can be used for this task (Sabins, 1998).

Therefore, the main objective of this project is to use satellite images for identification of the available rock and sand deposits for construction work and also use of GIS analysis for demarcation of economically viable construction material occurrences in the area considering all the factors such as construction sites, road networks and environmental factors.

This method could be developed as a technology to be applied in similar situations that will save our time, money and tireless efforts towards the old conventional methods of locating quarries.

2. MATERIALS AND METHODS

2.1. Methodology

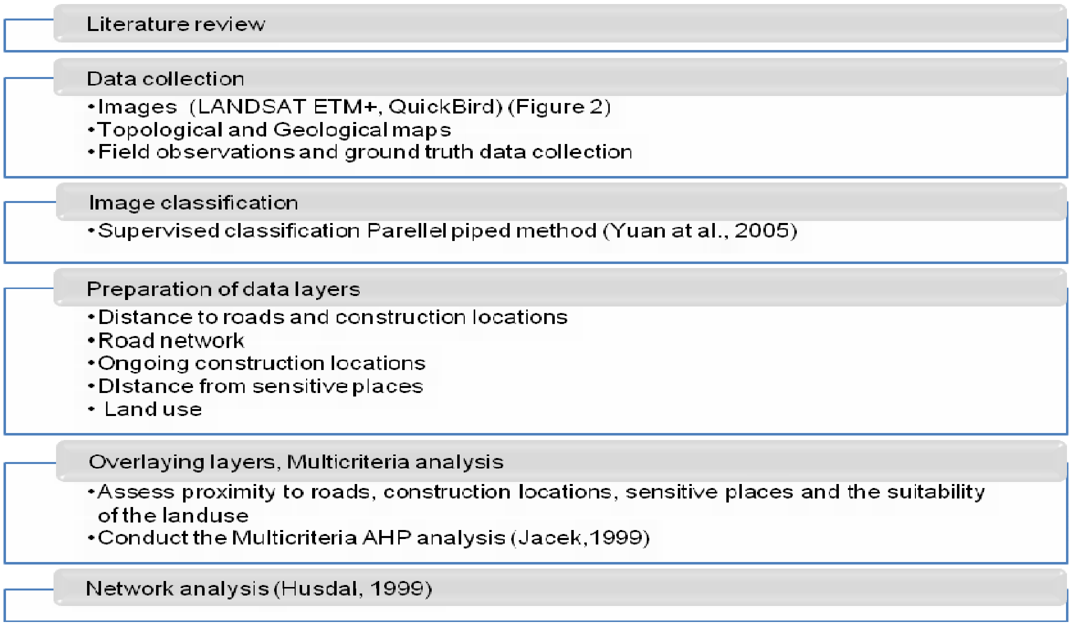


Figure 1 Methodology

2.2. Images Used

PRODUCT_CREATION_TIME = 2004-02-12T15:21:14Z *GROUP = ORTHO_PRODUCT_METADATA* *ACQUISITION_DATE = 2001-09-06* *WRS_PATH = 141* *WRS_ROW = 054* *SCENE_CENTER_LAT = +8.6728384* *SCENE_CENTER_LON = +80.9365654*	PRODUCT_CREATION_TIME = 2008-02-22T17:33:44Z GROUP = ORTHO_PRODUCT_METADATA ACQUISITION_DATE = 2001-05-26 WRS_PATH = 140 WRS_ROW = 055 SCENE_CENTER_LAT = +7.2367862 SCENE_CENTER_LON = +82.1485112	PRODUCT_CREATION_TIME = 2008-02-22T17:27:45Z GROUP = ORTHO_PRODUCT_METADATA ACQUISITION_DATE = 2001-03-14 WRS_PATH = 141 WRS_ROW = 055 SCENE_CENTER_LAT = +7.2362455 SCENE_CENTER_LON = +80.6215420

Figure 2 Landsat ETM+ images (Global Land Cover Facility)

3. RESULTS AND DISCUSSION

In this study, highly exposed rocks and sand areas were accurately classified, but the classification accuracy (1) of rocks is greater than the sand (Table 1).Sand deposits along the flood plain of the Mahaweli River, sandy soil, beach and lagoons were classified as sand abandoned areas. Examples of comparison of the rock and sand classification results with Google earth were given in Figure 3 and 4.

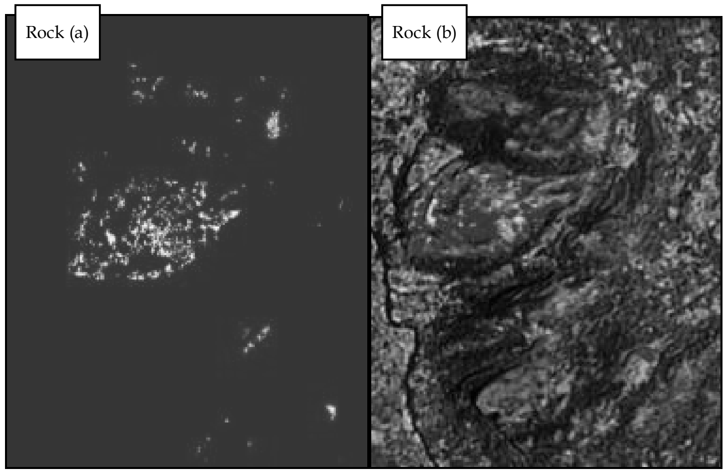


Figure 3 Classification for rocks using Landsat ETM+ (a) and Classification overlay on Google Earth (b); yellow, green & red rock classification overlay on Google Earth in red color

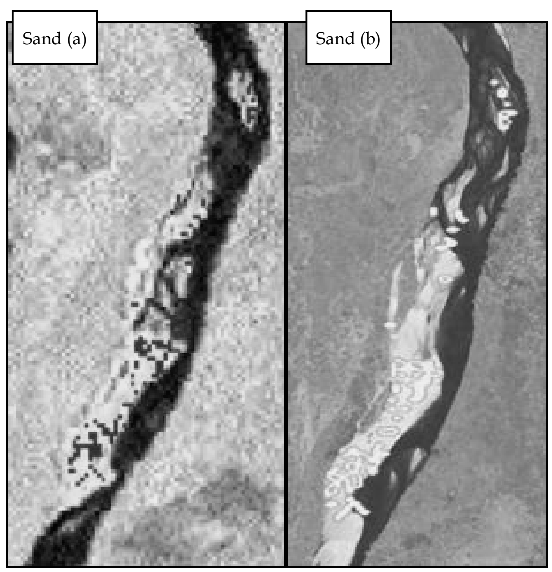


Figure 4 Classification for sand using Landsat ETM+ (a) and Classification overlay on Google Earth (b); red sand classification overlay on Google Earth in yellow color

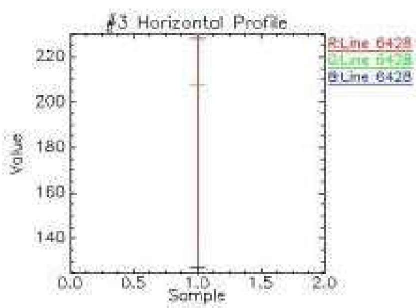
$$Accuracy = \frac{\text{No of classified rocks/sand}}{\text{Total No of rocks/sand}} X100\% \quad (1)$$

Table 1 Accuracy of classification

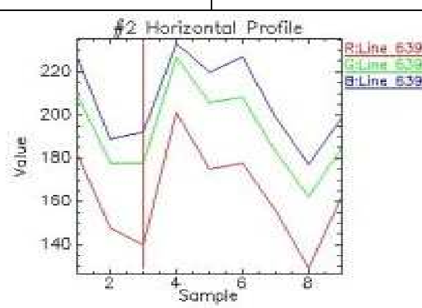
Construction Material	Accuracy of Classification
Rocks	91.47%
Sand	85.21%

The classification gave a few erroneous results; mostly the roofs thatched using "Asbestos" and some flat bare lands were wrongly classified as rocks and sand respectively. The collected ground truth data (Table 2) showed that rocks were not classified where the vegetation cover and overburden is thick and rock slopes are steep. Also, where vegetation is less but scattered all over the rock top minimizing the visible area for one pixel has excluded that area from the classification. In the classification of sand, the major obstacle encountered was the classification of sandy soils which are not suitable for sand mining. Locating only the possible sites for rocks and sand is not sufficient as they may not be economically viable to put up a quarry.

Table 2 Ground truth data collection – Rocks and Sand

<table>
<tr><th>Location</th><th>classify</th><th colspan="3">Description</th></tr>
<tr><td rowspan="2">1
Rock</td><td rowspan="2">yes</td><td colspan="2">

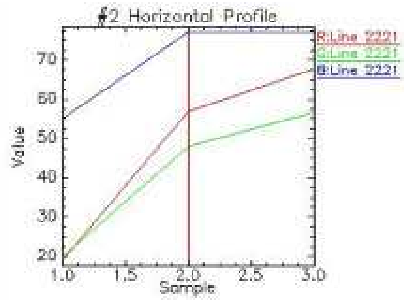
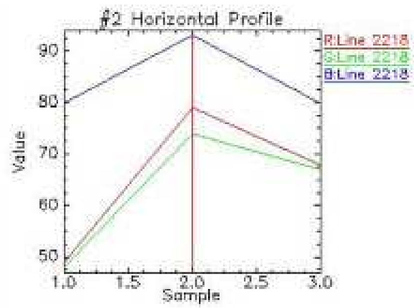
Pixel values (7,5,4 in Red, Green and Blue channels)</td><td></td></tr>
<tr><td>Height: 140m
Area: 100 x 50± 25m

GPS Points:
7.33792 N
81.019567 E</td><td>Mineral Present:
Mafic 50% (black)
Felsic (50%)
charnockite gneiss
Vegetation cover: <10%</td><td>Remarks:
Accesible
Mining Feasible
No quarry in operation (people have shown interest though)
State owned
No apparent problems</td></tr>
<tr><td rowspan="2">2
Rock</td><td rowspan="2">no</td><td colspan="2">

Pixel values (7,5,4 in Red, Green and Blue channels)</td><td></td></tr>
<tr><td>Height: 50m
Area: 50 x 400 m²

GPS Points: 7.3382 N
81.01957 E</td><td>Mineral Present:
Pigmatic gneiss
Mafic <20%

Vegetation cover:
40 – 50%</td><td>Remarks:
Quarry in operation</td></tr>
</table>

3 Sand	yes			
		Pixel values (7,5,4 in Red, Green and Blue channels)	GPS point: 7.561138 N 81.339064 E	Remarks: Sand mining in Operation
4 Sand	yes			
		Pixel values (7,5,4 in Red, Green and Blue channels)	GPS point: 7.906561 N 81.089219 E	Remarks: Sand mining in Operation

Calculated weights for Individual criterion using Multicriteria AHP techniques were shown in Table 3, the following criteria were ranked;

- The rocky land should be easily accessed,
- Must be located close to the construction sites,
- Should be easy to acquire for quarry operation and
- The quarry should be located considerable distance away from sensitive locations.

Table 3 Calculated weights for Individual criterion

Criteria	Weight
Proximity to roads	0.4929
Proximity to construction locations	0.3082
Land use	0.1056
Proximity to sensitive locations	0.0936

The overall land suitability (2) should address all the above needs (Figure 5). Economically viable Quarries and sand mines should be categorized based on that land suitability.

*Land suitability = [DR] * 0.4929 + [DC] * 0.3082 + [LU] * 0.1056 + [DI] * 0.0936* (2)

where [DR] is the Proximity to roads, [DC] is Proximity to construction locations, [LU] is the Land use and [DI] is Proximity to sensitive locations

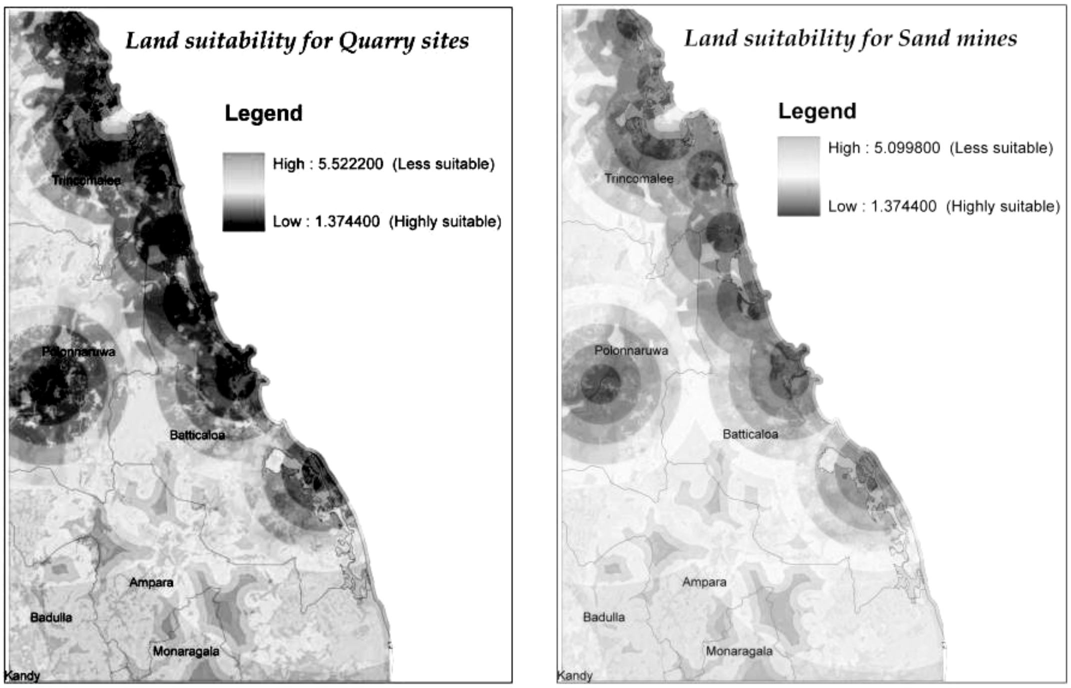


Figure 5 Land suitability for Quarry sites and Sand mines

Under the prevailing categorization of the suitability of rocks and sand deposits for quarry operations, highly suitable category contains the most preferable places to locate quarries and sand mines (Figure 6). The criteria and ranking in the decision making process can vary depending on the type of data input and the objectives of the stakeholders.

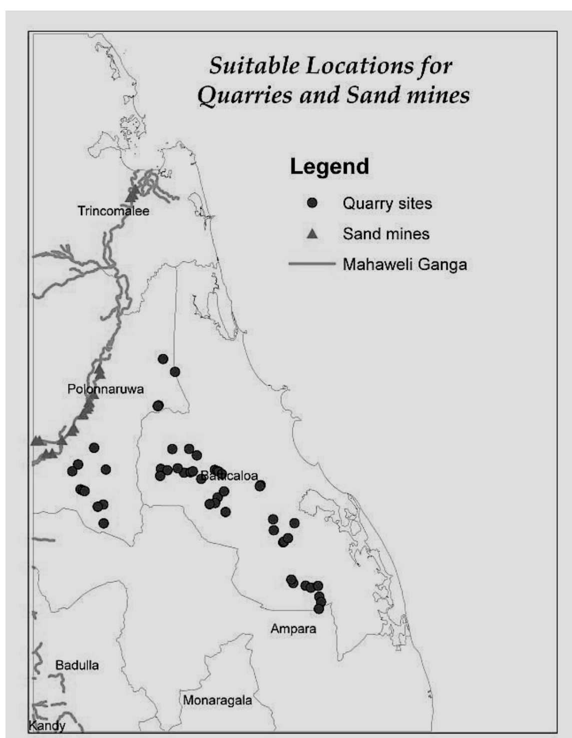


Figure 6 Suitable Locations for Quarries and Sand mines

Finally, the network analysis was used to obtain the best quarry sites and sand mines with least cost (distance, time) manner to reach construction sites. That is the best path in which a particular quarry site can transport its construction material to a construction site with minimum cost.

The accessibility to roads and construction locations were assessed based on the distance from them to the quarry sites. The cost of taking the relevant path way was not taken in to account. Any network analysis requires impedances (speed) associated with each road in the network, by which priorities are given to the different roads for analysis. The vehicle speeds were assigned to individual road types that are main roads and jeep or car tracks (Vinod and Sukumar, 2003). The time taken for the turns was also not considered.

The shortest path between quarries and the customers will facilitate the truck drivers to deliver construction materials to maximum number of customers in an efficient manner. This helps a quarry to have an idea about how many customers are within a particular distance and the closest cities from the quarry to carry out selling of construction materials.

Shortest paths between quarry sites and construction sites are shown in Figure7.

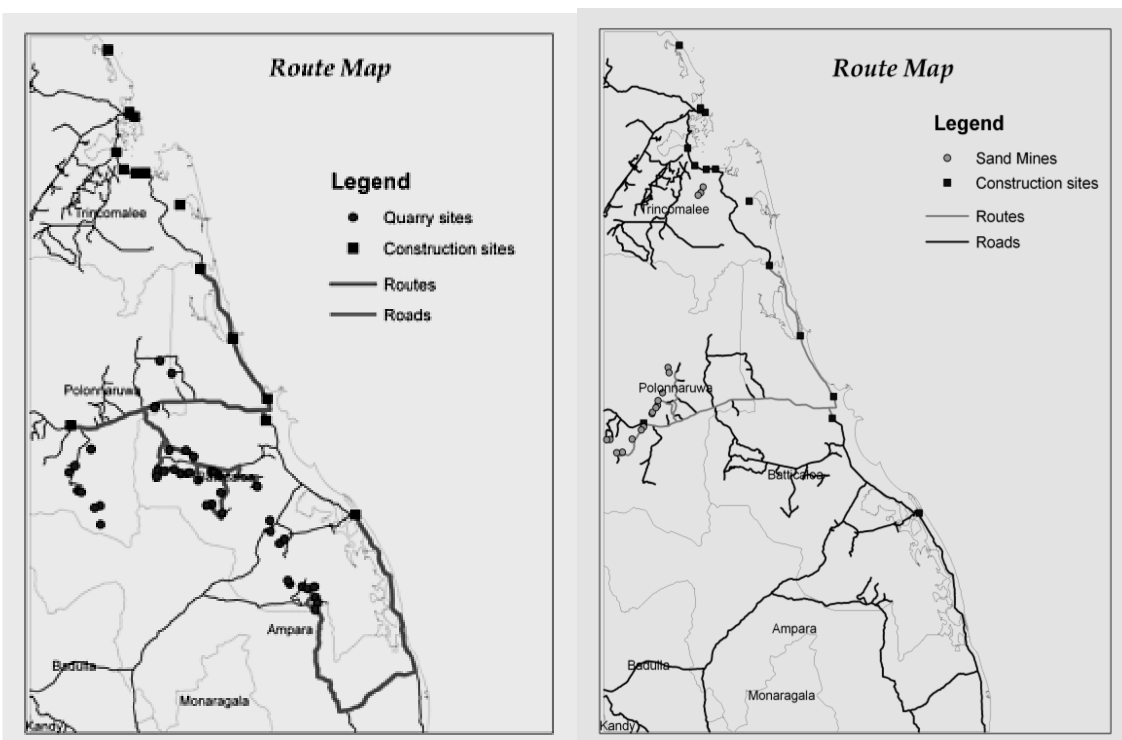


Figure 7 Route maps for Quarry sites and Sand mines

4. CONCLUSIONS

The accuracy of the rocks and sand classification is satisfactory enough to proceed with the remaining analysis. Therefore, 15m upgraded resolution LANDSAT ETM+ images are suitable for rocks and sand identification. Rocks tend to classify accurately if the exposure is high with a less overburden and low vegetation cover.

The highly suitable quarries indicate that area is within the favorable limit of the criteria defined according to the study objectives.

Final results after network analysis gives feasible quarries based on the route suitability selected to reach the construction sites in a minimum time.

The extent of the archeological sites cannot be identified by satellite images and need to be integrated to the GIS database to optimize the final result. For a more comprehensive result mineralogy and the properties of rocks can be incorporated to the multicriteria analysis.

5. ACKNOWLEDGMENTS

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6. REFERENCES

Husdal, J. (1999),*Network analysis network versus vector a comparison study*, Unpublished working paper, University of Leicester, UK.

Jacek, M. (1999),*GIS and Multicriteria decision analysis*, John Wiley and sons.

Sabins, F. F. (1998),*Remote sensing for mineral exploration*, Ore Geology Reviews.

Vinod, R.V. B. and Sukumar, A. S. (2003),*Transport Network Analysis Of Kasaragod Taluk, Kerala Using GIS*

Yuan, F., Sawaya, K. E., Loeffelholz, B. C., Bauer, M. E., (2005),*Land cover classification and change analysis of the Twin Cities (Minnesota) Metropolitan Area by multitemporal Landsat remote sensing, Remote Sensing of Environment*

Global Land Cover Facility, Earth Science Data Interface, viewed 21 February 2010
<http://glcfapp.glcf.umd.edu:8080/esdi/index.jsp>

The World Bank News & Broadcast 2008, Sri Lanka: Second North East Housing Reconstruction Program, viewed 23 December 2009,
<http://go.worldbank.org/APSTZ45CU1>