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GIS and remote sensing in urban waste disposal and management: A case study of Usilampatti municipality, India

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Abstract
At the core of the problems of solid waste management were the absence of adequate policies, enabling legislation, and an environmentally stimulated and enlightened public. Several factors have to be considered in site selection for waste disposal. Due to the involvement of different parameters, deciding upon a suitable location for waste disposal is very complicated, costly and time consuming. Geographic Information System (GIS) allows users to view, understand, question, interpret and visualize spatial and non-spatial data in many ways that reveals relationships, patterns and trends in the form of maps, reports and charts. The present study details about locating a suitable waste disposal site for Usilampatti municipality. Selecting a suitable disposal site should adhere to the government safety norms and ensure there is no risk involved to the people or the environment. Factor considered for site selections include natural physical characteristics as well as socioeconomic, ecological and land-use factors. Multi-criteria overlay analysis has been done for solid waste disposal site selection in this study. Geographical Information System (GIS) integrates Geographical, Geomophological and other parameters with population and other relevant data in selection of suitable disposal.

Keywords: GIS, Solid waste Management, Multi-criteria, weightage overlay analysis.

1. Introduction
The solid waste materials in cities are the natural outcome of human activities. Most of our cities and municipalities in third world countries like India is a major concern of the government due to the health problems associated with improper disposal of waste. The rapid growth of population and urbanization decreases the non-renewable resources and disposal of waste matter and toxic waste haphazardly are some of the major environmental issues posing threats to the existence of human being. The most common problems associated with improper management of solid waste include diseases transmission, fire hazards, odor nuisance, atmospheric and water pollution, aesthetic nuisance and economic losses (Basagaoglu, H. et.al. 1997) [2]. Waste disposing is an important part of waste management system, which requires much attention to avoid environmental pollution. Only major cities have some sort of waste disposal system. In this study we did a research on identifying a suitable site for solid waste disposal in Usilampatti municipality, Tamil Nadu.
A Disposal site must consider all the socio-economic, environmental and land use factors within the city as well as people safety. Geographical Information System (GIS) can analyze the suitable site selection for urban waste disposal considering all the criteria (Multi-criteria Analysis) which will help local governing body as a part of e-governance. The use of GIS in selection process will reduce the time and enhance the accuracy.
Many studies have been conducted to estimate the composition of waste in Indian cities, as it was an important parameter in choosing the process method to be adopted and the design of the process plant. The studies revealed that the organic fraction of the waste makes up 40 – 75 % of the waste (National Solid waste Association of India, 2003, CPCB, 1998). Studies have stated that the composition of waste varies depending on the income and life style (Zurbrugg, 2004).
The process of solid waste disposal management mainly consists of collection, processing, recycling and disposing. At present, waste disposal in most cities is done in simple form of

landfill deposing (Akbari *et al*., 2008) [1]. However finding a good waste disposal area is difficult since land is a scarce resource. An increasing environmental awareness, increasing cost, community and political opposition and public health concerns have made choosing suitable land for landfills quite difficult (Din *et al*., 2008) [4].

Landfill site is a complex process involving the processing of massive amount of spatial data. Technological development in computer science has introduced geographical information system (GIS) as an innovative tool in landfill process (Kontos *et al*., 2005) [6]. GIS is a digital database management system that is ideal for advances site-selection studies because it can effectively store, retrieve, analyze and display information according to user-defined specifications (Kao and Lin, 1996, Sener, 2004 and Shamshiry *et al*., 2011) [5, 7, 8]. The multi-criteria decision technique that helps to the decision maker to ser the priorities and make the best decision by reducing complex evaluations to a series of pair wise comparisons (Casini *et al*., 2006) [3]. This technique can be used in combination with GIS to arrive at optimal solutions in waste disposal area siting process.

2. Study area

Usilampatti town lies 28 km south west of Theni town and 38 km west of Madurai city on the Rameswaram – Cochin National Highway Extension No.49. It is situated between 10° 37’ north latitude and 77° 20’ on east longitude. It is a second grade municipality with an area of 3.85sq. km. The lands which lies in between railway line and Peraiyur road and Battalakundu road, are mostly of wet lands which restrict the development of the town in the southern direction. Hence, the town is likely to expand along both sides of Peraiyur roads and Madurai roads only. Madurai road has been elevated as NH 49 (Extension) and Rameswaram to Cochin road is also passing through this town; this is an important feature of the town.

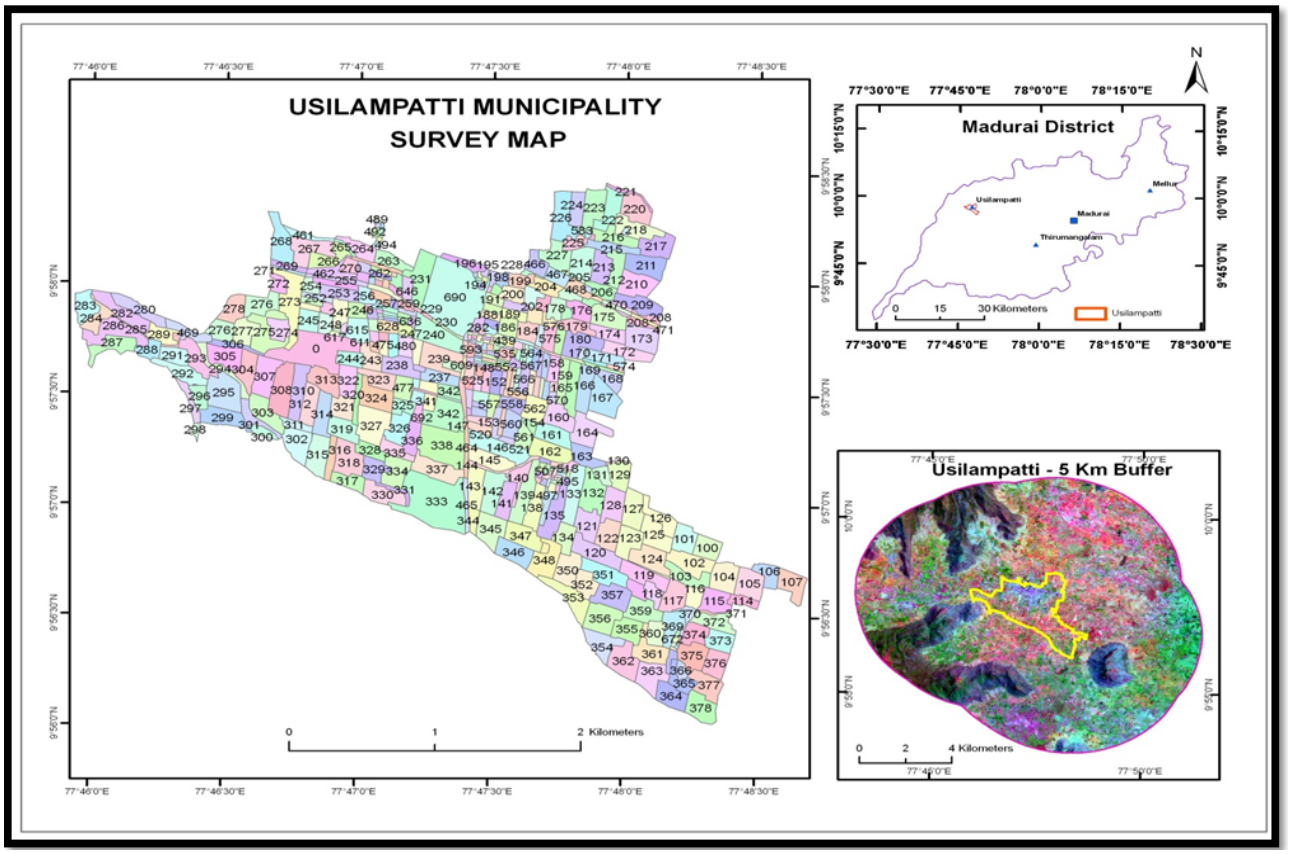

Fig 1: Study area

3. Aim and Objectives

The study aimed at understanding the current problems of waste disposal in Usilampatti municipality and suggest best possible site for waste disposal using GIS and Remote sensing techniques. The objectives of this study are as follows:

1. To examine the various factors affecting the site selection for Usilampatti municipal solid waste disposal.
2. To select the suitable site as waste disposal ground depending on weightage overlay analysis through GIS and remote sensing application.

4. Methodology

Solid waste management was certainly an important element in terms of efficiency as profitability for any municipality, particularly in industrialized nations. It’s essential complex dimension was resulted, not only of the direct relationship with a number of factors that originate the living standard of a society, but also of our continuously rising consuming lifestyle which analogically enhances the existing operational difficulties (Modak *et al*., 1996). For present study various data been used such as remote sensing data, geologic data, surface hydrologic data, underground water and meteorological data. In the present investigation information from Quick Bird Imaginary and IRS P6 LISS IV and high–resolution PAN imagery were extracted for the identification of wasteland to be considered for solid waste disposal. The following are the key thematic layers created for the selection of solid waste disposal sites: -

1. Boundary 5 km buffer
2. Satellite Image
3. Geology
4. Geomorphology
5. Land Use
6. Soil Type
7. Slope
8. Water Level
9. Road network
10. Population around the site in 1km radius.

These thematic layers are then added with a weightage and a corresponding rating value in order to assess their importance to be considered for potential solid waste disposal site. The logical sequence was as follows:

4.1 Weighted Overlay Analysis

Weighted Overlay was a technique for applying a common measurement scale of values to diverse and dissimilar inputs to create an integrated analysis. Geographic problems often require the analysis of many different factors. For instance, choosing the site for a new housing development means assessing such things as land cost, proximity to existing services, slope, and flood frequency. This information exists in different raster layers with different value scales: dollars, distances, degrees, and so on. Each and every key parameter for which we have created a thematic layer will be assigned a weightage value to indicate their importance in taking a decision. The below table shows the weightage given to each parameter.

Table 1: Criteria with Weightages for Municipal Waste Disposal sites

S.No	Criteria	No.	Attribute Measurement	Weightage
1	Accessibility	1	Type of road	50
		2	Distance from collection area	50
2	Receptor	1	Population within 1km	50
		2	Distance to nearest drinking water sources	55
		3	Use of site by nearby resident	25
		4	Distance to nearest building	15
		5	Public utility facility within 2 km	25
		6	Public acceptability	30
3	Environment	1	Critical environment	55
		2	Distance to nearest surface water	55
		3	Depth to ground water	60
		4	Land use	80
4	Geology	1	Geomorphology	90
		2	Geology	90
		3	Soil Type	90
		4	Soil permeability	90
		5	Slope pattern	90
	Total			1000

5. Analysis and Results

5.1 Identification of suitable dumping sites

The result of the study include several layers of thematic maps viz., geomorphology, geology, land use/land cover, soil, ground water level, slope etc., These layers were assigned due weightage and ranking so that the right spots for solid waste disposal sites could be identified. All these geo-spatial layers were ranked based on their merits to be identified as a potential disposal site. Once the weightage and ranking were assigned these layers were ready for a cumulative overlay analysis resulting in the identification of disposal sites. Each thematic layer prepared for the study and the corresponding weighted maps were the potential results leading to the final map of potential disposal site map.

- The major Geological features observed in Madurai District were Hornblende - biotite gneiss and Charnockite apart from calcareous gritty sandstone and clay and sandstone with clay. The higher rank of indicates favorable class of geology in which the disposal site could be kept safe. charnockite and quarts was the best suitable geology followed by Garnetiferous quartzofeldspathic gneiss, while charnockite and quarts was the least suitable geology class for considering disposal site.
- To locate the potential dumping sites, suitable geomorphic landscapes were identified in Usilampatti district. Following geomorphologic features were observed in Usilampatti District; Bazada, Deep Pediment, Duri crust, Flood plain, Paleo Sand dune, Pediment, Shallow Pediment, Structurial Hill and valley fill. As far as Usilampatti was concerned pediment was considered to be the ideal zone for dumping site. Pediment got rank1 and occupies 29 percent of the Madurai district area, second rank was given to shallow pediment and it occupies around 22 percent. The deep pediment occupies 19 percent of the study area; therefore more than 50 percent of study area comes under Pediment zone area. Other geomorphic landscapes were considered not suitable for locating dumping site.
- There were three types of soil available according to the soil survey and landuse planning maps in Usilampatti Madurai, Red soil, Black clayey soil and alluvial soil. Red soil was found in all the blocks of the district while black clayey soil found in Tirumangalam, Usilampatti and Peraiyur blocks of the district and alluvial soil was found along the courses of the river.
- Usilampatti municipality was covered by high degree of slope on the 'south eastern' side. Low slopes in the range 2 º to 5 º and 5 to 10 º slope forms rest of the area. Thus the topography of Usilampatti can be defined as very gentle to moderate sloppy around municipality were except on the western part.
- Major parts of Usilampatti District covers crop lands which occur on varieties of terrain, often associated with

terrain patterns such as river plains. The Tonal contrast of crop land varies from bright red to red depends upon the health of the crop in satellite imagery. In the study area some places were covered by dry crop lands. There were plantations found all over the imagery including coconut, eucalyptus plantations and vineyards.

- Post-monsoon water level depth was 2-5m and 5-10m observed in Usilampatti municipality. The depth of water level was little higher than the Thirumangalam municipality. The higher depth of water level can be seen in the northern and NW part of the area

5.2 Result of Weighted Overlay analysis

Weighted Overlay was a technique for applying a common measurement scale of values to diverse and dissimilar inputs to create an integrated analysis. Based on different thematic layers possible location for waste disposal sites have been identified. For the present study using weighted overlay of each layer, viz., geology, geomorphology, soil, slope, landuse, and actual field data, suitable site sensitivity index was arrived. Weightage was assigned to different thematic layers based on their significance in deciding the site suitability. The value of site sensitivity index when multiplied by the corresponding weightage, results in a score or rank (ranging from 1 to 4) indicating the site suitability.

The top ranking 17 parameters were short-listed and weightage of attributes (Wi) were assigned based on the pair wise comparison method (Canter, 1996) such that the total weightage was 1000. Each attribute was measured in terms of a sensitivity index (Si) on scale of 0-1(0.0-0.25, 0.25-0.5, 0.5-0.75, 0.75-1.0) to facilitate computation of cumulative scores called Risk Index (RI) that can be used for short listing of landfill sites. While "0" indicated potential site. "1" indicated the low potential site. Allotment of sensitivity indices for the selected parameters was made following earlier studies (Saxena and Bhardwaj, 2003). The RI of the site was calculated using the following formula:

$$RI = \sum_{i-1}^{n} WiSi$$

Where

Wi = Weightage of the with variable ranging from 0- 1000

Si = Sensitive index of the i'th variable ranging from 0- 1

RI = Risk Index variable from 0-1000

Based on availability of field data, this attribute can be graded on the four levels of scales for the particular site and total of 1000 points were divided among the four criteria such as Accessibility, Receptor, Environmental and Geological related attributed 100, 200, 300, 400, respectively using Delphi approach. The value of the sensitivity index multiplied by the corresponding weightage value would give risk index score for each parameter. Similarly scores were calculated for all parameters to get the final score for site selection. Comparisons of score were done for all sites and least score sites has considered as ideal site for dumping yard. The total scores (out of 1000) can be interpreted in terms of the sensitivity of the site as follows.

Rank 1 – Highly Suitable (Score below 300)

Rank 2 – Suitable (Score between 300 to 450)

Rank 3 – Moderately Suitable (Score between 450-600)

Rank 4 – Least Suitable and (between 600-750)

Not suitable area was given a white colour in the maps

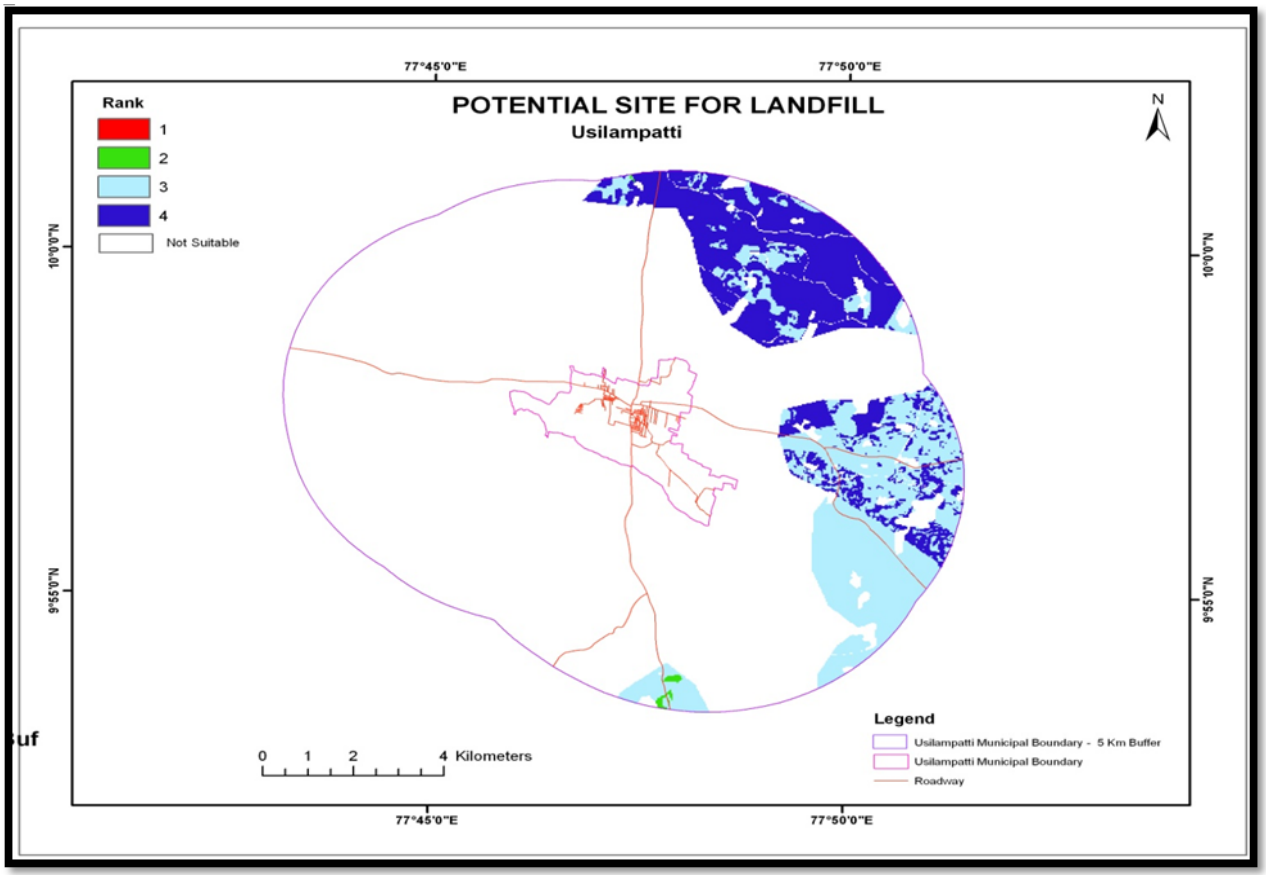

Fig 2: Suitable waste disposal sites in Usilampatti District

Weightage was assigned to different thematic layers based on their significance in deciding the site suitability. The value of site sensitivity index when multiplied by the corresponding weightage, results in a score or rank (ranging from 1 to 4) indicating the site suitability.

6. Conclusion

In the present study as result of the multi criteria overlay analysis the following suitable locations for solid waste disposal were suggested for Usilampatti municipality. The accuracy of the proposed sites was directly related to the number of data layers considered for analysis. Each data layer was to be judged with respect to environmental, social and community impact and due weightages need was assigned before taking any decision. The suitable sites were derived after the weighted overlay analysis in GIS. Finding locations at Usilampatti is little difficult where the rank 1 locations were not in the 5 km buffer regions. However, rank 2 and rank 3 locations were found in the western and south western regions. Geographic Information System combined with Remote sensing techniques were most suitable tools to address problems related to spatial dimension, one like finding suitable location for solid waste disposal. GIS as an information tool, has helped in the acquisition of recent land use information and geomorphologic data. With further analysis on the data, our administrators can solve many issues like identifying a suitable site for waste disposal. Thus with the use of these technologies management of municipal waste will no longer be a problem for city administrators.

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