Geospatial Technology to Assess the Site Suitability of Solid Waste Management in Salem Corporation, South India

[1]Kumar G and [2]Baskar S

[1]Assitant Professor, [2]Assistant Professor
[1&2]Department of Civil Engineering, Vel Tech Rangarajan Dr.Sagunthala R&D Institute of Science and Technology, Chennai, Tamil Nadu, India.

Abstract: In developing countries like India, the solid waste management is one of the vital environmental problems. Due to increasing of business, built-up and infrastructure development due to the population growth create negative impact on the environment. One of these impacts is due to location of dumping site in unsuitable areas. This research aims to delineate the suitable sites for disposal of Solid Waste generated from Salem Corporation using Remote Sensing (RS) and geographic information system (GIS) techniques. The land suitability factors of geomorphology, geology, road density, slope (angle), drainage density, land use / land cover and soil were chosen for this study. Based on the land suitability for solid waste dumping all the thematic maps were assigned rank and weights. The final suitability map was prepared by overlay analyses on Arc map and classified into as most suitable, suitable, moderately suitable and unsuitable zones of the study area were determined. The results revealed that only 20% of the study area is suitable for solid waste dumping and remaining (80%) of land for not suitable for waste dumping of the corporation and these sites will increase the environmental risk and human health problems.

***IndexTerms* - Solid Waste, Remote Sensing, GIS, Weight Overlay, Salem.**

I. INTRODUCTION

In the urban areas the solid waste dumping is one of the environmental problem due to most of the solid wastes are not properly dumped in the suitable areas. In recent times, it is the important global environmental problem and key component of the infrastructure for a sustainable community. Bringi, (2007) explain the definition of the waste is a material discharged from each stage of daily human life activities, which leads to adverse impacts on human health and the environment. Babatunde et al (2013) referred, the solid waste are the leaves/ twinges, food remnants, paper/cartons, textile materials, bones, ash/dust/stones, dead animals, human and animal excreta, construction and demolishing debris, biomedical debris and household hardware. Elmira et al (2010) analyzed the increasing population, rapid economic growth and the rise in community living standards accelerate solid waste generation in the world. Many researchers suggested that the solid waste dumping site should be located within a 1 km buffer from the roads and other transportation facilities (Chang et al., 2008).

Sener et al. (2011) find out in Turkey, the distance between disposal sites and settlement areas must be more than 1000 m and the haul distance between the solid disposal site and the main city centre should not exceed 30 km. Remote sensing and GIS techniques is very useful to reduce cost and time and can provide information about the various spatial criteria such as land use/land cover, drainage density, slope, etc for the estimation of solid waste management (Emun, 2010). The main objective of the present study to understanding the current problems of waste disposal in Salem Corporation and suggest best possible site for waste disposal using integrated analysis.

II. STUDY AREA

Salem Corporation was selected for solid waste management study. It has the fifth largest population of 7.54 lakhs as per 2011 census in Tamil Nadu. The fort area is the oldest part of the town. The study area covers the part of toposheets of Survey of India No.58 I/2 (1:50,000,1972), 11° 39′ 0″ to 11.65N and 78.16 to 78° 9′ 36″ E (Fig.1). Salem Corporation consists of 60 wards categorized under 4 Zonal with 91.34 (sq.km). The soil types of the study area are red non-calcareous and red calcareous soils. The temperature is generally very high during summer and it ranges from 20.0 to 37.9°C.

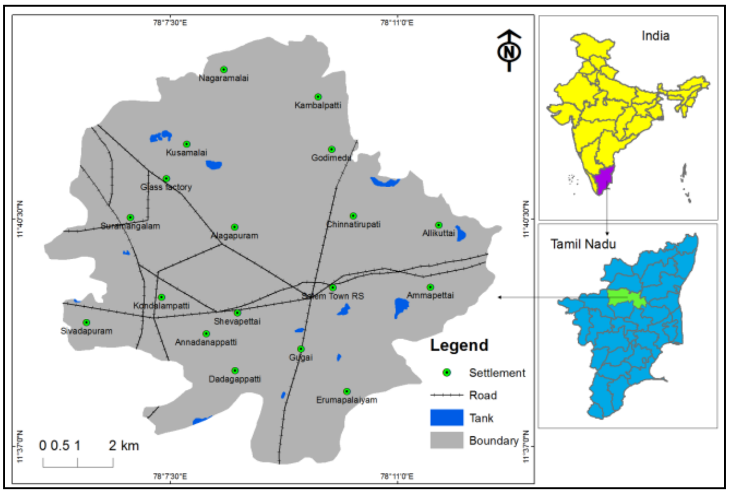

Figure 1 Location of the Salem Corporation

Climate around Salem from January to March is the driest part of the year. Hot weather begins in March and reach maximum during April-May and cools down progressively from mid June. The average annual rainfall is 700 to 900 mm. The Salem area forms a broad pediplain with a few isolated hills rising upto 600m. Some of the solid wastes dumping in the study area are show in Figure 2.

Figure 2 Solid waste dumps in the study area

III. METHODOLOGY

The thematic maps of geomorphology, geology, road density, slope (angle), drainage density, land use / land cover and soil were selected according to study areas local characteristics for solid waste management. The geomorphology, land use / land cover and lineament is generated from LISS III images of IRS P6 satellite image. Based on the land suitability for solid waste dumping all the thematic maps were assigned rank and weights. Using ArcGIS analysis tool final suitability map was prepared by overlay analyses on Arc map and leveled as most suitable, suitable, moderately suitable and unsuitable zones of the study area were determined. The slope map was generated from SRTM derived Digital Elevation Model. The individual themes were discussed as follows.

A. Geomorphology

Geomorphology is one of the important parameter for solid waste management studies. Geomorphology map were prepared from IRS P6 LISS III satellite data. The different geomorphological features are present in the study area (Fig.3). The pediment and dissected hills and valleys are the dominant landforms found all over the study area. Pediplains are the result of denudation landforms. The thickness and intensity of these land forms vary depending upon the slope and structural disturbance of the area. The entire feature assigned for rank and weights.

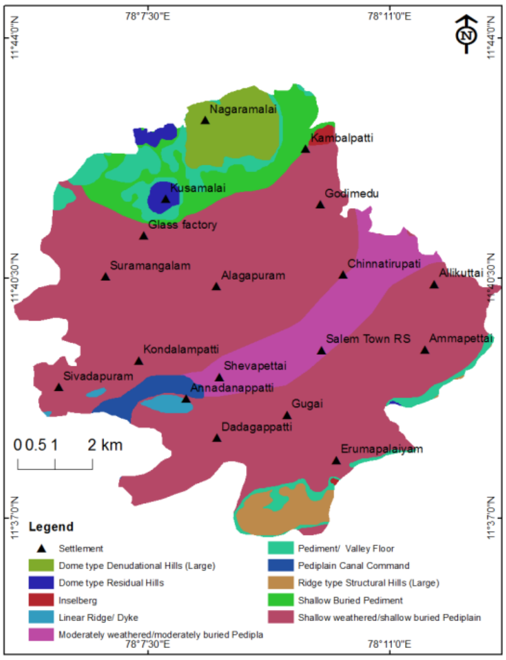

Figure 3 Geomorphology of the study area

B. Geology

Geological features are the source to leakages of solid waste during the rainy seasons. The study area is underlain entirely by archaean crystalline formations with recent alluvial forms. The hard consolidated crystalline rocks of archaean age represent weathered and fractured formations of Granite Gneiss, Granite, Charnockite, and other associated rocks. Geology map of the study area is shown in Figure 4. Based on the land suitability condition, the rock types were assigned rank and weights.

C. Road Density

Road network are the main source to solid waste dumping. The road network comprises of the railway network, national highway, state highway and other local roads that almost link all the towns and villages of the Salem Corporation while the drainage network consists of the major river. Road density map prepared from road network using line density tool available in the ArcGIS (Fig.5). It is classified into four categories from 0 to 14.51 km/sq.km.

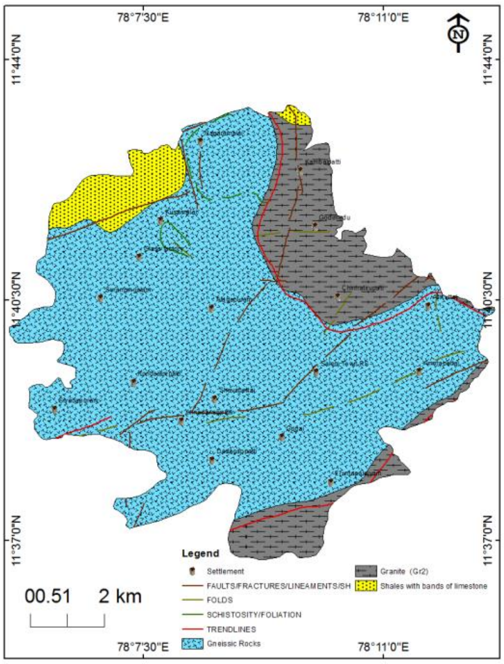

Figure 4 Geology of the Salem Corporation

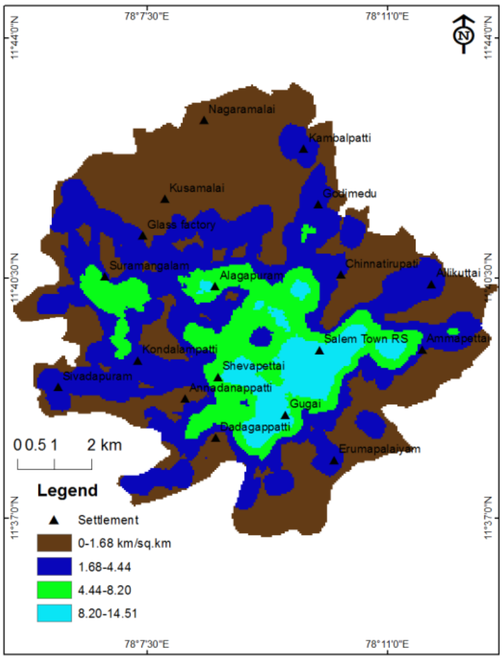

Figure 5 Road density of the study area

D. Slope

Slope is an important parameter in the identification of landfill site. According to Leao et al. (2001), the land with a slope less than 10% is highly suitable for solid waste dumping. The slope map was generated from the digital elevation model (SRTM-DEM). The areas with high slopes are not ideal for solid waste disposal and flat areas are not ideal either. The preferred areas for waste disposal are those with medium slope of not more than 22°. The slope map is shown in Fig 6. This study considered the lower slope most suitable than the land with higher slope. Different research shows that areas with high slopes will have high risk of pollution and potentially not a good site for dumping.

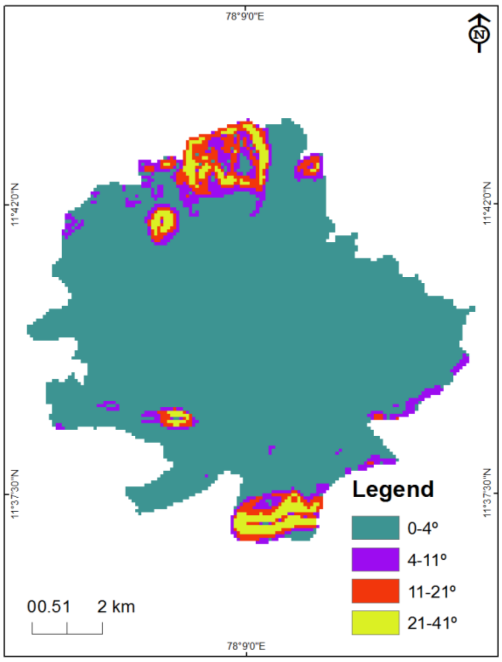

Figure 6 Reclassified slope angle in the study area

E. Drainage density

The dumping side is carefully located not near side of drainages. It will generated water quality problem The drainage density map was prepared from drainage map using density option available in ArcGIS tool. The drainage density map was reclassified into four classes (Fig.7). Apparently region having high drainage density is not suitable for considering the site for solid waste disposal as it exploits the surface and groundwater through the process of leachate. Hence a region with low drainage density is preferable.

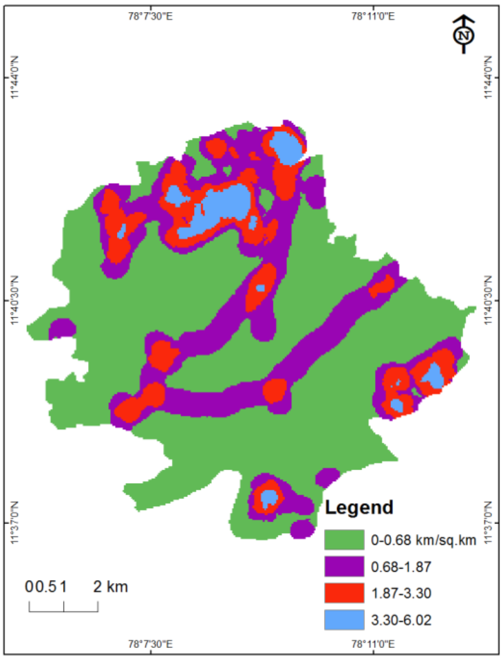

Figure 7 Drainage density of the study area

F. Land use/land cover

The land use / land cover is the natural and human landscape that may be exposed by the threats imposed because of landfill adjacency. The dumping site should not be selected close to the built up area to avoid adversely affecting land value and future development and to protect human being from environmental hazards created from dumping sites (Clark et al., 1974). It should be selected at a suitable distance farther from the residential area. Scrub land and barren land are most suitable for the dumping site. Information of the area land use / land cover can be get from the IRS P6 LISS III satellite image (Fig.8.) In the study area, major land cover and use classes were water bodies (5%), scrub land (20%), urban areas (45%), agricultural land (20%), and forest cover (10%). Hence, the highest value is given for suitable land class types to solid waste disposal site selection.

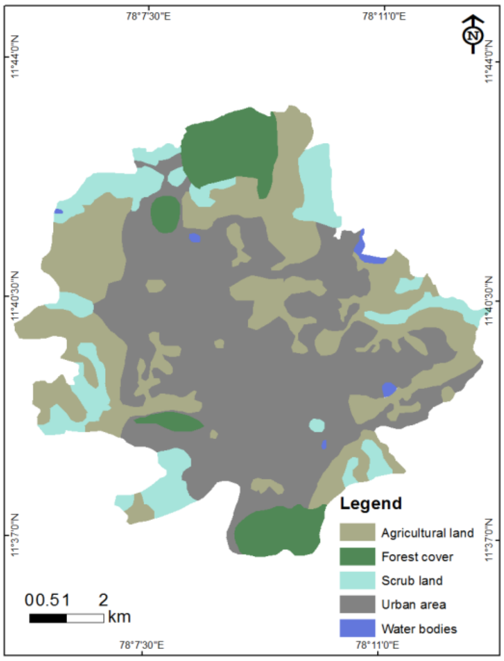

Figure 8 Land use / Land cover in the study area

G. Soil

The soil order of the study area is broadly grouped into alfisol, entisol, vertisol, and reserved forest and miscellaneous (Fig.9). The alfisol type of soil is found predominant in the study area. The vertisol soil is found towards the western portion whereas the entisol soil is seen distributed on the northern portion of the study area.

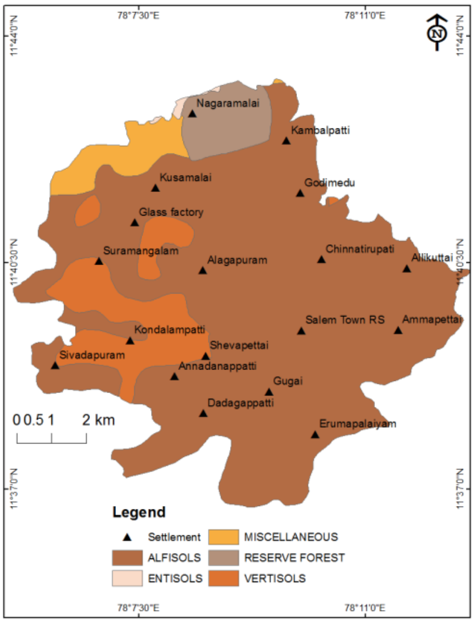

Figure 9 Soil order in the study area

IV. RESULTS AND DISCUSSION

Weighted Overlay was applied based on different thematic layers possible location for waste disposal sites have been identified. Rank and weights were assigned to all the thematic layers based on their significance in deciding the site suitability (Table 1). The value of site sensitivity index when multiplied by the corresponding weights results in a score or rank (ranging from 1 to 4) indicating the site suitability. According to Canter (1996), the top ranking 7 parameters were shortlisted and weights of attributes (Wi) were assigned based on the pair wise comparison method, such that the total weights 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 “4” indicated potential site. “1” indicated the low potential site.

Table 1 Rank and Weights for various parameters

Themes	Feature Class	Weights	Rank	Score
Geomorphology	Denudational hill	25	4	100
	Residual hill		4	100
	Inselberg		3	75
	Linear ridge		3	75
	Moderate pediment		2	50
	Valley floor		1	25
	Canal command		1	25
	Structural hill		4	100
	Shallow pediment		2	50
Geology	Gneissic Rocks	10	3	30
	Granite		4	40
	Shale with bands of limestone		1	10
Road density, km/km^2	0-1.68	15	4	60
	1.68-4.44		3	45
	4.44-08.20		2	30
	08.20-14.51		1	15
Slope	$0-4^o$	10	4	40
	$4-11^o$		3	30
	$11-21^o$		2	20
	$21-41^o$		1	10
Drainage density, km/km^2	0-0.68	10	4	40
	0.68-1.87		3	30
	1.87-3.30		2	20
	3.30-6.02		1	10
Land use / land cover	Agricultural land	20	1	20
	Scrub land		4	80
	Forest cover		3	60
	Water bodies		1	20
	Urban area		2	40
Soil	Alfisols	10	3	30
	Entisols		2	20
	Miscellaneous		4	40
	Reserve Forest		4	40

The RI of the site was calculated using the following formula:

$$RI = \sum_{i-1}^{n} \text{WiSi} \quad (1)$$

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 weights 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 – Most Suitable (Score below 300)
Rank 2 – Suitable (Score between 300 to 450)
Rank 3 – Moderately Suitable (Score between 450-600)
Rank 4 – Unsuitable and (between 600-750)

To demarcate the solid waste disposal sites all the thematic layers were integrated into a weighted index process. The final suitability map was prepared by overlay analyses on Arc map and leveled as most suitable, suitable, moderately suitable and unsuitable zones of the study area were determined (Fig.10). The results indicate that 25% of the study area is unsuitable for solid waste dumping; 20% suitable; 45% moderately suitable; and 10% most suitable. The Salem Corporation is one of the fast developing townships in Tamil Nadu state. At present the urban solid waste is being discarded at a site in a new bus stand area. The site is almost filled with solid waste and it may not be able to accommodate any further. Similarly, several constructions have come up near this site in recent years which is a violation. Finally, Nagaramalai adivaram and near Erumapalayam is the most suitable for management of solid waste in the study area in Salem Corporation. The selected sites were checked for accessibility by overlaying the road network map and were found to be the most accessible sites in the study area. The research has also shown that sitting criteria can be modified based on local constraints.

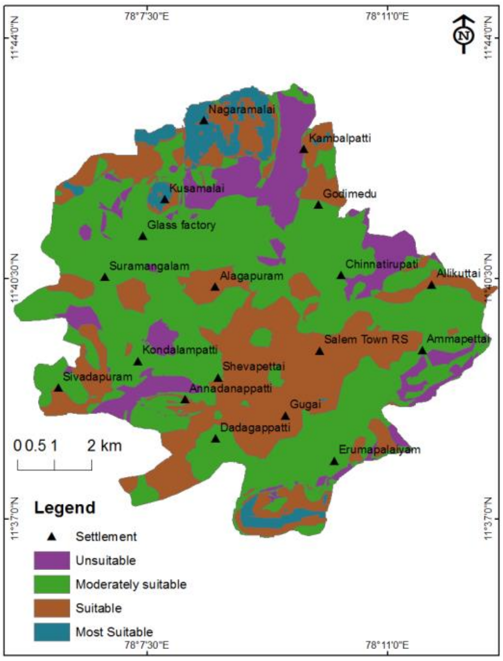

Figure 10 Suitable sites for solid waste dumping in Salem Corporation

V. CONCLUSION

In the present study as result of the multi criteria overlay analysis the following suitable locations for solid waste disposal were suggested for Salem Corporation. 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 weights need was assigned before taking any decision. The suitable sites were derived after the weighted overlay analysis in GIS. In the study area most suitable indicating the suitable site for waste disposal could be located in the northern portions. 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.

REFERENCES

[1] Babatunde BB, Vincent-Akpu IF, Woke GN, Atarhinyo E, Aharanwa UC, Green AF, Isaac-Joe O (2013). Comparative analysis of municipal solid waste (MSW) composition in three local government areas in Rivers State, Nigeria. Afr. J. Environ. Sci. Technol. 7(9):874-881.

[2] Bringi SD (2007). Application of 3D principles to solid waste management on the Asian Institute of Technology (Ait) Campus. Unpublished M.Sc. Thesis.Indonsia.

[3] Chang N, Parvathinathan G, Breeden JB (2008). Combining GIS with fuzzy multi criteria decision-making for landfill sitting in a fast-growing urban region. J. Environ. Manage. 87(1):139-153.

[4] Clark, R.M., and Gillean, J (1974). Systems Analysis and Solid Waste Planning. Journal of the Environmental Engineering Division. 7-25

[5] Elmira S, Behzad N, Mazlin BM, Ibrahim K, Halima T, Saadiah H (2010). Urban solid waste management based on geoinformatics technology, University Putra Malaysia, Malaysia. Environmental Engineering and Management Program School of Environment, Resources and Development -SERD.

[6] Emun GM (2010). Multi criteria approach for suitable quarry site selection in Addis Ababa using remote sensing and GIS. Unpublished M.Sc. Thesis, Addis Ababa University, Ethiopia.

[7] Sener S, Sener E, Nas B (2011). Selection of landfill site using GIS and multicriteria decision analysis for Beysehir Lake Catchment Area Konya, Turkey. J. Eng. Sci. Des.1(3):134-144.