International Journal of Innovation and Scientific Research
ISSN 2351-8014 Vol. 58 No. 1 Dec. 2021, pp. 59-68

http://www.ijisr.issr-journals.org/

Analyzing Site Suitability for Solid Waste Dumpling Through GIS and MCDMHP: A case study of Gazipur City Corporation, Bangladesh

Md. Fazlee Rabby[1], Ummeh Saika[2], and Mohammad Ismail Hossain[3]

[1]Research student, MSGED, Department Geography and Environment, Jahangirnagar University, Dhaka, Bangladesh

[2]Associate Professor, Department of Geography and Environment, Jahangirnagar University, Dhaka, Bangladesh

[3]Post-doc, Department of Tourism Science, Tokyo Metropolitan University, Tokyo, Japan

ABSTRACT: Locating a suitable solid waste disposal site has been a major problem in the municipal environment in developing countries. Especially, urban solid waste management system needs solid waste management technique. Several, countries like Bangladesh are struggling to establish proper waste management systems in the context of increasing population, urbanization, and industrialization. The main objective of this study was to select potential areas for suitable solid waste dumping sites, which are environmentally suitable. This study were Landsat images; digital elevation model (DEM) and ground control point collected by GPS and topographical map of the study area. The maps were prepared by overlay and suitability analysis of GIS, Rs and MCA methods. Relative importance weight of each criterion in the GIS and AHP was determined and finally the suitability map was prepared. A probability map was created based on field observations and the final suitability map, appropriate solid waste landfill site. Therefore, government, private and other organizations are using these techniques for development planning and implementation at every sector. These findings may provide policymakers with crucial information for better solid waste management policy development, which Government, private and other organizations are using these techniques for development planning and implementation at every sector.

KEYWORDS: Geospatial techniques; Government; Implementation; Landsat images; Planning.

1 INTRODUCTION

Municipal solid waste (MSW) is commonly defined as all solid waste produced by domestic, manufacturing, commercial, administrative, or construction waste and its constituents, such as metals, food, plastics, glass, and paper [1]. In the world today, solid waste has become a global environmental and health challenge in both developing and developed countries [2]. Such environmental problems, along with social, fiscal, and land scarcity considerations, raise questions about land management and assessment strategies [3,4]. Due to population development, urbanization, and poor human awareness, problems are getting at an alarming level in developing countries where the non-scientific method of solid waste management is used. In recent decades, many African, Asian, American, and European countries have changed their waste management practices from landfilling to incineration [5]. Waste, which is generated because of a variety of human actions, causes significant problems in human environments. Population development, fast economic growth, and the living standards have all increased the production of solid waste around the world [6]. As a result, careful site selection for dumping solid waste away from natural facilities, residential neighborhoods, water bodies, highways, faults, and settlements is critical for proper solid waste management. Solid wastes in urban areas are often made up of plastics, bottles, materials, metals, and kitchen waste, all of which have a diverse structure and are slow to degrade, causing more environmental damage. The current waste management strategies are based on the principles of reuse, recycling, energy efficiency, and energy recovery [7].

Geographical Information Systems (GIS) have been increasingly important in the decision-making process in recent years. The benefit of using a GIS-based method for site selection is that it saves time and money. It also offers a digital data inventory for the site's long-term monitoring [8]. GIS can use, generate, and analyze spatial or attribute data for solid waste disposal site selection practices, and remote sensing can provide knowledge about different spatial parameters such as land-use/land-cover [1]. There is a vast literature on landfills that can potentially be used to select solid waste landfill sites [8,9].

GIS applications for identifying possible waste disposal sites have been examined in different of locations [10]. Over the last few decades, researchers have widely used remote sensing and GIS-based multi-criteria decisioz analysis (MCDA) to show that sanitary landfilling is the most appropriate waste management system [4,11]. These methods are useful in resolving the issue of successfully identifying waste dumping location and management [10]. This study aimed to identifying suitable zone for solid waste dumping and recycling based on some special criteria using combine Multi Criteria decision-making analysis and GIS analysis in Gazipur City Corporation, Bangladesh.

2 METHODS

Study area: Gazipur City Corporation lies between 23°52′45″ and 24°6′12″ north latitudes and between 90°15′2″ and 90°29′50″ east longitudes (Figure 1). Total area is 329.53sq.km and population is approximately 3 million and situated in the center of the country [12]. GCC is the largest and 11th city corporation of the country. Textile and garment factory are the major industrial collaboration here. Along with that rice mills and other factory are in production [13].

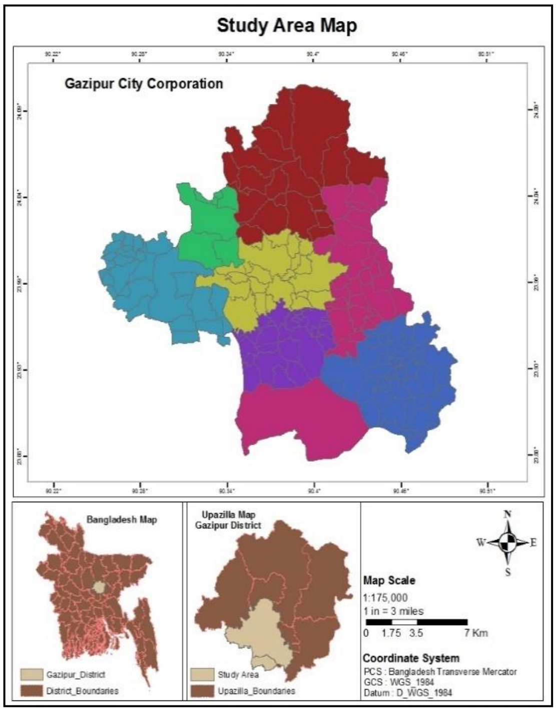

Fig. 1. Geographic location of the study area; Gazipur City Corporation, Bangladesh

Criteria determining factor: The governing factors of occurrence of suitability cite selection to choose best waste dumping sites in the study region were used as criterion, which indicate the relationships between solid waste dumping site suitability selection and natural factors that evaluate its occurrence. In this study, four (Highway roads, major roads and streets, river and rail line) standards for determining solid waste dump site selection were chosen. The research took into consideration factors such as land use/cover, geological formations, lithology, slope, distance to river, built-up, path, soil, drainage, and well points.

The analysis incorporated both primary and secondary results. Field surveys and observations were used to gather primary data. Secondary data for the study was gathered from the internet, reports, books, journals, public agencies, and other sources. The key data for this analysis is an image view of the town with a spatial resolution of 30 m, the town's master plan, and the town's topographical map. To improve the analysis of the topographical map file, preprocessing operations such as radiometric, image reconstruction, and rectification were used.

Table 1. Scales of Pair Wise Comparison

Scale	Description
1	Equally Preferred
2	Equally to Moderately Preferred
3	Moderately Preferred
4	Moderately to Strongly Preferred
5	Strongly Preferred
6	Strongly to Very Strongly Preferred
7	Very Strongly Preferred
8	Very to Extremely Strongly Preferred
9	Extremely Preferred

The research used a spatial multi-criteria analysis approach to find the best solid waste disposal location. By narrowing down possible options based on predefined parameters and weights and allowing sensitivity analysis of the outcomes from these procedures, multi-criteria approaches (MCA) have the potential to minimize the costs and time involved in siting facilities [14,15]. The mapping of solid waste disposal site selection was performed using multi-criteria assessment and layering to provide a single performance chart or evaluation index [16].

On different layers, classifications were made, and values were allocated ranging from most suitable to least important. After distance measurement, reclassification of layers was grouped into the 1's, 2's, 3's, 4's and 5's scoring scheme, where 1 reflected Not Suitable, 2 Less Suitable, 3 Moderate Suitable, 4 Suitable and 5 Most Suitable. As previously mentioned, these standards were established by consulting various references in the literature. The results of the pair-wise analysis of parameters were then entered into a comparison matrix. The matrix is filled with numbers ranging from 1 to 9 and fractions ranging from 1/9 to 12 to reflect the relative importance of each element in the pair.

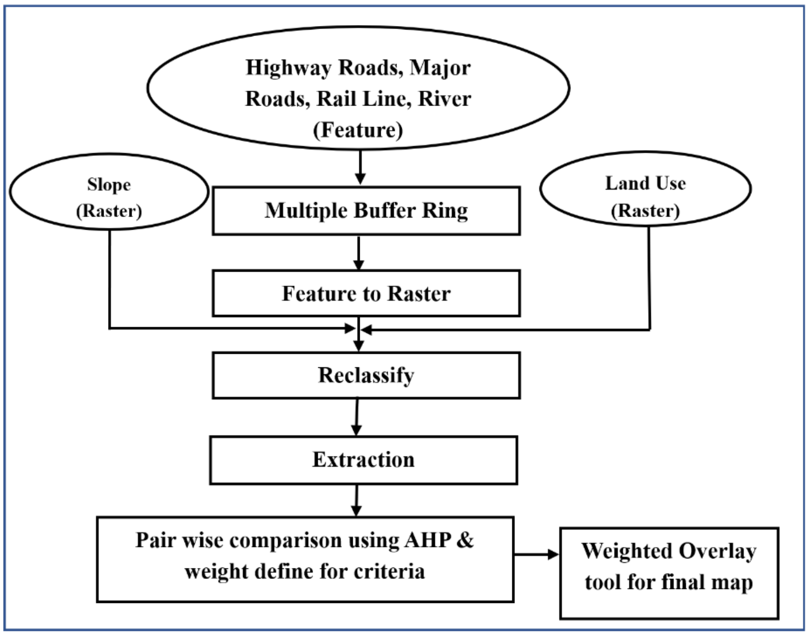

Fig. 2. Methodology framework of the study

The matrix's values must be consistent, which ensures that if x is compared to y and gets a 5 (high importance), y to x should get a 1/5. (Little importance). When everything is related to itself, it receives a ranking of one (equal importance). Each column's weights were added together, and each factor in the matrix was divided by the number of the column's weights. Finally, an average was determined using the elements from each row of the normalized matrix. The consistency ratio (CR) was measured to ensure that decision makers' comparisons of parameters were consistent. The law is that a reciprocal matrix with a CR less than or equal to 0.10 is permissible, whereas one with a CR greater than 0.10 is not. This procedure yields weights that are the sum of all possible weights.

Consistency Index = (Lambda max – n) / (n – 1)

Lambda max (λ) is the Principal Eigen Value; n is the number of factors.

Consistency Ratio = Consistency Index (CI) / Random Index (RI)

If, CR is less than 10% or.10 indicates that the consistency ratio level in the matrix is satisfactory and acceptable. AHP method is popular because of its simplicity for obtaining the weights and decision problems.

Table 2. Criteria for dump site selection suitability and their rank

Factors	Parameter (M)	Suitability Class	Rank	Weight	Area (ha)	Area (%)
Highway Roads	0-500	1 Not Suitable	1	0.103	5349.262	23.726
	500-1500	2 Less Suitable	5		9371.386	41.567
	1500-1800	3 Moderate Suitable	4		2507.721	11.123
	1800-2200	4 Suitable	3		3157.720	14.006
	2200-2500	5 Most Suitable	2		2158.974	9.576
Major Roads & Streets	0-100	1 Not Suitable	1	0.249	4157.483	16.995
	100-400	2 Less Suitable	5		10144.259	41.467
	400-600	3 Moderate Suitable	4		4601.612	18.810
	600-800	4 Suitable	3		3210.473	13.123
	800-1000	5 Most Suitable	2		2349.102	9.602
Rail Line	0-500	1 Not Suitable	1	0.043	4000.920	24.698
	500-1500	2 Less Suitable	5		6854.610	42.315
	1500-1800	3 Moderate Suitable	4		1728.037	10.667
	1800-2200	4 Suitable	3		2135.322	13.181
	2200-2500	5 Most Suitable	2		1479.891	9.135
River	0-800	1 Not Suitable	1	0.161	5878.826	28.444
	800-2000	2 Less Suitable	5		6696.714	32.401
	2000-2500	3 Moderate Suitable	4		2387.541	11.551
	2500-3500	4 Suitable	3		3991.783	19.313
	3500-4000	5 Most Suitable	2		1713.089	8.288
Land Use	Water Bodies	1 Not Suitable	1	0.379	1161.697	3.624
	Forest & mixed-use area	2 Less Suitable	2		11564.055	36.079
	Built up area	3 Moderate Suitable	3		3922.987	12.239
	Industrial area	4 Suitable	4		1780.11	5.553
	Crop & bare Land	5 Most Suitable	5		13622.4	42.501
Slope	0-3	1 Not Suitable	5	0.065	22721.995	71.041
	3-8	2 Less Suitable	4		9042.282	28.271
	8-11	3 Moderate Suitable	3		185.483	0.579
	11-15	4 Suitable	2		27.888	0.087
	15-29.53	5 Most Suitable	1		6.489	0.020

3 RESULTS AND DISCUSSION

Highway roads suitability: The Highway roads suitability distance calculated is shown in In the study area, 41.567% and 11.123% of the area are less suitable and moderately suitable, respectively, while 23.726%, 14.006% and 9.576% of the area is not suitable, suitable, and most suitable, respectively, for waste disposal sites. Major Roads & Streets proximity in the remaining study area is less suitable (41.467%), for solid waste disposal sites. The dump site should also be far from commercial buildings, urban green space, service area and industries.

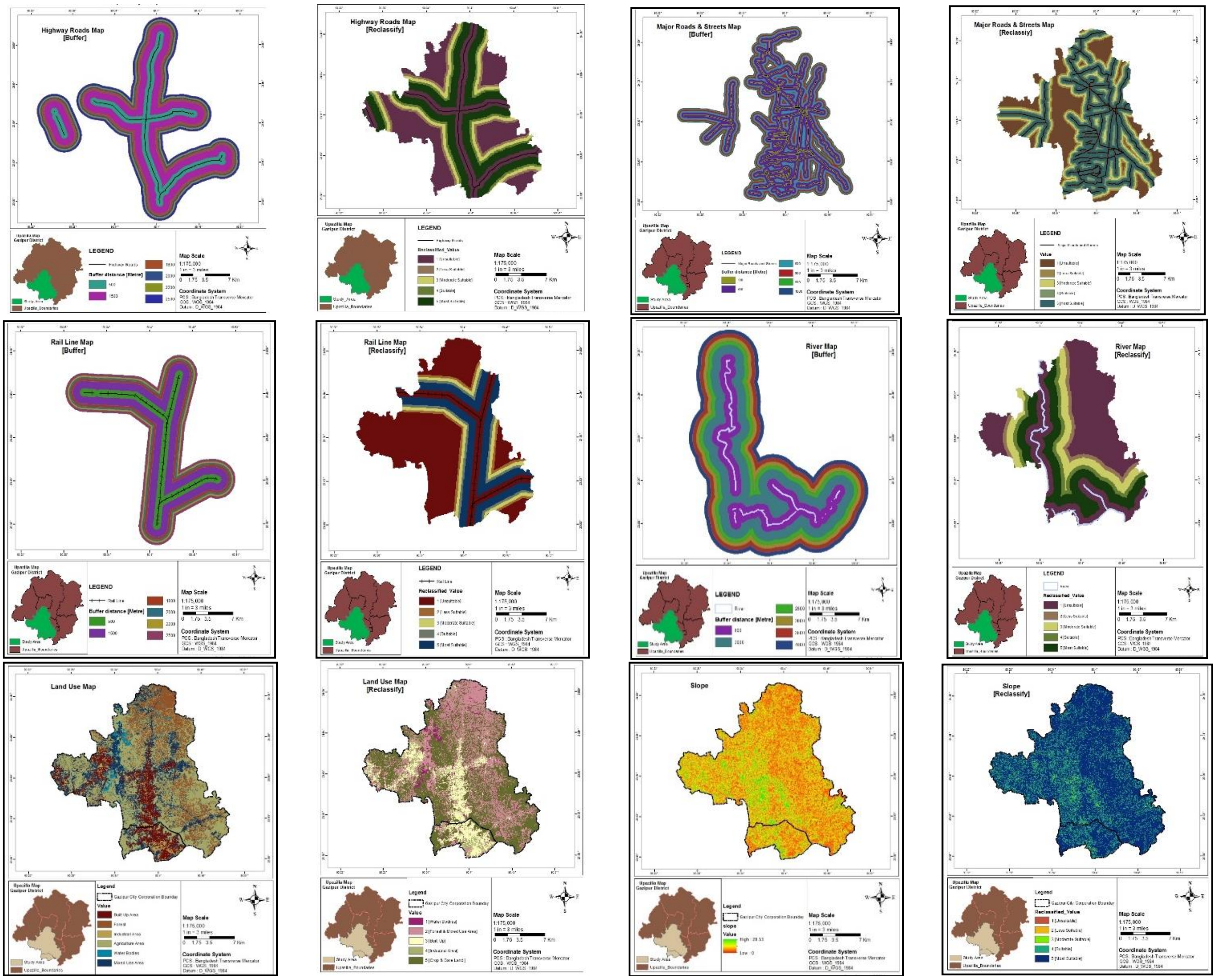

Fig. 3. Original and reclassified thematic maps.

Major roads & streets: The Major roads and streets suitability distance calculated is shown in In the study area, 41.467% and 18.810% of the area are less suitable and moderately suitable, respectively, while 44.3%, 13.123% and 9.602% of the area is unsuitable, suitable and highly suitable, respectively, for waste disposal sites. Road proximity in the remaining study area is moderate to less suitable, for solid waste disposal sites. The dump site should also be far from commercial buildings, urban green space, service area and industries.

Rail line: The Major roads and streets suitability distance calculated is shown in In the study area, 42.315% and 10.665% of the area are less suitable and moderately suitable, respectively, while 24.698%, 13.181% and 9.135% of the area is not suitable, suitable, and most suitable, respectively, for waste disposal sites. Road proximity in the remaining study area is moderate to less suitable, for solid waste disposal sites. The dump site should also be far from commercial buildings, urban green space, service area and industries.

River: Solid wastes disposed near the river cause ecological, agricultural and health problems. Considering these problems, the suitability of solid waste dump site map was produced (and Figure 3). Accordingly, 28.444% of the area was not suitable, 32.401% was less suitable, 11.551% was moderately suitable, 19.313% was suitable, and 8.288% was not suitable for solid waste disposal site in GCC. Based on figure 3 the above standards, suitability map of river point was prepared.

Land-use/land-cover suitability: Land-use/land-cover map was produced for dumping waste with an overall accuracy of 86%. The land-use map displays the land utilized by human and natural cover in the GCC. The land-use map indicates the areas of water bodies, forest and mixed-use area, buildup area, industrial area, and crop & bare area. Most of the region is occupied by crops & bare area. Based on the land-use/land-cover suitability, the largest part of the study area (42.501%) is most suitable for solid waste disposal sites, whereas 5.553% and 36.079% of the area were suitable and less suitable, respectively. The remaining 3.624% of the study area was not suitable for solid waste disposal site.

Table 3. Pair wise comparison in nine point continuous scale

Criterion	Land Use	Major Roads & Streets	Slope	Highway	River	Rail Line
Land Use	1					
Major Roads & Streets	1/2	1				
River	1/3	1/2	1			
Highway	1/4	1/3	1/2	1		
Slope	1/5	1/4	1/3	1/2	1	
Rail Line	1/6	1/5	1/4	1/3	1/2	1
Total	2.45	4.283	7.083	10.833	15.500	21

Slope suitability: The topography of the study area is dominated by a slope of 0–3°,which accounts for 71.041% was not suitable of the total study area. The second most dominant topography of the study area is 3-8° covering 28.271% of total area and the remaining 0.020%of the area is with a slope >20° (Table 2). Based on the slope suitability coverages of GCC, the extent of highly suitable, suitable, and unsuitable sites was demarcated, and the suitability map was prepared (Figure 3).

Overlaying and identifying suitable area: The site selection for solid waste disposal dumping site involves comparison of different options based on environmental, social and economic impact. Hence, based on experience and likely impact on surrounding environment, different weights were assigned to all the parameters. The larger the weight, the more important is the criterion in the overall utility. The weights were developed by providing a series of pair wise comparisons of the relative importance of factors to the suitability of pixels for the activity being evaluated. The procedure by which the weights were produced follows the logic developed by [17] under the Analytical Hierarchy Process (AHP). Weight rates were given based on pair wise comparison 9-point continuous scale (Table 3). These pair wise comparison was then analyzed to produce of weights that sum to 1 (Table 3). The factors and their resulting weights were used as input for the multi criteria evaluation (MCE) module for weighted linear combination of overlay analysis.

According to Nordström, Eriksson, & Öhman, (2010) and Thomas L. Saaty, (1977) if the consistency ratio is less than or equal to 0.1, it signifies acceptable reciprocal matrix. The consistency ratio of this study indicated that 0.03 was acceptable (Table 4). To combine all the layers to process overlay analysis, standardization of each data set to a common scale of 1, 2, 3, 4 (value 1 = unsuitable (restricted), value 2 = less suitable, value 3 = moderately suitable, value 4 = suitable, and value 5 = most suitable) was performed. Finally, all the parameters were weighted with their respective percent of influence and overlay to produce the suitability map. The factors, their values and weights are summarized in According to the degree of importance, they have the role of selecting suitable solid waste dumping site. After the overlay analysis of the given factors the following suitable solid waste dumping site map was produced (Figure 4).

The final map (Figure 4) has five colors (classes): Dep pink (unsuitable), Burlywood (less suitable), Dark olive green (Moderate suitable), Chartreuse (suitable) and Dark green (most suitable). The most suitable area for solid waste dumping site is marked by deep green color shaded (class 5). Out of the total area of the study site, about Direct overlay methods are applied to prepare the map. Here, weights are distributed equally for all criteria and 5.591 sq. km of area found as most suitable area. This area covers 1.77% of total area. And 78.451 sq km is found as suitable zone which covers 24.84% of the total area. Weights are assigned as per "criterion weights table" for the map as because consistency ratio was satisfactory. After analysis 8.81sq km area is found as most suitable zone that covers 2.79% of the total area. Along with that 97.25 sq km. found as suitable zone that is 30.79% of total area.

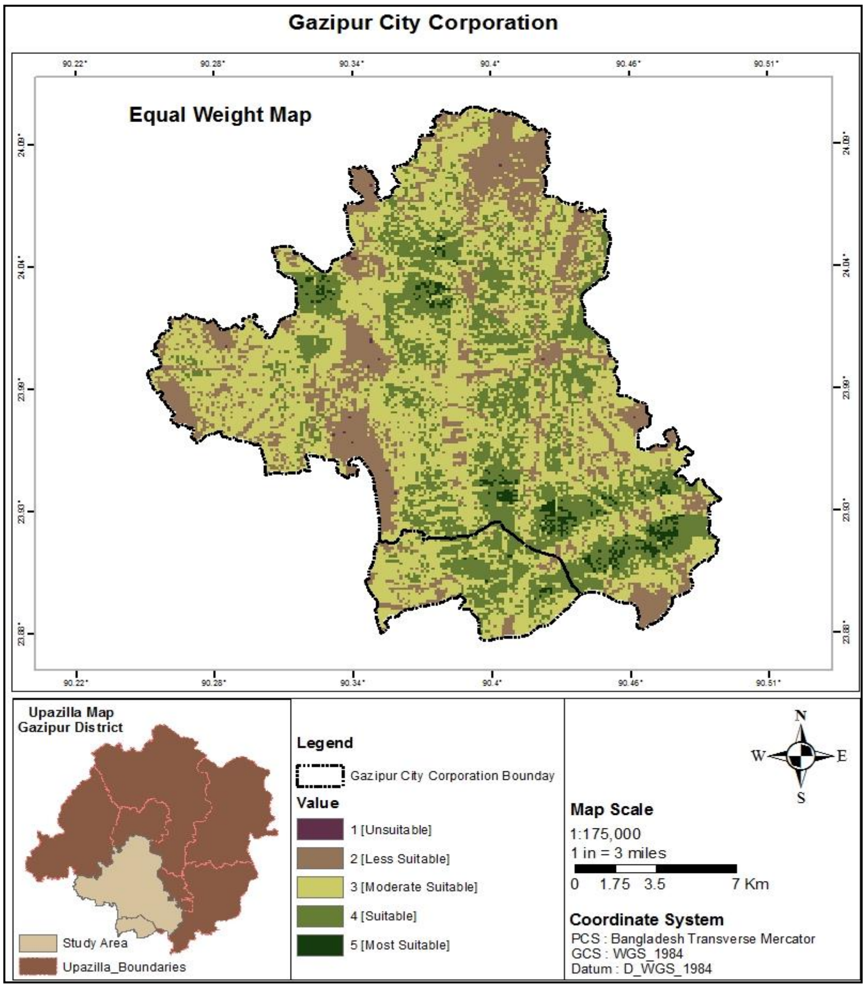

Fig. 4. Equal weight map

Table 4. Equal Weight and Defined Weight by calculating the principal eigenvector of pair wise comparison matrix

		Equal Weight		Defined Weight	
Score	**Level**	**Area (sq.km)**	**Area Coverage (%)**	**Area (sq.km)**	**Area Coverage (%)**
1	Unsuitable	0.285	0.09	1.873	0.59
2	Less Suitable	70.051	22.18	66.169	20.95
3	Moderate Suitable	161.488	51.12	141.770	44.88
4	Suitable	78.451	24.84	97.246	30.79
5	Most Suitable	5.591	1.77	8.807	2.79

The present study represents an important step in addressing a critical gap in the detection of waste disposal sites and to enhance cost-effectiveness and efficiency of waste management efforts. Due to their ability to manage large volumes of spatial information from various resources, GIS is ideal for site selection studies [8], and are being widely applied in the recent past for site selection studies. The integration of both GIS and multi-criteria techniques improves decision-making because it establishes an environment for transformation and combination of geographical data and stakeholders preferences [10]. Solid waste dumping site should be located at a suitable distance from roads to facilitate transportation and consequently to reduce relative costs. In GCC, waste dumping is mostly on the roadside. According to Mussa & Suryabhagavan, (2019), a minimum distance of 700 m buffer should be maintained for road suitability dumpsite location and used multiple buffer ring extents and the grading values for roads. At present GCC has grown at an unexpected growth and as a result, the distance of the facility to the nearest residential area is only few kilometers. Groundwater circulation and the downward flow of pollutants through rocks and soils depend on the hydrogeological condition of the materials; more specifically hydraulic properties such as porosity, permeability, and transitivity. The proximity of a solid waste dump site to a groundwater well point is an important environmental criterion in the dumpsite selection so that well points may be protected from the runoff and discharge. Therefore, solid waste disposal sites should be away from wells. Additionally, it can have irreversible human and environmental effects. Distance from groundwater well was considered as an important to prepare the water sources for activities and drinking water, and they are influenced by many factors including agricultural, and reactions occurred in landfill sites.

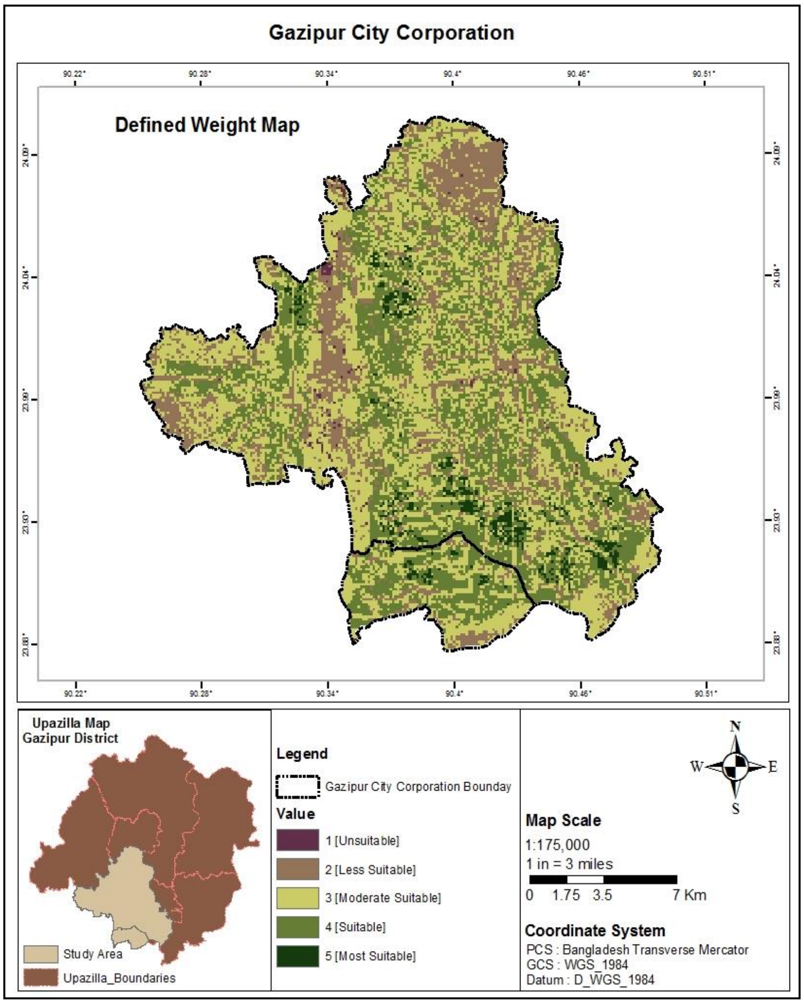

Fig. 5. Defined weight map

In GCC area, existing landfill site is clearly unsuitable with respect to public health, hygiene, noise, dust and odor. The overall dump site suitability selection showed five dump site suitability classes, viz. unsuitable (restricted), less suitable, moderately suitable, suitable and highly suitable. Bare-land, water body, built-up areas and forest lands were used for dump site selection processes due to their land-use land-cover effect and values. Bare land in the study area was identified as the best option for solid waste dump sites. Areas with slope >15° were excluded as they were unsuitable and areas with slope 0−3° were found to be the suitable for dump sites. Areas within 700 m radius were excluded to minimize public health effects. This restricted area included well points, river/streams, fault, road, built-up area in the first order, followed by permeable locations, faults, geology, areas with a steep slope (>15°), built-up and forest and areas close to roads. Ground/surface water-related criteria are more influential than rest of the criteria as they need protection against leachate contamination from dump sites. By using the stated criteria, the suitable areas for solid waste dumping site fall on the eastern and southern west direction from the town (Figure 5). The selected site areas are significantly at the optimum distance from from major roads. The areas were most suitable for solid waste dumping site.

After eliminating the restricted land with the combination of environmentally sensitive, socially important and economically significant areas, only 537.5 ha. (6.4%) and 189.4 ha (2.2%) of the study area were identified as suitable and highly suitable, respectively, for waste dump sites. Waste dump site in these areas is preferred because of the least effects that may cause on the environment and public. Most of the highly suitable landfill sites are situated in the northern part of the study area. The south-eastern part of Logia town having high elevation was excluded from the selection of dump site as it comprises the recharge area for low-lying regions of the town. Similarly, the south-west part of Logia is a potential source of groundwater for the town and its surroundings and hence excluded from the dump site. Therefore, a high suitable dump site should be identified most preferably from the northern part of GCC. The current open dump site was in an unsuitable site. It is placed surrounding the built-up area, roadsides, and nearby river. Considering the effect of solid waste on environment, health, economy and other aspects of human life, the suggested selected site can be accessed by road. It is evident that multi-criteria decision making with GIS integrated methods would be useful for environmental, human health and developmental issues and they should become statutory obligations for location of dump site selection in human dwellings.

4 Conclusion

The generation of solid waste has expanded extensively amid the ongoing past because of the rising worldwide population and rapid urbanization and its improper disposal and poor management in GCC. The goal of this study was to pursue proper selection process while avoiding environmental problems, and to suggest suitable site for landfill using GIS and multi-criteria decision-making techniques to facilitate shifting the present dumpsite to an alternative location. This site is easy to access for disposal of solid wastes. It is in the west, northern and east of the study area. There are highly suitable and suitable classes, which might be suitable from environmental, transportation and economic point of view. The use of AHP with GIS and remote sensing for identification of suitable solid waste dumping site will minimize environmental risk and human health problems. Further studies should be conducted to examine the feasibility of integration deposit refund system as a segment of the legislative initiative. Findings taken from this research are supposed to be an academic knowledge source for getting the better understanding which helps city policymakers and environmental managers to design and improve the solid waste management. Globally, this study also contributes the literature to lay the foundations for a successful solid waste management policy applying in the same geographical regions

Acknowledgements

The authors are grateful to Dr. Ummeh Saika for supervise and Mohammad Ismail Hossain for editing support throughout this study.

References

[1] Mallick, J. Municipal solid waste landfill site selection based on fuzzy-ahp and geoinformation techniques in ASIR region Saudi Arabia. Sustain. vol.13, pp.1–33 2021.
[2] Mussa, A.; Suryabhagavan, K. V. Solid waste dumping site selection using GIS-based multi-criteria spatial modeling: a case study in Logia town, Afar region, Ethiopia. Geol. Ecol. Landscapes, pp1–13, 2019.
[3] Salemi, M.; Hejazi, R. A GIS- Based suitability analysis for siting a solid waste in an urban area. Doi.Org vol.2, pp. 57–68, 2017.
[4] Coban, A.; Ertis, I.F.; Cavdaroglu, N.A. Municipal solid waste management via multi-criteria decision making methods: A case study in Istanbul, Turkey. J. Clean. Prod. pp. 159–167, 2018.
[5] Rezaei, M.; Ghobadian, B.; Samadi, S.H.; Karimi, S. Electric power generation from municipal solid waste: A techno-economical assessment under different scenarios in Iran. Energy pp. 46–56, 2018.
[6] Hiremath, S.S. Population Growth and Solid Waste Disposal : a Burning Problem. Indian Streams Res. J. vol.6, 1–7, 2016.
[7] Perrot, J.F.; Subiantoro, A. Municipal waste management strategy review and waste-to-energy potentials in New Zealand. Sustain. 2018.
[8] Yıldırım, Ü.; Güler, C. Identification of suitable future municipal solid waste disposal sites for the Metropolitan Mersin (SE Turkey) using AHP and GIS techniques. Environ. Earth Sci. vol.75, pp.1–16, 2016.
[9] Sustainability, E. Integrated Waste Management in India; 2016; ISBN 978-3-319-27226-9..
[10] T, B.; Tajdari, P.; Manjunatha, M.C.; Balasubramanian, A. Application of Remote Sensing and GIS on Waste Disposal Site Selection and Environmental Impact Assessment around Mysore City, Karnataka, India. Int. J. Earth Sci. Eng. vol. 06, pp. 1801–1808, 2013.
[11] AKTHER, A.; AHAMED, T.; TAKIGAWA, T.; NOGUCHI, R. GIS-based Multi-criteria Analysis for Urban Waste Management. J. Japan Inst. Energy, vol.95, pp.457–467, 2016.
[12] CARE Bangladesh Urban Socio-Economic and Vulnerability Study of Gazipur City Corporation (GCC),pp. 1–50. 2014,.

[13] Wang, L. Analyzing Urban Sprawl and Sustainable Development in Dhaka, Bangladesh. J. Econ. Sustain. Dev, vol.11, pp.9–20, 2020.

[14] Purvis, A.; Gittleman, J.L.; Cowlishaw, G.; Mace, G.M.; Hansen, M.C.; Stehman, S. V.; Potapov, P. V.; Loveland, T.R.; Townshend, J.R.G.; DeFries, R.S.; et al. Cropland expansion changes deforestation dynamics in the southern Brazilian Amazon. Proc. Natl. Acad. Sci. U. S. A. 2012.

[15] Analytic hierarchy process. In Multi-Criteria Decision Analysis: Methods and Software; 2013 ISBN 9781118644898..

[16] Zabihi, H.; Alizadeh, M.; Langat, P.K.; Karami, M.; Shahabi, H.; Ahmad, A.; Said, M.N.; Lee, S. GIS multi-criteria analysis by orderedweighted averaging (OWA): Toward an integrated citrus management strategy. Sustain. 2019.

[17] Saaty, T.L. The analytic hierarchy process: a 1993 overview. Cent. Eur. J. Oper. Res. Econ. 1993.

[18] Nordström, E.-M.; Eriksson, L.O.; Öhman, K. Integrating multiple criteria decision analysis in participatory forest planning. For. Ecol. Manage. 2010.

[19] Saaty, T.L. A scaling method for priorities in hierarchical structures. J. Math. Psychol. 1977.