Journal of Environmental Informatics Letters 8(2) 86-94 (2022)

Journal of Environmental Informatics Letters

www.iseis.org/jeil

Geospatial Techniques for Suitable Site Determination for Municipal Solid Waste: A Case Study of Calangute/Saligao, Goa, India

S. B. Kadu[1], J. Dey[2, 3], R. Vijay[2, 3 *], and M. Suresh-Kumar[1]

[1] *Environmental Impact and Sustainability Division, Council of Scientific and Innovative Research-National Environmental Engineering Research Institute, Nagpur, Maharashtra 440022, India*
[2] *Council of Scientific and Innovative Research-National Environmental Engineering Research Institute, Nagpur, Maharashtra 440022, India*
[3] *Academy of Scientific and Innovative Research (AcSIR), Ghaziabad 201002, India*

Received 06 September 2022; revised 30 November 2022; accepted 07 December 2022; published online 30 December 2022

ABSTRACT. Solid waste management is one of the biggest concerns faced by the developing nations like India since phenomenon of urbanization has risen uncontrollably in recent years in these developing countries. This has led to develop and adopt new technologies for more constructive and efficient waste management system so as to reduce the pressure of solid waste management on the authorities as well as on environment. The initial step in the solid waste management is landfill site selection which is quite complex as it implicates many environmental factors. Suitability of the selected site is always accountable for loss or gain of the environment in the future and also it determines the economics and benefits or loss. Hence, it is always advisable that suitability should be determined considering economical and socio-environmental factors. This paper throws a light on the viability of new geospatial technologies like remote sensing and geographic information system (GIS) in the process of site selection for municipal solid waste in Calangute/Saligao, Goa, India. For the current study, Weighted Overlay Analysis is used to identify the suitability of the site. The research work identifies the arability of land for disposal of MSW in a systematic manner that ensures the environmental protection and management of waste products. This study provides the suitable dumping sites for municipal solid waste, which may be subjected to the green city management and city planning. Thus, this study provides an advance way to manage the solid waste of an urban area. This study expresses the efficiency of model-based technique that can help to deal with a burning issue like MSW across the globe. This model-based study can reduce laborious activities, minimize the cost of the project. Thus, it helps an urban planner to for better site selection for MSW management and overall city planning. This study will provide a base line for future study like leachate management, land degradation, loss of biodiversity, etc.

Keywords: solid waste management, object-based image analysis, weighted overlay analysis, remote sensing, GIS

1. Introduction

Solid waste can be defined as "anything that is garbage, refused, sludge or material that is air dried. These materials can be solid, liquid, semisolid or gaseous generated from industrial, commercial, agricultural and community activities" (Mohammedshum et al., 2014). Solid waste materials in urban areas are mainly the typical result of human activities. Developing countries like India are facing huge stress, and health issues because of inappropriate dumping and disposal of waste (Shivashankar et al., 2017). The most important aim of sustainable waste management is to safeguard the well-being of human beings, and the environment, and to protect and restore resources. Besides that, it also helps in the prevention of the spread of waste-related issues in the coming time (Allesch et al., 2014). Over the past few decades, issues related to municipal solid waste (MSW) management have attained distressing situations in developing countries. In developing countries, the proportionate production of solid waste in urban areas is much less compared with the developed countries. However, the capacity of developing countries to collect, process, dispose of, or reuse solid wastes in a cost-effective manner is significantly limited compared with developed countries (Allesch and Brunner, 2014). The most widespread problems associated with improper management of solid waste comprise of transmission of diseases, fire risk, and annoyance of odor. The various types of pollution including atmosphere, land, and water, loss of aesthetics, and economy are the results of improper solid waste management. Proper disposal of the MSW is the most vital part of the waste management system for the preservation of the environment (Sivasankar et al., 2017). The proper disposal and management of the MSW is a huge and difficult task. Several issues such as deficiency of technical knowledge, scarcity of manpower, shortage of transportation modes for collection and transfer of waste and inadequate space (Abdel-Shafy and Mansour, 2018) are there. The appropriate and technical solid waste disposal demands the selection of the correct location or site which is related to many different aspects that influence the site selection.

* Corresponding author. Tel.: +91-712-2249402.
E-mail address: r_vijay@neeri.res.in (R. Vijay).

ISSN: 2663-6859 print/2663-6867 online
 doi:10.3808/jeil.202200093

These aspects are mainly classified into 3 sections i.e., Economic, Social, and Environmental (Tamilenthi et al., 2011).

Despite all issues, solid waste management should be tackled more systematically which includes an introduction to new and advanced strategies for which multiple vacillating urban models should be taken into account. A proper landfill site selection for MSW is a complicated procedure involving various environmental, social, and technical parameters along with government rules. For all these processes to be carried out requires a huge quantity of spatial as well as non-spatial data is required. remote sensing and GIS are of such tools which can provide a lot of options in minimum time with cost efficiency. It can help to handle data in a very efficient way and to generate new options (Ahmed et al., 2006). MSW management needs gathering of significant data necessary to take preventive measures along with appropriate planning to make sure sustainability (Slack et al., 2005).

Calangute/Saligao is severely contaminated due to unscientific disposal, leading to a serious risk to air, soil, surface water, and groundwater resources in and around the existing site. Therefore, the present study is aiming to determine the suitability of the site for MSW management considering all environmental parameters along with its positive environmental impacts caused due to new and advanced techniques. Hence, a holistic approach has been followed for planning an integrated MSW treatment facility at Calangute/Saligao in North Goa.

2. Application of Remote Sensing and GIS for Landfill Site Identification

In solid waste management cost efficiency is definitely the most significant aspect. Other complicated aspects of site selection are not only directly proportional to the elements that deter- mine the standard of living of the society but also to the rising complications in the current management due to the rapidly growing population and demanding way of life (Sivasankar et al., 2017). Detection and identification of the new waste disposal site is a much more complex process because it needs substantial proficiency in social and environmental sectors viz., soil, geology, topography, land use, sociology, economics, etc. The process of selection of new landfill sites also considers parameters such as transportation and access, settlements, infrastructure development, and the tendency of the soil to leach infection. Hence, the positioning of the site must include spatial data processing, rules to be followed, and acceptable standards (Sumathi et al., 2008). Remotely sensed data gives a broad sighting of the considerably larger regions. This multispectral data is useful to delineate differences between different features having the facility to provide temporal data to identify ongoing changes (Poorna and Vinod, 2016). With the use of remote sensing and GIS techniques, the operational cost of the whole process can be lessened by providing a database for supervising the site in succeeding times. A combination of GIS and spatial data can provide circumstantial data with good quality and quantity providing answers to spatial problems up to large extent. All these qualities prove remote sensing and GIS powerful and vital tools for the study of a particular area, especially for dump sites (Mussa and Suryabhagavan, 2021). According to (Nishanth et al., 2010), integrating remote sensing data with attribute data for various factors related to the environment stored within GIS domain can produce an outstanding structure for all kinds of data operations like data acquisition, storing, manipulation, calculations and exploration. Hence, this study aimed to find the suitability of the pro-posed MSW dumping site to minimize loss to the environment using remote sensing and GIS.

3. Study Area

The current research work was carried out to detect the MSW site near Saligao/Calangute village, Bardez Taluka, North Goa district of the state of GOA which is situated on the western coast of India. The latitudinal and longitudinal span of the area goes from 15°29′30″ ~ 15°37′66″ N latitude and 73°44′00″ ~ 73°52′20″ E longitude. The total area under study is 151.89 square kilometer. The new site which will be found suitable for the Centralized Municipal Solid Waste Management Facility (CMSWPF) at Calangute/Saligao will serve to 3 ~ 3.5 Lakhs population. It will also cover a north-western area of the beachfront which produces a huge amount of waste due to the local and tourist populations. In addition to this, it will also influence the localities on the eastern side. The area and talukas to be covered by the facility are shown in Figure 1.

4. Experimental Procedures

In this study, suitability analysis was carried out along with the assessment of land use land cover (LULC) with the help of geospatial techniques like remote sensing and GIS. Methodology of the study was carried out in III phases followed by the flowchart of the methodology (Figure 2). In this study Phase I deals with Satellite data and field data collection and GIS map preparation, and Phase II describes the remote sensing analysis and image interpretation, and Phase III is about Suitability analysis.

4.1. Phase I: Satellite Data and Field Data Collection and GIS Map Preparation

The first step which was carried out in this study was the gathering of the data. There were two types of data collected viz. digital data in the form of satellite images and ground truth data in the form of GPS points for authentication of the observations. To carry out the LULC analysis, false color composite (FCC) satellite data of Resource Sat 2A, linear imaging self-scanning sensor (LISS) IV for the year December 2018 was used (Figure 3). Ground survey was carried out in order to validate the observations and results of analysis, in which ground truth points were collected with the help of global positioning system (GPS).

4.2. Phase II: Remote Sensing Analysis and Image Interpretation

To take decisions and carry out the research by authorized bodies, as well as to the detection of the changes that are taking

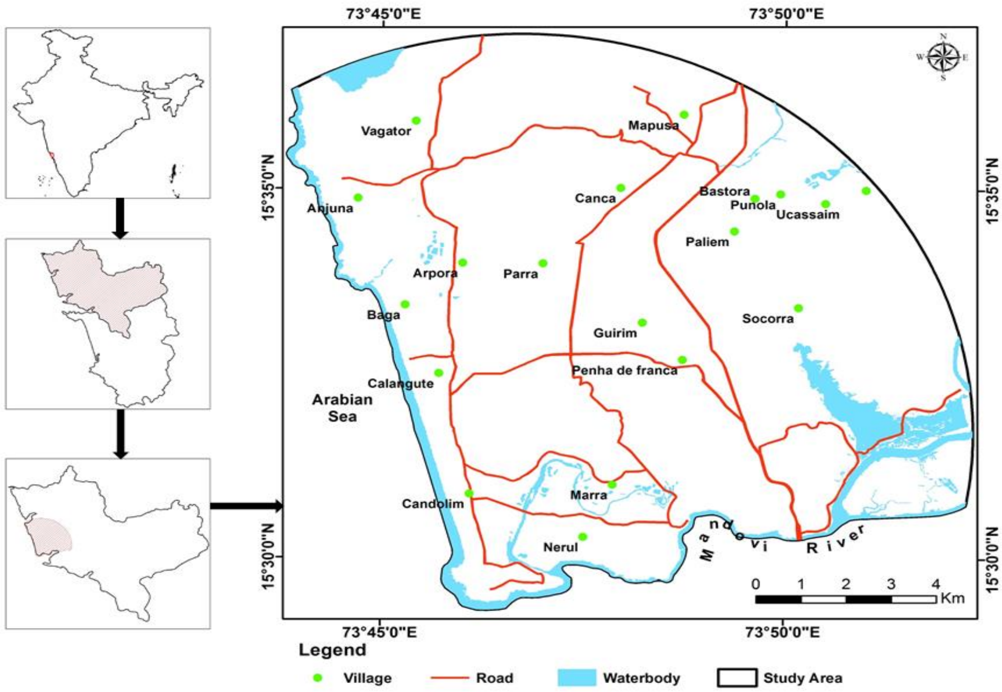

Figure 1. Study area.

place globally, information regarding LULC plays the most important part (Cui et al., 2015). Traditionally pixel-based classification methods like supervised and unsupervised classification are the easiest and most popular in which pixels are assigned the values of cover that is present on the land (Amalisana and Hernina, 2017). Whereas, in the object-based image analysis (OBIA), the image object is the component for all interpretations which holds more substantial information including components like shape, association with the adjacent object, texture, necessary spatial data depending upon different resolutions, etc., which permits maximum utilization regarding the spatial environment (Attri et al., 2015). According to Im et al. (2008), it is more resourceful and of great benefit to carry out analysis based on OBIA for high-resolution data because OBIA splits the imagery into relevant analogous parts considering shape, size, texture, and other surrounding features; which is also called as image segmentation. Hence, for this research work, the OBIA technique is used to perform LULC analysis in order to extract more accurate information from satellite data. This classification was carried out with the help of a tool called e-Cognition developer. This technique of OBIA uses two steps for carrying out the procedure among which the first is segmentation and the latter is classification (Amalisana and Hernina, 2017). Among these two, first-step segmentation is found to be the most necessary which split up the image into a number of correlative objects (Wang, 2008) followed by steps of adding smaller objects into larger ones (Karakış et al., 2006) depending upon the scale of their concurrence (Zhou et al., 2008). There are six parameters, which are required to carry out segmentation along with their designated weightage viz. color, shape, scale, compactness, smoothness, and weightage to spectral bands, etc. (Dey et al., 2018). For the current research scale factor, shape factor, and compactness which were allocated are 10, 0.3, and 0.8 respectively. Also, different spectral bands were assigned a weightage for Near-infrared (NIR) which is 2, and the rest of the bands like Green, Red, and Mid-Infrared (MIR) were given a weightage of 1. All these processes lead to the generation of spectral indices for all the classes described in Table 1. Total 9 classes as agriculture, forest, mudflat, waterbody, vegetation, barren land, built-up, mangrove, and beach were taken into consideration for LULC analysis (Figure 4).

Final stage in the image analysis is of accuracy assessment, for which a detailed ground survey was carried out using GPS. Points were collected for all the classes care was taken that all points should be homogenous and well spread through the area.

4.3. Phase III: Suitability Analysis

Determination of the landfill for solid waste dumping needs a descent assessment procedure, so that an ideal place for disposal can be recognized, i.e., an area which will qualify all the government regulatory conditions as well as it should be cost effective in terms of socio-economic aspect and environmental health (Siddiqui et al., 1996; Sumathi et al., 2008). For the study, data regarding various suitability parameters was collected from the field which includes topography, LULC, Geomorphology, Ground water depth, and distance from both waterbody and roads. Arc Map 10.2 was further used in preparations of base map, sampling location maps, for making inventory of all the LULC classes etc. Current research assessment rules are regulated by Central Pollution Control Board (CPCB), Municipal Solid Waste (Down To Earth, 2016) and Central Public Health & Environmental Engineering Organization (CPHEEO) manual (Jayhaye et al., 2014). All parameters and their decision rules are

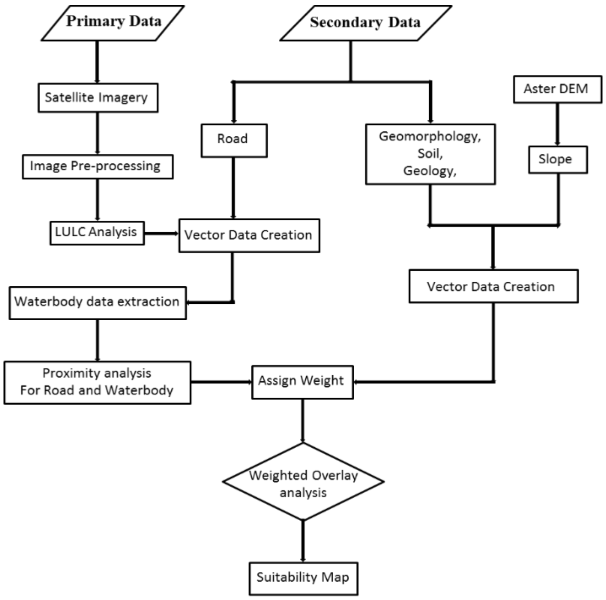

Figure 2. Flowchart for methodology.

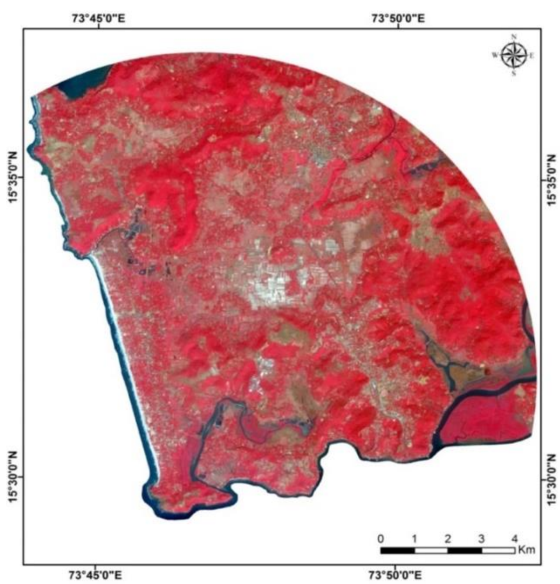

Figure 3. False color composite (FCC) imagery of study area-December 2018.

explained below:

(1) Topography: In topography, the slope was considered to detect suitability. Many distinct studies have stated that areas having higher slopes are more prone to the risk of contamination and pollution and hence not considered a suitable site for dumping. This suggests that lands with lower slopes are more appropriate for landfill sites (Ebistu and Minale, 2013). To apply this parameter a slope map (Figure 4a) was prepared in view of various slope categories. To determine slope classes raster image of ASTER DEM having a spatial resolution of 30 m was used. The slope is always indicated in terms of degrees. Slopes in the area are categorized as Gentle (0° ~ 5°), Moderate (5° ~ 16.5°), and Strong (16.5° ~ 24°) according to NRC 1998. Weightage for each slope criterion according to their suitability is mentioned in Table 2.

(2) Geomorphology: Geomorphology of the area is defined as "a science that deals with the relief features of the earth and seek an interpretation of them based on their origins and development" (Merriam-Webster, 2022). A geomorphological map of the area is downloaded from the national remote sensing center (NRSC) site (Indian Geo-Platform of ISRO, 2021) (Figure 4b).

Different types of geomorphological features that occur in the study area, were assigned different ranks according to their suitability in order to carry out overlay analysis. Weightage for each geomorphological feature according to their suitability is mentioned in Table 3. Lower rank suggests less suitability and vice versa.

(3) Soil and geology: The geology of the area does not show very much variance in its appearance as the whole area is covered by quartzite and biotite. Lateritic soil is covering the whole area showing no variance. This sol appears to be in reddish color and is composed of ferric-aluminum oxides.

(4) Land use and landcover: As mentioned above, land use and landcover for this study were extracted from the Indian remote sensing satellite (IRS) LISS IV image. According to (Jaybhaye et al., 2014) for averting adverse effects on land credits and future development and moreover for protecting mankind from environmental risks caused by MSW landfill sites, it is necessary that these sites should be far from human settlements. (Kamboj and Pandey, 2017) also suggest that there must be a significant distance between these sites and water resources like rivers and lakes, forests, vegetation, and agricultural land. Barren land, Scrub land, and fallow land are considered to be the most appropriate for dumping sites. All these LULC classes are represented in (Figure 6a). Weightage for each LULC class criteria according to their suitability is shown in Table 4. Lower rank suggests less suitability and vice versa.

(5) Ground water table: The landfill site area is referred to as one of the main factors for the contamination of groundwater all around the world (USEPA, 1984; Rajkumar et al., 2010). Hence, to minimize or restrict the contamination of the groundwater by the leachate from MSW, it is important that the site should be placed at a location where the groundwater table should be substantially deep. For this reason, map for the groundwater table depth was created using the data for depth which was collected from the ground (Figure 5b). This map was provided by ranks to the actual depth in the areas in order to carry out suitability analysis. Table 5 indicates the suitability criteria for the site with respect to water table depth. Lower rank suggests less suitability and vice versa.

(6) Waterbody: To determine the suitability of the land for dumping sites, its distance from lakes, rivers, or any surface water resource is the main criterion. Land which is at a considerable distance or away from waterbody is preferable for landfill sites (Ebistu and Minale, 2013). So, there should be no issues regarding threats of the contamination of water or health hazards. In the overlay analysis, a buffer map for the increasing

Table 1. Class Wise Range of Spectral Indices in the Present Study

LULC class	Spectral index/band	Range
Agriculture	NDVI	0 ~ 0.41
Vegetation	NDVI	0.41 ~ 0.50
Forest	NDVI	0.60 ~ 0.78
Mudflat	Red*	53 ~ 56
Waterbody	Green*	20 ~ 50
Barren Land	Red*	72 ~ 92
Built-up	Brightness*	42 ~ 64
Mangrove	NIR*	52 ~ 56
Beach	Brightness*	72 ~ 74

Note: *mean value of the band

Table 2. Criteria and Weightage for Slope

Parameter	Criteria	Rank	Extent of suitability	Total weightage
Slope	< 5°	5	Highly suitable	15
	5° ~ 16.5°	3	Moderately suitable	
	16.5° ~ 24°	2	Less suitable	
	> 24°	1	Unsuitable	

Table 3. Criteria and Weightage for Geomorphology

Parameter	Criteria	Rank	Extent of suitability	Total weightage
Geomorphology	Waterbody/ younger coastal plain	1	Unsuitable	20
	Pedimet	2	Less suitable	
	Moderately disected hill	3	Moderately suitable	
	Older coastal plain	4	Suitable	
	Disected plateau	5	Highly suitable	

Table 4. Criteria and Weightage for LULC

Parameter	Criteria	Rank	Extent of suitability	Total weightage
Landuse/ landcover	Waterbody/built-up/beach/mangrove /mudflat	1	Unsuitable	20
	Agriculture/ vegetation/forest/	2	Less suitable	
	Barren land	5	Highly suitable	

Table 5. Criteria and Weightage for Ground Water Table

Parameter	Depth (m)	Rank	Extent of suitability	Total weightage
Ground water depth	< 16	1	Unsuitable	15
	16 ~ 20	2	Less suitable	
	20 ~ 29	3	Moderately suitable	
	29 ~ 35	4	Suitable	
	> 35	5	Highly suitable	

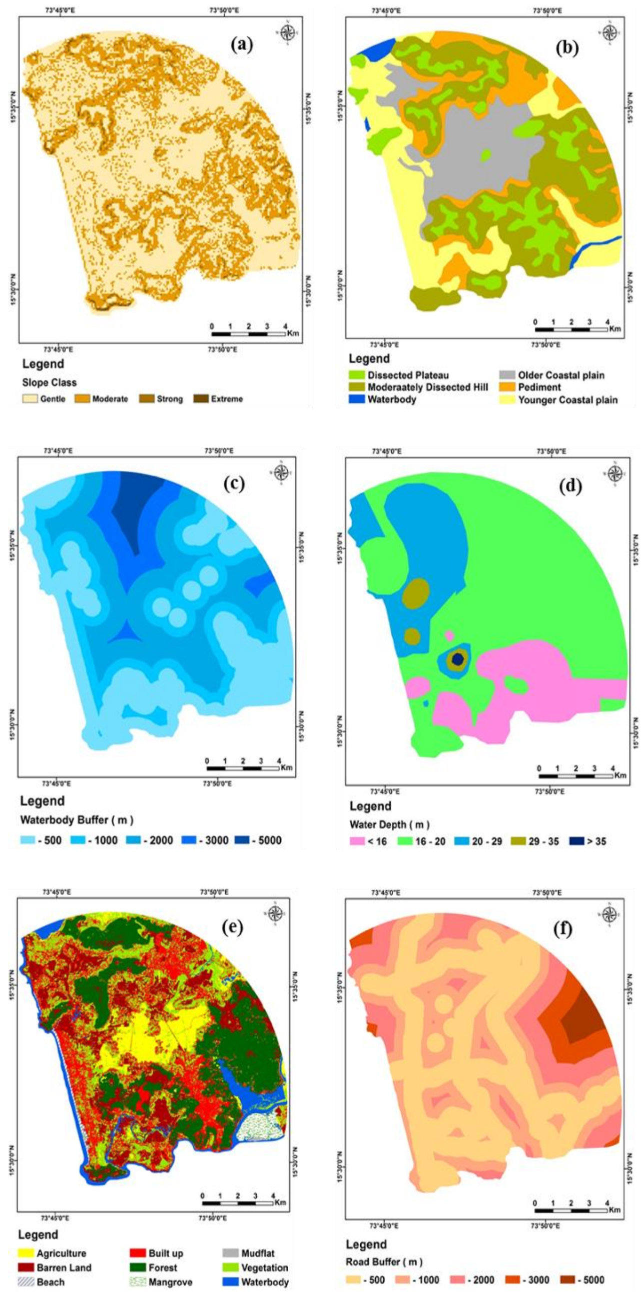

Figure 4. (a) Slope map, (b) Geomorphological map, (c) Waterbody proximity, (d) Water table depth, (e) Land use/land cover map, and (f) Road proximity map.

proximity was prepared and assigned ranks according to its suitability (Figure 5a). Table 6 indicates the suitability criteria for a site with respect to water resources (Jaybhaye et al., 2014). Lower rank suggests less suitability and vice versa.

(7) Transportation: Construction of new roads specifically for transport to MSW dumping sites needs a great amount of money in advance. Hence, it is preferable that the site should be well connected to the road network (Aziz and Khodakarami,

Table 6. Criteria and Weightage for Waterbody Proximity

Parameter	Criteria (m)	Rank	Extent of suitability	Total weightage
Waterbody proximity	< 500	1	Unsuitable	15
	< 1000	2	Less suitable	
	< 2000	3	Moderately suitable	
	< 3000	4	Suitable	
	≥ 5000	5	Highly suitable	

Table 7. Criteria and Weightage for Road

Parameter	Distance (m)	Rank	Extent of suitability	Total weightage
Transportation	0 ~ 500	1	Unsuitable	15
	500 ~ 1000	4	Suitable	
	1000 ~ 2000	5	Highly suitable	
	2000 ~ 3000	3	Moderately suitable	
	> 3000	2	Less suitable	

2013). But proper maintenance of the area, health, and hygiene is also important to consider. Hence, it is advisable to keep a minimum safe distance in order to avoid noise, traffic blockings, and disfigurement of the road due to heavy vehicles (Kaoje et al., 2016). By considering both the conditions mentioned above it is evident that the occurrence of transportation and its distance plays a key role in decision-making while thinking of the suitability of the site. Figure 6b represents the occurrence of the roads and their buffer area which is required to generate suitability analysis. Table 7 depicts suitability criteria with respect to transportation.

All these parameters were then used to create thematic layers using ArcGIS 10.5. Using the same software, integration of all the thematic layers was carried out. Weighted overlay analysis is the method used to create a suitability map as output to get the potential land for MSW dumping.

All these parameters were first reclassified in order to assign ranks and weights using the spatial analyst tool. The ranks which were allocated to the feature, or the class mainly define their impact or significance on the study area for the identification of suitable sites whereas weightage is allocated to the respective layers considering what kind of feature it includes for their response towards the study area (KAMARAJ, 2018). Weights also specify the prominence of a particular layer or theme as compared to other decision-making criteria (Al-Anbari et al., 2018). Then all the reclassified data was combined and overlaid using these ranks and weights to acquire the final output in the form of a suitability map.

5. Results and Discussion

This paper examines the approaches to detect the suitability of the solid waste management disposal or dumping site in the city. The current study evaluates that the integration of remote sensing and GIS with the study of multiple parameters evaluation is beneficial in many ways. The suitability of the site is decided by considering and studying all the mentioned parameters. To carry out this suitability analysis, the weighted overlay technique was used with the help of ArcMap software. The slope map (Figure 4a) shows that area is comprised of moderate and in some cases strong slopes. The extreme slope is very discrete in the area. But most of the land is having a gentle slope. From Table 2 it is clear that the area of gentle slope having slope < 5° proved to be the most suitable land. The Figure 4b (Indian Geo-Platform of ISRO, 2021) is representing the geomorphological structure of the study area. Geomorphological features that are present in the area are dissected plateau, older coastal plain, waterbody, moderately dissected hill, pediment, and younger coastal plain. From Table 3, it can be depicted that dissected plateau region was found to be the most suitable place for the allocation of the site, as it provides a flat surface which is having gentle slope at the top. The Figure 4c shows a waterbody proximity map while Figure 4d shows the map for the water table depth map. From the observation of both these maps, it can be seen that moderately suitable and above area from waterbody proximity is having water table depth of moderately to highly suitable. From Figure 4e, the LULC pattern in the study area can be explained. The major portion of the area is under forest followed by vegetation, barren land, built-up, agriculture, waterbody, mangrove, beach, and mudflat having areas 24.42, 20.26, 18.87, 18.28, 9.04, 6.62, 1.81, 0.60, and 0.09%, respectively. Among these, built-up areas and waterbody are totally restricted from any kind of MSW dumping. As forest and other vegetation have considerable areal coverage over there, is very sensitive to establish solid waste dumping sites. Mangrove forests are also there, which is a known eco-sensitive area that should be protected from anthropogenic activities. Agriculture areas should also be protected for food security. The Beach area and waterbody could not be used for MSW dumping purposes to ensure water security. In this context, barren land is considered to be the most suitable for MSW dumping sites. After LULC analysis, accuracy assessment was done using ground truth points, which deter- mines the accuracy as 86.3%. The inventory of these LULC classes is shown graphically in the Figure 5. But these barren land areas are necessary to follow suitability criteria regarding transportation rules which are depicted in the Table 7. The Figure 4f is presenting a road proximity map created using buffer distance rules in Table 7, which is important in order to follow weighted overlay analysis. All these components are analyzed, classified, and quantified critically to generate the site suitability map for the landfill sites. The ranking system is applied for every parameter and its different categories, which is helpful to generate a landfill site map. The research work identifies the arability of land for disposal of MSW in a systematic manner that ensures the environmental protection and management of waste products. This study provides suitable dumping sites for MSW, which may be subjected to green city management and city planning. Thus, this study provides an advanced way to manage solid waste in an urban area.

When all these parameters were overlaid with each other, it represented a suitability map for the study area, which categorized the whole area into four classes viz. unsuitable area, less suitable, moderately suitable, and highly suitable as shown in Figure 6.

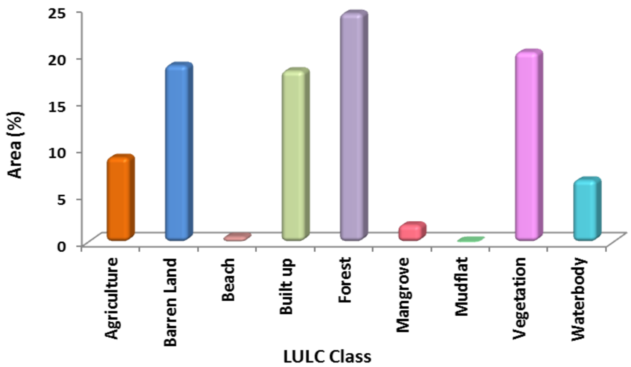

Figure 5. Inventory of LULC.

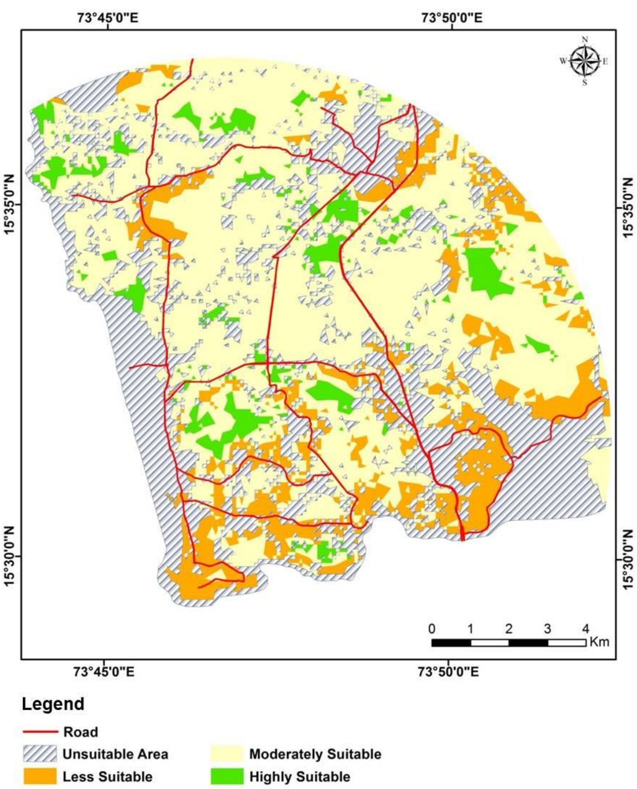

Figure 6. Suitability map for potential landfill sites.

Figure 6 is the overlay analysis of all the parameters. The final output clearly identifies the unsuitable, less suitable, moderately suitable, and most suitable areas. From the figure, it can be depicted that areas that are categorized as unsuitable, are mainly waterbodies and built-up. The unsuitable areas cover densely populated areas, recreational places, and touristy areas that generate a lot of waste materials that need to be disposed of and managed properly at the solid waste management facility site. As touristy places seem to be overcrowded and major sources for pollutant emission, disposal, and management site for solid waste should be available in proximity areas but not in a residential area. In view of this population is a major component to establish a solid waste management site. As MSW is highly sensitive to public health and environmental degradation, solid waste management sites should be established in safe areas. Built-up areas are also categorized as less suitable. Areas that are identified as moderately suitable, are those which are qualifying criteria like slope, water, and road proximity, ground-water table depth but do not attain satisfactory weightage with respect to geomorphology and LULC of the area. Whereas the highly suitable land portion clearly dominates all the criteria including landform and LULC needed for a potential site as it is clearly seen that most of the suitable sites are located on the plateau which is flat land, and it is also coming under the barren land category. The weightage of these sites is also high due to their ideal distance from the road network.

6. Conclusions

In today's society, issues related to solid waste dumping and disposal are much more complex due to the increasing population and rapid urbanization. The limitation of funding is one of the main concerns related to solid waste dumping. Hence, it has become the need of time to rely on new technologies in order to reduce stress related to money and time in the process.

The above study revolves around the use of Remote Sensing and GIS in order to analyze and find suitable land for solid waste dumping. This study incorporates Remote Sensing and GIS-weighted overlay analysis method for analyzing and finding out suitable landfill sites for the MSW dumping sites. The research work considers many parameters like Land, Slope, Geomorphology, Geology, Soil, Waterbody, proximity, Water table depth, LULC, Transportation, etc. which were then overlaid using weighted overlay analysis to find the suitability of the land. After considering the results of the analysis of parameters, it can be concluded that the sites which are categorized as highly suitable are satisfying all the decisive criteria for suitability for an ideal dumping site far from waterbodies, easy to access, existing on a gentle slope and on barren land, etc. These potential sites are on relatively plain land, hence the topography, as well as geology, is not anticipated to change due to the proposed project. Also, work regarding formation and construction will be less. It is noteworthy that these sites are at a significant distance from the major roads like main connecting roads in the urban areas or highways so as to preserve the aesthetic appeal of these areas. The finding of this work can prove to be useful for developers and management.

All these observations can conclude that Remote sensing and GIS have played a major role in this research proving to be a very powerful tool for determining the suitability of the land. This study addressed how remote sensing and GIS model-based study can determine the several parameters that require for site suitability assessment. This study expresses the efficiency of model-based techniques that can help to deal with a burning issue like MSW across the globe. This model-based study can reduce laborious activities and minimize the cost of the project. Thus, it helps an urban planner for better site selection for MSW management and overall city planning. In this study weighted overlay analysis in GIS was integrated with Remote Sensing which can help decision-makers in the identification of problems and their solutions associated with MSW site suitability calculations. The capability of GIS to store, retrieve and update the data can help planners to predict the positive and negative effects of the MSW site on a particular site. Remote sensing and GIS have proved themselves as cost and time-efficient tools for deciding suitability over traditional long processes. From the study, more use of Remote Sensing and GIS is recommended in these types of work. This study will provide baseline data for future studies like leachate management, land degradation, loss of biodiversity, etc.

Acknowledgments. Authors are thankful to the Director CSIR-National Environmental engineering Research Institute, Nagpur, for providing necessary infrastructure and support for carrying out this research study.

References

Abdel-Shafy, H.I., and Mansour, M.S. (2018). Solid waste issue: Sources, composition, disposal, recycling, and valorization. *Egyptian Journal of Petroleum*, 27(4), 1275-1290. https://doi.org/10.1016/j.ejpe.2018.07.003

Ahmed, S.M., Muhammad, H. and Sivertun, A. (2006). Solid waste management planning using GIS and remote sensing technologies case study Aurangabad City, India. *In 2006 International Conference on Advances in Space Technologies*, Islamabad, Pakistan, 196-200. https://doi.org/10.1109/ICAST.2006.313826

Ahsan, A., Alamgir, M., El-Sergany, M.M., Shams, S., Rowshon, M.K. and Daud, N.N.N. (2014). Assessment of municipal solid waste management system in a developing country. *Chinese Journal of Engineering*, 2014, 1-11. http://dx.doi.org/10.1155/2014/561935

Al-Anbari, M., Thameer, M. and Al-Ansari, N. (2018). Landfill site selection by weighted overlay technique: case study of Al-Kufa, Iraq. *Sustainability*, 10(4), 999. https://doi.org/10.3390/su10040999

Allesch, A. and Brunner, P.H. (2014). Assessment methods for solid waste management: A literature review. *Waste Management and Research*, 32(6), 461-473. https://doi.org/10.1177/0734242X14535653

Amalisana, B. and Hernina, R. (2017). Land cover analysis by using pixel-based and object-based image classification method in Bogor. *In IOP Conference Series: Earth and Environmental Science*, 98(1), 012005. https://doi.org/10.1088/1755-1315/98/1/012005

Attri, P., Chaudhry, S. and Sharma, S. (2015). Remote sensing & GIS based approaches for LULC change detection - A review. *International Journal of Current Engineering and Technology*, 5(5), 3126-3137.

Aziz, R.S. and Khodakarami, L. (2013). Application of GIS models in site selection of waste disposal in an urban area. *WIT Transactions on State-of-the-art in Science and Engineering*, 77(9), 27-35. https://doi.org/10.2495ISUD130041

Baiocchi, V., Lelo, K., Polettini, A. and Pomi, R. (2014). Land suitability for waste disposal in metropolitan areas. *Waste Management and Research*, 32(8), 707-716. https://doi.org/10.1177/0734242X14545642

Basavarajappa, H.T., Tazdari, P., Manjunatha, M.C. and Balasubramanian, A. (2013). Application of remote sensing and GIS on waste disposal site selection and environmental impact assessment around Mysore City, Karnataka, India. *International Journal of Earth Sciences and Engineering*, Cafetinnova, 6(2), 1801-1808.

Choudhury, S. and Das, S. (2012). GIS and remote sensing for landfill site selection-a case study on Dharmanagar Nagar Panchayet. *IOSR Journal of Environmental Science, Toxicology and Food Technology*, 1(2), 36-43. https://doi.org/10.9790/2402-0123643

Cui., L.L., Jun, S., Ping, T. and Du, H.Q. (2008). Comparison study on the pixel-based and object-oriented methods of land-use/cover classification with TM data. *In 2008 International Workshop on Earth Observation and Remote Sensing Applications*, Beijing, China, 1-5. https://doi.org/10.1109/EORSA.2008.4620294

Dey, J., Sakhre, S., Gupta, V., Vijay, R., Pathak, S., Biniwale, R. and Kumar, R. (2018). Geospatial assessment of tourism impact on land environment of Dehradun, Uttarakhand, India. *Environmental Monitoring and Assessment*, 190(4), 181. https://doi.org/10.1007/s10661-018-6535-4

Ebistu, T.A. and Minale, A.S. (2013). Solid waste dumping site suitability analysis using geographic information system (GIS) and remote sensing for Bahir Dar Town, North Western Ethiopia. *African Journal of Environmental Science and Technology*, 7(11), 976-989.

França, D.G., Lotte, R.G., de Almeida, C.M., Siani, S.M., Körting, T. S., Fonseca, L.G. and da Silva, L.T. (2015). Object-based image analysis for urban land cover classification in the city of Campinas-SP, Brazil. *In 2015 Joint Urban Remote Sensing Event (JURSE)*, Lausanne, Switzerland, 1-4. https://doi.org/10.1109/JURSE.2015.7120351

Im, J., Jensen, J.R. and Tullis, J.A. (2008). Object-based change detection using correlation image analysis and image segmentation. *International Journal of Remote Sensing*, 29(2), 399-423. https://doi.org/10.1080/01431160601075582

Indian Geo-Platform of ISRO. (2021). Thematic map of NRSC. https://bhuvan-app1.nrsc.gov.in/thematic/thematic/index.php (accessed November 30, 2022)

Islam, S.M., Rahman, S.H., Hassan, M. and Azam, G. (2016). Municipal Solid Waste Management using GIS Application in Mirpur Area of Dhaka City, Bangladesh. *Pollution*, 2(2), 141-151. https://doi.o rg/10.7508/pj.2016.02.004

Jaybhaye, R.G., Mundhe, N. and Dorik, B. (2014). Site suitability for urban solid waste disposal using geoinformatics: a case study of Pune Municipal Corporation, Maharashtra, India. *International Journal of Advanced Remote Sensing and GIS*, 3(1), 769-783.

KAMARAJ. (2018). Identification of artificial recharge zones and study of effects of recharge structures in Neyveli Basin Tamil Nadu India using remote sensing and GIS techniques. https://shodhganga.inflibnet.ac.in/bitstream/10603/190695/5/chapter%204.pdf (accessed November 30, 2022).

Kamboj, N. and Pandey, N. (2017). Spatial distribution of solid waste disposal sites in Allahabad city, Uttar Pradesh, India using GIS approach. *Archives of Agriculture and Environmental Science*, 2(4), 357-360. https://doi.org/10.26832/24566632.2017.020420

Kaoje, I.U., Dankani, I.M. and Ishiaku, I. (2016). Site suitability analysis for municipal solid waste disposal in Birnin Kebbi, Nigeria. *IOSR Journal of Humanities and Social Science (IOSR-JHSS)*, 21(7), 1-10. https://doi.org/10.9790/0837-2107030110

Karakış, S., Marangoz, A.M. and Büyüksalih, G. (2006). Analysis of segmentation parameters in ecognition software using high resolution quickbird MS imagery. *ISPRS Workshop on Topographic Mapping from Space (with Special Emphasis on Small Satellites)*, Ankara, Turkey, 14-16.

Karsauliya, S. (2013). Application of remote sensing and GIS in solid waste management: a case study of surroundings of River Yamuna, India. *International Journal of Environmental Engineering and Management*, 4(6), 2231-1319.

Mahamid, I. and Thawaba, S. (2010). Multi-criteria and landfill site selection using GIS: a case study from Palestine. *The Open Environmental Engineering Journal*, 3, 33-41. https://doi.org/1 0.2174/1874829501003010033

Merriam-Webster, Geomorphology. (2022). https://www.merriam-webster.com/dictionary/geomorphology (accessed November 30, 2022).

Mohammedshum, A.A., Gebresilassiea, M.A., Rulindaa, C.M., Kahsaya, G.H. and Tesfay, M.S. (2014). Application of geographic information system and remotesensing in effective solid waste disposal sites selection in Wukro town, Tigray, Ethiopia. *International*

Archives of the Photogrammetry, Remote Sensing & Spatial Information Sciences, Toronto, Canada, 115-119. https://doi.org/10.5194/isprsarchives-XL-2-115-2014

Mussa, A., and Suryabhagavan, K.V. (2021). Solid waste dumping site selection using GIS-based multi-criteria spatial modeling: A case study in Logia town, A far region, Ethiopia. *Geology, Ecology, and Landscapes*, 5(3), 186-198. https://doi.org/10.1080/24749508.2019.1703311

Nagarajan, R., Thirumalaisamy, S. and Lakshumanan, E. (2012). Impact of leachate on groundwater pollution due to non-engineered municipal solid waste landfill sites of erode city, Tamil Nadu, India. *Iranian journal of environmental health science and engineering*, 9(1), 35. https://doi.org/10.1186/1735-2746-9-35

Nishanth, T., Prakash, M.N. and Vijith, H. (2010). Suitable site determination for urban solid waste disposal using GIS and Remote sensing techniques in Kottayam Municipality, India. *International Journal of Geomatics and Geosciences*, 1(2), 197-210

Poorna, C.A. and Vinod, P.G. (2016). Solid waste disposal site selection by data analysis using GIS and remote sensing tools: a case study in Thiruvananthapuram corporation area. *International Journal of Geomatics and Geosciences*, 6(4), 1734-1747

Sahzabi, H.Y. (2004). Application of GIS in the environmental impact assessment of Sabalan geothermal field, NW-Iran. *The United Nations University*, 439-474.

Siddiqui, M.Z., Everett, J.W. and Vieux, B.E. (1996). Landfill siting using geographic information systems: a demonstration. *Journal of environmental engineering*, 122(6), 515-523. https://doi.org/10.1061/(ASCE)0733-9372(1996) 122:6(515)

Sivasankar, S.D. and Rathinam, V.K. (2017). Application of remote Sensing and GIS in solid waste management: a case study of Mellur Municipality, India. *International Journal of Innovative Research in Science, Engineering and Technology*, 6(8), 16174-16180. https://doi.org/10.15680/IJIRSET.2016.0608077

Slack, R.J., Gronow, J.R., and Voulvoulis, N. (2005). Household hazardous waste in municipal landfills: contaminants in leachate. *Science of The Total Environment*, 337(1-3), 119-137. https://doi.org/10.1016/j.scitotenv.2004.07.002

Sumathi, V.R., Natesan, U. and Sarkar, C. (2008). GIS-based approach for optimized siting of municipal solid waste landfill. *Waste Management*, 28(11), 2146-2160. https://doi.org/10.1016/j.wasman.2007. 09.032

Tamilenthi, S., Chandra Mohan, K., Vijaya Lakshmi, P. and Suja Rose, R.S. (2011). The data base, land use and land cover and solid waste disposal site-using remote sensing and GIS: A case study of Sakkottai block, Sivagagai District, Tamil Nadu, India. *Advances in Applied Science Research*, 2(6), 379-392.

USEPA. (1984). A ground water protection strategy for the Environmental Protection Agency. https://semspub.epa.gov/work/HQ/175381.pdf (accessed November 30, 2022).

Wang, M. (2008). A multiresolution remotely sensed image segmentation method combining rain falling watershed algorithm and fast region merging. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Science*, XXXVII (Part B4). Beijing, 1213-1218.

Zhou, W., Troy, A. and Grove, M. (2008). Object-based land cover classification and change analysis in the Baltimore metropolitan area using multitemporal high resolution remote sensing data. *Sensors*, 8(3), 1613-1636. https://doi.org/10.3390/s80316